PACIFIC GAS AND ELECTRIC COMPANY
EMERGING TECHNOLOGIES PROGRAM

APPLICATION ASSESSMENT REPORTS #0806, #0813, AND #0814

ADVANCED LIGHTING CONTROLS FOR DEMAND SIDE MANAGEMENT (ENERGY EFFICIENCY ASSESSMENT)

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Executive Summary

Energy Solutions evaluated the functional performance and energy efficiency potential of three advanced lighting control technologies under contract to the Emerging Technologies Program of Pacific Gas and Electric Company (PG&E). This report summarizes the results of monitoring and evaluation of the Adura LightPoint System, Universal Demand Control Lighting (DCL) System and DEMANDFlex ballast, and Echoflex Solutions system in an office environment. The Adura and Echoflex technologies utilize wireless radio frequency (RF) and the Universal system utilizes powerline carrier (PLC).

During the technology evaluations, controls were used to decrease lighting energy use on a daily basis for a period of approximately two weeks. Power measurements were taken using Dent Instruments Elite Pro Data Loggers (Line Powered, Extended Memory) with 20 amp current transformers (CTs) before and during the test.

The types of energy efficiency controls strategies employed include providing occupants with wireless remote light switches, using controls to tune ballasts to a lower ballast factor, and using wireless photocells for daylight harvesting. Onsite verification and monitoring showed that all three technologies generally performed as expected during the evaluation period, and have good potential to deliver energy efficiency savings of up to 50% or greater.

Statewide interior lighting energy use for the large and small office sectors is 4,331 GWh/year and commercial lighting energy use in general is responsible for roughly 29% of total statewide energy use[1]. However, lighting controls are not widely installed because it is expensive to retrofit a building with wired controls. The types of advanced lighting controls evaluated in this report better enable customers to install lighting controls due to ease of installation and decreased costs, relative to wired controls. These benefits could increase market penetration of lighting controls from less than 1% to something on the order of 10%.

Objectives

The primary purpose of the evaluation was to provide functional testing of the advanced lighting controls, within the context of energy efficiency. The approach was two-fold, including functional testing of the system (i.e., did the control technology work as intended) and quantification of energy savings resulting from use of the controls.

The control strategies were also evaluated for ease of installation, reliability, and customer acceptance. Additional technology performance criteria, including system costs, are presented in the report Conclusions.

These technologies were also evaluated in regards to their ability to deliver peak demand reduction. Those results are summarized in a separate report to PG&E and available on the Emerging Technologies Coordinating Council website.

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[1] California Commercial End-Use Survey data, queried May 22, 2009 (http://capabilities.itron.com/CeusWeb/Chart.aspx).

Key Findings

Currently, market penetration of lighting controls technologies is low, and where controls are installed, it is not uncommon to find them disabled, unbeknownst to facility managers. Our results demonstrate that advanced technologies are available to capture savings potential for commercial lighting applications in the new or retrofit sector. Comprehensive lighting controls systems exist that include two-way communication for better management of lighting systems, flexibility in design and commissioning, and combined demand response and energy efficiency opportunities—at a price that is more cost-effective for retrofit applications than wired controls.

The three manufacturers' technologies achieve similar ends through fairly different means in regards to communication, dimmability and wireless controls options. The types of energy efficiency controls strategies employed included providing occupants with wireless personal light switches, using controls to tune ballasts to a lower ballast factor, and using wireless photocells for daylight harvesting. The table on the following page summarizes the attributes of each product.

Table 1. Comparison of Evaluated Advanced Lighting Control Technologies

Product	Control Strategy	System-level Controllability	Communi-cation	Method of Field Com-missioning	Dimming Capability	Integrated Wireless Controls
Adura LightPoint	Personal control of individual fixtures via wireless personal light switches	Switch-leg to ballast-level control (e.g., can control two ballasts and three lamps to provide inboard/outboard control)	2.4 GHz/ Zigbee RF	Adura software, commissioned by Adura	Controls lamps (on/off) ballast by ballast to offer stepped-down dimming (i.e., via bi-level switching). Current generation expected to work with continuously dimming ballasts.	Wireless personal light switch requiring batteries
Universal DCL + Universal DEMAND-flex ballast	Tuning ballast factor of continuously dimming ballasts	Circuit-level control	Powerline carrier signal	Universal software, commissioned by installation contractor or facility staff	DEMANDflex ballasts respond to DCL controls. (Non-DEMANDflex ballasts may be connected to DCL controlled circuits and will have on/off capability.) DEMANDflex ballasts continuously dim to at least 50% of their rated input power.	Wireless photocell and occupancy sensor controls are in development
Echoflex	Photocells, individual wireless personal light switches, and continuously dimming ballasts	Individual fixtures or groups of fixtures—does not need to be based on circuit	EnOcean-- 315 MHz RF	Wireless light switches (by using a specific series of manual clicks), commissioned by installation contractor or facility staff	Compatible with 0-10v continuously dimming ballasts.	Wireless, battery-less personal light switch, photo sensor, and occupancy sensor

RESULTS OF FUNCTIONAL TESTING

As summarized above, this project evaluated three different advanced lighting control strategies. Our evaluation of the functional testing of advanced lighting controls included host surveys, as well as our own observations of the installation and commissioning process. Each host site contact was asked to characterize, via a rating system:

- the ease of understanding how the lighting control system would interface with their existing lighting system
- the ease of installation of the lighting control system
- the design of the lighting control system, including its ability to integrate well with their existing lighting system

Table 2: Summary of Functional Testing Findings for Evaluated Control Strategies

Product	Control Strategy	Ease of Installation	Ease of Commissioning	Ease of Operation
Adura LightPoint	Personal control of individual fixtures via wireless personal light switches	Contractor found the system easy to install even though they had no experience with system. (Adura provided brief on-site training at start of installation.)	Manufacturer commissioned system successfully.	Control strategy was popular with occupants, who generally found it easy to understand and enjoyed utilizing it.
Universal DCL + Universal DEMAND-flex ballast	Tuning the ballast factor of continuously dimming ballasts*	Installation requires trained or manufacturer-certified Contractors.	Mixed success. Commissioning by contractor, and later by manufacturer, was somewhat successful at first site. Commissioning by manufacturer was completely successful at second site.	System functioned as expected. Reduced light levels were not noticed and were accepted by occupants.
Echoflex	Photocells, individual wireless personal light switches, and continuously dimming ballasts	Contractor found it easy to install even though they had no experience with system.	Was eventually successful, but required a complicated set of actions.	Dimming rate was too rapid for occupants to accept technology.

* Our findings for the Universal Lighting Technologies control strategy are specific to the use of a sophisticated, integrated demand response/ energy efficiency software and hardware package that would not be recommended for simply tuning the ballast factor. This sophisticated controls strategy was used because the DCL system and DEMANDflex ballast were monitored for demand response capability under a parallel evaluation and report. DEMANDflex ballasts can also be tuned using a ballast-commissioning tool, or hardware kit, which reduces the ballast factor and provides consistent energy efficiency savings without the use of additional controls.

ENERGY SAVINGS

To estimate energy efficiency savings resulting from the use of the various advanced lighting controls, monitoring included the collection of power data before, during, and after the energy efficiency test period. CTs, voltage probes, and a data logger were installed on the proper electrical circuits to record power and energy readings at a given interval for the designated time period.

Onsite verification and monitoring showed that all three technologies generally performed as expected during the evaluation period, and have good potential to save energy, as shown below.

Table 3: Summary of Energy Efficiency Findings for Evaluated Control Strategies

Control Strategy	Manufacturer	Site	Measured Energy Savings	Theoretical Range of Energy Savings
Personal control of individual fixtures via wireless, handheld light switches	Adura	ACWD	51.4% - 72.6%	33% - 100% (for three-lamp fixture)
Tuning ballast factor of continuously dimming ballasts	Universal	ACWD	10.4%	1% - 50%
Tuning ballast factor of continuously dimming ballasts	Universal	Anheuser-Busch	16.5% - 18.2%	1% - 50%
Photocells and continuously dimming ballasts	Echoflex	Energy Solutions	63.6%	Depends on third-party ballast used

The energy efficiency results presented here should not be interpreted as a comparison. Instead, they describe three independent assessments taken in different building spaces, each employing a limited subset of the available energy control measures offered by the selected technologies. The measured savings are a function of our test design and do not necessarily represent the maximum energy efficiency potential of any given technology. For example, the Universal DCL system could have been tuned to further reduce ballast power levels or to respond to sensed daylight levels[2], which could have produced more dramatic savings. Similarly, the Echoflex system delivered deep savings, but some occupants reported that they needed higher light levels (which could have been provided had the evaluation period continued).

Savings *potential* is not necessarily represented by a technology selection or by exploitation of a single energy control measure, and it is bounded by the particular characteristics of a target building space: circuit and luminaire layouts, windows, hours of operation, use patterns, light level requirements, etc. A controlled comparison would require evaluation within identical spaces and constraints. It is expected that under such test conditions, each technology would be found suitable for a subset of application types.

[2] Reductions based on daylighting could have been achieved through the use of Universal's wired controls or a third-party wireless control, neither option of which was deemed appropriate for this evaluation.

Project Background

Despite the significant potential benefit to energy utilities and their customers, several barriers to the widespread promotion and adoption of lighting control technologies have existed.

1) Dimming ballasts are more expensive than non-dimming ballasts.
2) Installation of wired controls in existing buildings is expensive.
3) Lighting controls need to be commissioned properly in order for them to function as intended and deliver maximum benefits.
4) The range of building types and energy efficiency strategies do not make for easy quantification of savings nor rebate levels. Lighting controls are rare in existing buildings and the level of controllability and functions of these controls can vary greatly from site to site.

Advanced lighting controls, as well as the decreasing cost of dimming ballasts, can help address economic barriers and increase implementation.

Market Potential

Advanced lighting controls represent a significant energy efficiency opportunity in the commercial sector for retrofit as well as new construction applications. Statewide interior lighting energy use for the large and small office sectors is 4,331 GWh/year and commercial lighting energy use in general is responsible for roughly 29% of total statewide energy use.[3] Despite their energy saving potential, lighting controls are not widely installed because it is expensive to retrofit a building with wired controls. However, the increased prevalence of the Internet and the development of RF and PLC technologies have created new opportunities for installing lighting controls, particularly in existing buildings. In addition, the efficacy of the latest generation of dimming ballasts, at full light output, is within 2% of the efficacy of program start ballasts and 8% the efficacy of instant-start ballasts.

The types of advanced lighting controls evaluated in this report better enable customers to install lighting controls due to ease of installation and decreased costs, relative to wired controls. These benefits could increase market penetration of lighting controls from less than 1% to something on the order of 10%.

[3] See Note 1.

Descriptions of Technologies Evaluated

ADURA LIGHTPOINT SYSTEM (ALPS)

The Adura LightPoint System is a wireless switching device that is connected to the ballast to provide precise control of individual light fixtures or rows of fixtures. This approach to controls is referred to as distributed lighting control. Because Adura controls the lighting system on a ballast-by-ballast basis, it is very flexible, allowing customizable energy efficiency strategies based on user input during set up. Using Adura LightLogic software and a graphic user interface (GUI) currently under development, the system can provide web-based control, configuration, and monitoring capabilities for facility lighting[4]. The Adura system can also be commissioned to respond to a demand response signal sent via the Internet to their onsite Gateway device that communicates the signal wirelessly to the Light Controller, turning individual ballasts and the associated lamps on or off. Light Controllers also enable personal occupant controls using the Adura wireless light switch, which operates on batteries with an estimated useful life of 10 years.

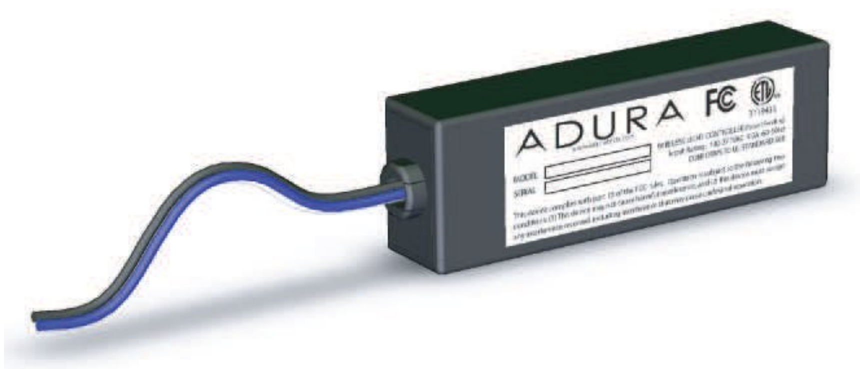


Figure 1. Adura Light Controller

The Adura system we evaluated is well-suited to control three-lamp, two-ballast fixtures enabled for bi-level switching. For example, the system can be commissioned to respond to the Adura remote light switch by turning off the inboard lamp (33% demand reduction) when the light switch is first clicked, and turn off the outboard lamps and turn on the inboard lamp (66% demand reduction) when the light switch is clicked again, and turn on all lamps when the light switch is clicked yet again. In theory, this technology should be applicable to a significant proportion of office building fixtures as a result of California's Title 24 Building Standard requiring bi-level switching. In

[4] At the time of this evaluation, the system did not include a user interface for commissioning; therefore, only Adura could commission the system.

practice, it is difficult to say what percentage of California building stock meets this requirement—for example, in the office where we evaluated the Adura technology, we initially found that a single ballast was wired to all three lamps and it appeared a second ballast was at one time installed but later disabled. In early 2009, Adura unveiled a Light Controller that controls 0 – 10 volt dimming ballasts, which will broaden this technology's market potential further. This study did not evaluate the Adura Light Controller that works with dimming ballasts.

Because the communications for Adura controls are entirely wireless, the system is minimally intrusive. It does not require space in lighting circuit closets, nor does low voltage wiring need to be run between individual lighting fixtures. Rather, the Light Controllers are wired directly to the ballasts within the lighting fixture, and the Gateway requires only a few square inches of space. However, we found that the current iteration of the Light Controller could not be accommodated by a 2' x 2' light fixture due to space constraints. In order to ensure that communications from one fixture to the next and back to the Gateway would not be interrupted, repeaters were installed in the area of the 2' x 2' fixtures (e.g., under desks).

UNIVERSAL DCL SYSTEM AND DEMANDFLEX BALLAST

DEMANDflex ballasts are high efficiency, dimmable program start ballasts with the flexibility to be tuned at the circuit level to set power levels during initial installation. The tuning process, which reduces the ballast factor, allows up to a 50% reduction in power levels and is fully adjustable by the user at any time. The DCL system requires no fixture modifications other than a standard ballast retrofit. It provides controllability with no requirement for fixture level control wiring and with no requirement for additional in-fixture devices. The ballasts receive communications via a low level signal injected on the powerline.

The DCL system currently includes wired controls for scheduling, daylighting and other controls, and can be configured to work with third party controls. (This study did not evaluate the DCL system for scheduling, daylighting or third party controls). Although not ready at the time of this demonstration, Universal is developing wireless controls, including a photocell and occupancy sensor, for use with the DCL system. The DCL system can be used for tuning as part of the broader energy management system functionality described below.

The DCL system includes a Relay Sensing Module (RSMDCL) and Single Circuit Controllers (SC20s) to create an energy management system that has energy efficiency and demand response capability. For example, a customer could use the DCL system to set a maximum power level of 90% for purposes of energy efficiency, while also using the DCL system to set power reduction levels according to demand response signals received and interpreted through the use of contact closures or relay contacts.

The RSMDCL inputs include sensing circuits for eight external contacts. The RSMDCL processes the states and transitions of these contacts, and issues programmed responses to the DCL system. All commands are sent as broadcasts to the entire data bus and all are subject to range restrictions established during commissioning of the DCL circuit level controls. Table 4 shows the light level relative to 100% light output, as it relates to the power level associated with each relay contact.

Table 4. Power Level Control Mode for Universal's RSMDCL

Input	Command (Power Level)	Light Level
Contact 1	100%	100%
Contact 2	90%	88%
Contact 3	80%	76%
Contact 4	70%	63%
Contact 5	60%	51%
Contact 6	50%	38%
Contact 7	OFF	n/a
Contact 8	Safety Device: Open contact state forces 100% and locks out other contacts	

Figure 2. Universal DCL System

ECHOFLEX

The Echoflex Solutions wireless lighting control system evaluated in this report is comprised of Echoflex wireless/battery-free switches and Echoflex controllers that receive wireless switch signals to modify controlled loads. Echoflex controllers are wired to line voltage and mounted on junction boxes or at the lighting fixture. The "Complete Room Controller" model (EDRC – C) evaluated in this study controls loads through a low voltage circuit (0 – 10 volt) wired to a dimmable ballast. The system is designed to perform day-to-day lighting control functions, including switching, daylighting and occupancy controls.

Echoflex battery-free switches resemble normal light switches but transmit wireless signals to control lights instead of directly interrupting line voltage. Because these switches are unwired they can be installed at junction boxes or "flush mounted" to any surface with screws, tape, or adhesive. The switches are powered by energy harvesting technology utilizing a coil and magnet inside the switch that generates energy from the force used to press the switch. Wireless switches require no wiring and are intended to be maintenance-free for over 20 years. Each controller can store the unique ID of up to 30 switches and is re-programmable, simplifying the addition of switches in the future. In addition, each switch can be paired with an unlimited number of controllers. The wireless communication and control system operates on a unique frequency designated for this purpose and therefore should not interfere with other wireless devices such as WLAN networks.

Echoflex is developing a dual channel controller that will allow each controller to drive two offices, a two-ballast set up, or handle both 0-10 volt dimming if the ballasts are available. This technology is anticipated to increase the product's flexibility and lower the system cost. This controller was not evaluated in this study.

The switches offer energy efficiency benefits by allowing for personal control of overhead lights according to individual occupant desires, and dimming capabilities if dimming ballasts are installed in the controlled fixtures. The wireless switches also serve as a commissioning tool for setting the controllers' demand response power levels. The process for adjusting demand response levels with the wireless switches is described in a separate report to PG&E regarding this product's demand response capability.

Figure 3. Echoflex Wireless Switch, Photosensor, and Complete Room Controller

Methodology

Host sites were chosen based on pre-existing experience with emerging or state-of-the-art technologies and/or participation in PG&E efficiency programs.

To test system function, the technologies were installed, commissioned and operated, and functionality was observed. To estimate energy efficiency resulting from the use of the various advanced lighting controls, monitoring included collection of power data before, during, and after the energy efficiency test. CTs, voltage probes, and a data logger were installed on the proper electrical circuits to record power and energy readings at a given interval for the designated time period.

Power measurements were taken using the Dent Instruments Elite Pro Data Logger (Line Powered, Extended Memory) with 20 amp CTs.

Adura LightPoint System

SITE DESCRIPTION: ALAMEDA COUNTY WATER DISTRICT

The Adura demonstration occurred at an Alameda County Water District (ACWD) office building located in Fremont, CA. The area chosen for the evaluation of the Adura product is approximately 2,000 square feet in the Operations Department. This area is located in a single-story building, dominated by an open floorplan with cubicles. There were 33 fixtures in the study, 31 of which were 2' x 4' recessed, lensed troffers. The other two fixtures were 0.5' x 4', single lamp recessed troffers. (One 2' x 4' fixture in the study area was wired similar to an emergency fixture—we could not locate a wired switch to control it; therefore, the fixture was excluded from the study.) Six of the 31 2' x 4' fixtures in the study were in three private offices (two in each); the rest were in an open floorplan area with cubicles.

Although the site initially had a single ballast controlling the three lamps in each fixture, all fixtures in the evaluation were retrofitted with two ballasts to enable inboard/ outboard switching prior to the energy efficiency testing. There were also seven 2' x 2' recessed troffers in the walkway areas between cubicle clusters-- three of which were emergency lighting—but none of these fixtures would accommodate the Adura Light Controller due to space constraints; therefore, they were excluded from the study.

Personal Control Groups

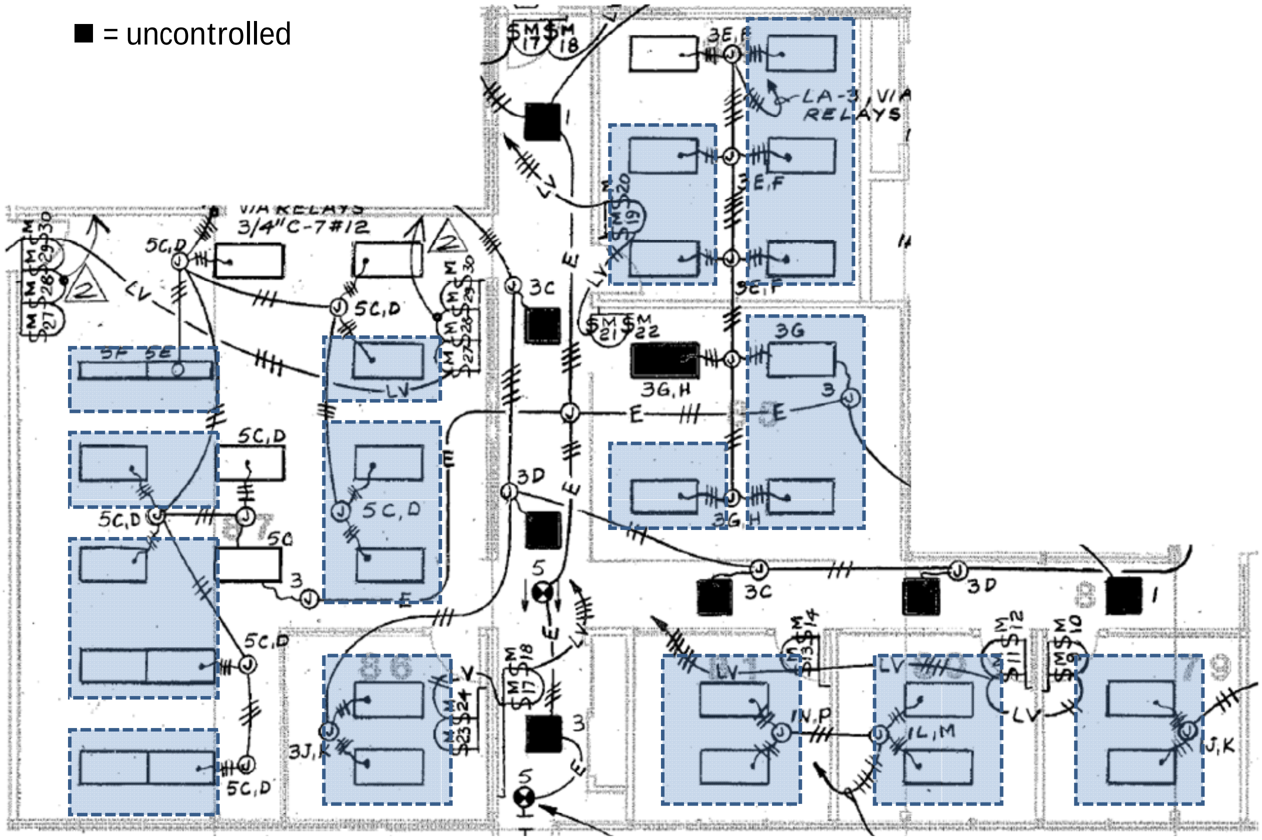


Figure 4: Monitoring and Evaluation Area at ACWD for Adura, showing controlled (blue) and uncontrolled (black) fixtures

ENERGY EFFICIENCY TEST DESCRIPTION

The energy efficiency test aimed to determine whether the personal occupant controls (wireless personal light switches) functioned properly and to measure the energy efficiency savings associated with giving occupants control over the fixtures directly over their workspace. Although the site initially had a single ballast controlling the three lamps in each fixture, all fixtures in the evaluation were retrofitted with two ballasts to enable inboard/ outboard switching prior to the energy efficiency testing. A single Light Controller (LC-2R) was connected to the two ballasts in each of the 33 fixtures in the study (each Light Controller can accommodate one or two ballasts). Two months of baseline power data was collected prior to the beginning of the energy efficiency testing, after which Adura commissioned the personal light switches in the following way:

Beginning with an initial state of having no lamps on:

First click → single inboard lamp turns on = one lamp on

Second click → single inboard lamp turns off and two outboard lamps turn on = two lamps on

Third click → two outboard lamps remain on and single inboard lamp turns on = three lamps on

Fourth click → inboard and outboard lamps turn off = no lamps on

In addition to supplying each occupant with a personal remote light switch, Adura retrofitted an existing wired wall switch with a wired master wall switch near the area's entryway. This switch controlled a limited number of fixtures, primarily illuminating walkways, to allow lighting for the safe passage of employees and afterhours cleaning crews as they moved about the office. This switch was commissioned so that clicking the switch turned on all lamps in the chosen walkway fixtures; clicking it a second time turned all lamps in the chosen fixtures off. There were no intermediary inboard/ outboard settings.

Once the switches were distributed and commissioned to control the appropriate fixtures, staff was informally advised of the change and provided a brief introduction to the clicking sequence outlined above. We then commenced with two weeks of energy efficiency testing and monitoring, from December 1 - 18, 2008 during which occupants were free to control the fixtures most directly positioned over their workspaces, and set lighting levels to their liking. This period concluded the energy efficiency testing and monitoring of the Adura system.

Universal DCL System and DEMANDflex Ballast

SITE DESCRIPTION: ALAMEDA COUNTY WATER DISTRICT

The Universal demonstration occurred at two sites. The first was the Alameda County Water District office building located in Fremont, CA. This site was chosen, in part, because the District participates in PG&E's Automated Critical Peak Pricing program through adjustments to their HVAC system during peak demand events.

The area in which the monitoring and evaluation took place is approximately 3,480 square feet of open office space in the agency's Engineering Department. The evaluation area was located in a single-story building and has an open floorplan with cubicles and some private perimeter offices. The lighting fixtures in the area were predominantly 2' x 4' recessed, lensed troffers, with three lamps controlled by a single ballast. There were a total of 68 fixtures powered by three lighting circuits, labeled Circuits 2, 3 and 5 in building plans. The host site requested that the private offices in the area be excluded from the evaluation. Therefore, two of these three circuits included some lighting load that was *not* controlled by the DCL/DEMANDflex technology. The following reflected ceiling plan color codes each demonstration circuit: Circuit 2 is blue, Circuit 3 is green, and Circuit 5 is red. Note that the perimeter private office fixtures not controlled by the DCL system have been shaded gray.

Figure 5: Monitoring and Evaluation Area at ACWD for Universal DCL System, Showing Three Separate Circuits Controlled

ENERGY EFFICIENCY TEST DESCRIPTION

To evaluate the energy efficiency capability of the DEMANDflex system, the Relay Sensing Module (RSM), was commissioned so that "normal" ballast power output was tuned to 90%, instead of the default 100%. This essentially changed the ballast factor to 0.9 of its manufactured ballast factor. Commissioning of the system was achieved using a software program provided by Universal that interfaces with the DCL and RSMs through a USB connection. The software and cable adaptor allow users to commission their own system's lighting power levels. For this demonstration, Energy Solutions staff loaded the software onto a laptop and brought it to the host site for commissioning. Using the software's GUI interface, the user sets scenes for each of the SC20s, which control all the ballasts on each individual circuit. In other words, all the ballasts on each circuit must be set to operate the same way, but each circuit can be set to operate distinctly from the other circuits. As stated above, in this case, all circuits were set to operate at a ballast power level of 90%.

Baseline lighting circuit power data was measured and recorded for a two week period, from November 17 - 30, 2008. After commissioning for the energy efficiency test, lighting circuit power was collected for a two week period, from December 2 - 18, 2008. The system was commissioned for another energy efficiency test during a visit on February 4, 2009, with two weeks of additional data collection following. During the second visit, spot power readings were also taken on the circuits through an array of power level settings to confirm system function. The outcomes of these tests are provided in Project Results.

SITE DESCRIPTION: ANHEUSER-BUSCH

The second host site at which the DEMANDflex system was evaluated was the Anheuser-Busch company in Fairfield, CA. The evaluation area was comprised of a small open office area with cubicles (~980 square feet), as well as one private office (~160 square feet). The lighting system consisted of 15 2' x 4' recessed troffers, each with three lamps controlled by one ballast. Two of the 15 fixtures were located in the private office. There were two lighting circuits in the demonstration area: One circuit serving two rows of overhead fixtures (four each) that were normally on during business hours, and a second circuit serving the balance of fixtures in the open plan, which were on their own switch leg, as well as the fixtures in the private office. Power data indicated that the fixtures in the open plan on the second circuit were often off during business hours while the private office lights were switched on and off according to occupancy. The reflected ceiling plan below shows the layout of the two circuits, labeled 13 and 15, retrofitted for this study.

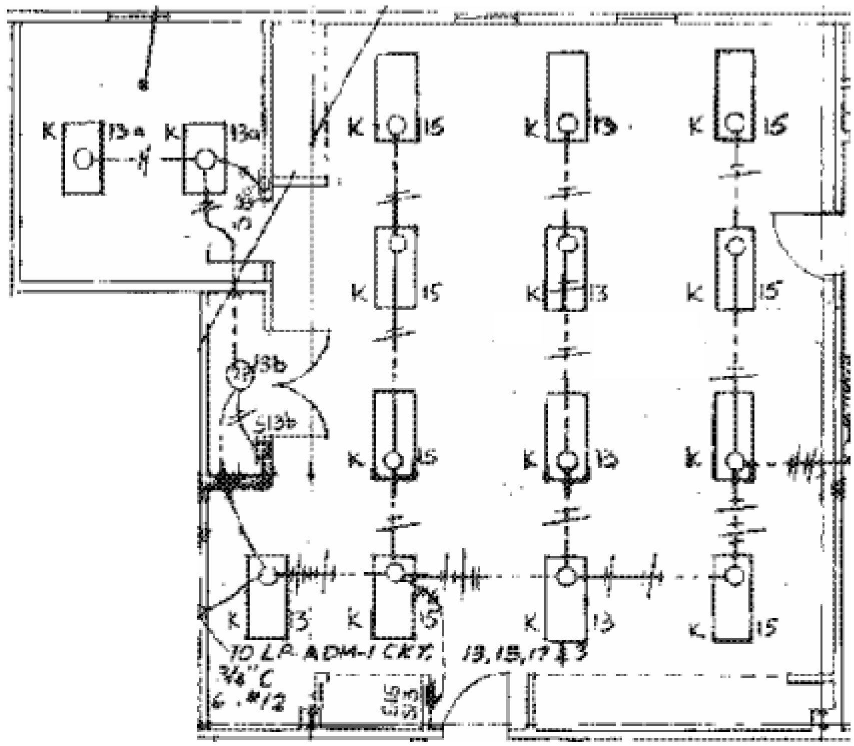


Figure 6 : Reflected Ceiling Plan for Monitoring and Evaluation Area at Anheuser-Busch for Universal DCL System

ENERGY EFFICIENCY TEST DESCRIPTION

The energy efficiency capability of the DEMANDflex system was also evaluated at the second site by commissioning "normal" ballast power output to a slightly more aggressive level of 85% of full power. Again, commissioning of the system was achieved using Universal's DCL Commissioning software. Commissioning was conducted by Energy Solutions on February 5, 2009 with host site staff present. Data was collected for one month before energy efficiency commissioning, and again for a three-week period at the new power settings.

The DCL controls at Anheuser-Busch had to be installed above the office space's drop ceiling against a firewall because the breakers where the circuits would otherwise be accessed were located in a small cabinet in a common hallway with no space for additional equipment. For access purposes this type of installation location was not ideal, requiring a ladder and removal of ceiling tiles.

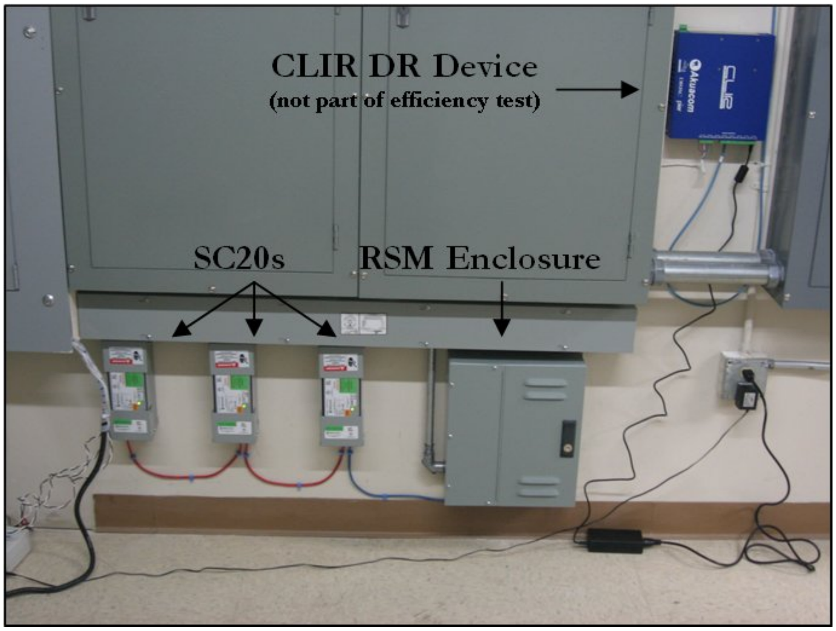


Figure 7. Photos of Installed Universal DCL System Controls at ACWD

Echoflex

SITE DESCRIPTION: ENERGY SOLUTIONS

The Echoflex technology was demonstrated at the Energy Solutions office building in Oakland, CA. The evaluation area included three large offices, each shared by two to three employees (no cubicles). The area of the offices totaled roughly 515 square feet. The rooms included a total of eight 2' x 4' lensed troffers with two lamps controlled by a single ballast in each fixture. One of the eight fixtures was wired to a circuit inaccessible to monitoring equipment and was therefore excluded from the evaluation.

Recall that for this technology, wireless switches and sensors are placed in the office space to transmit control commands, while controllers are installed on the lighting circuits and wired to dimmable ballasts to switch or dim fixtures based on received transmissions. The controllers set light levels through a 0 – 10 volt dimming circuit wired from the controller to the dimmable ballasts, which had to be installed in all demonstration fixtures. In this demonstration a single controller was installed to switch and dim two fixtures together for two of the offices (Offices 1 and 3 in the following diagram). A wireless switch and photo control was situated in each of these offices and programmed to communicate with the room's controller. In the third office, controllers were installed at each overhead fixture to dim each fixture independently. Each occupant in Office 2 was given a wireless switch that controlled and dimmed only the fixture over their desk. Two photo sensors were then installed in this office, one programmed to control two fixtures along the same wall and one programmed to control the remaining fixture. Note that once the photo sensors were commissioned, occupants turned lights on and off manually but fixture light levels were dimmed automatically. Occupants could dim fixtures below the level set by the photo sensor but could not override the system by increasing light level beyond the photo sensor setting.

The following view (not to scale) of the demonstration area shows the offices and fixtures where the controllers and dimmable ballasts were installed, the photo sensor locations, and the zones of lights they controlled.

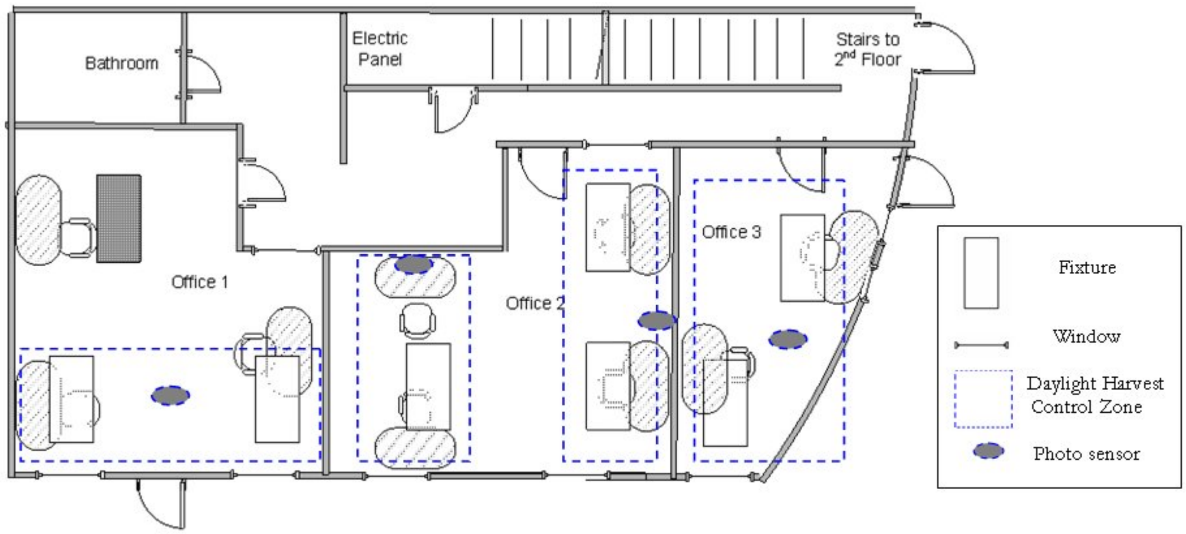


Figure 8: Monitoring and Evaluation Area at Energy Solutions for Echoflex System

ENERGY EFFICIENCY TEST DESCRIPTION

The Echoflex technology installed at the host site offered two potential energy efficiency capabilities: 1) wireless dimming switches that allowed occupants to turn light fixtures on and off, and manually dim light levels according to their preference; and, 2) wireless, battery-free photo sensors for daylight harvesting (automatic fixture dimming based on ambient light levels) in the offices-- which each had significant exposure to outside sunlight. For this energy efficiency evaluation, functional testing was carried out for the wireless switches and photo sensors, but energy savings were only measured for daylight harvesting with the photo sensors.

For the test period, the controllers and photo sensors were commissioned to dim or turn off the fixtures they controlled in order to maintain a target light level setting using the wireless switches as commissioning devices. Occupants were asked to turn their lights on during normal business hours; fixture light levels were then determined throughout the day based on photo sensor feedback and target light levels., which were set for each control zone based on occupant feedback. The photo sensors relayed ambient light levels at a regular interval to the controllers, which dimmed, brightened, or turned off overhead lights in order to maintain the target setting. Controllers were installed on each fixture in Office 2. In all three offices, the work areas affected by the controlled fixtures were within three to 15 feet of perimeter windows, which faced West/ Northwest, receiving indirect sunlight through AM hours and some direct sunlight in mid- to late- afternoon.

Using the wireless light switch, occupants were only able to dim light levels lower (not higher) than the level dictated by the photo sensor; however, occupants found they could override the photo sensor by turning the light fixture off and on, at which time the fixture would default to 100% light output until the next dimming event occurred.

To evaluate the efficiency capability of the Echoflex daylight harvesting technology, baseline power on each of the affected lighting circuits was measured for several weeks prior to installation of the controllers, dimming ballasts and photo sensors. Power levels were then logged for a two week period after commissioning of the photo sensors on April 7, 2009.

Project Results

Adura LightPoint System

Adura's LightPoint system was installed on fixtures served by Lighting Circuits 1, 3, and 5 of one of the host site's office areas. The energy efficiency strategy for the LightPoint System involved installation of wireless controls allowing individuals to switch single fixtures or groups of fixtures based on personal preference, in the "inboard/outboard" fashion described previously. Observation and experience at the installation confirmed that the wireless personal controls did function as intended by switching inboard and outboard lamps on and off according to the click sequence described previously.

To evaluate the efficiency potential of the Adura LightPoint System, a data logger was installed on these lighting circuits. The logger was programmed to record RMS volts, Amps, kW, and Power Factor at five minute intervals (averaged) for a period of two months before the installation of the personal controls and for several weeks after the system was installed and commissioned for efficiency purposes. The data logging equipment, a Dent ElitePro Datalogger with CTs and voltage probes, was provided by the Pacific Energy Center's Tool Lending Library.

Lighting load on each circuit dropped to zero or near zero power after business hours, though hours of occupancy showed some daily variation. To maintain a more consistent analysis for the baseline and energy efficiency comparison, the power data was filtered to business days, 8:00 AM to 5:00 PM, excluding holidays, to calculate average lighting power. Average Lighting Power Density (LPD, W/ft^2) was also calculated for each condition. Estimates of office area were based on scaled lighting plans and included the entire floor area under the three monitored circuits.

Average power for each circuit was calculated for two months prior to installation of the Adura personal controls technology (September 25 to November 25) and for the period from December 1, when the system was commissioned, to December 18, when the data logger was removed. Note that each lighting circuit served both Adura- controlled fixtures and uncontrolled fixtures. Though logged data was for entire circuits, the percent of each circuit's power dedicated to Adura-controlled fixtures was estimated to quantify lighting power reductions.

Across all three circuits there was a significant decrease in average lighting power, following personal control commissioning. The circuit level power data included Adura-controlled fixtures and uncontrolled fixtures, but all else being equal, it is reasonable to attribute the reduction in average lighting power to the Adura-controlled fixtures. As a control, data monitoring during the same time period in another office area in the same facility showed virtually no change in average lighting power. Total average lighting power on all three lighting circuits dropped by almost 40% during the energy efficiency period, when Adura remote light switch controls were in use. Since the measured reduction in average lighting power includes retrofitted fixtures and fixtures unaffected by the demonstration, it can be assumed that the lighting power reduction for the retrofitted fixtures alone was actually much greater. Based on the estimated percent of each circuit's power dedicated to Adura-controlled fixtures during the energy efficiency period, lighting power reduction for Adura Light Controller fixtures alone was over 70%, as shown in the table below.

As a useful comparison, California Energy Commission's Public Interest Energy Research Program (PIER) has also evaluated Adura's LightPoint System (in prototype) at a University of California at

Berkeley (UCB) office location. Similar to this demonstration, the PIER installation included personal wireless controls for overhead light fixtures and found a 65% reduction in lighting energy usage,[5] which agrees well with the results of this study.

Table 5: Adura LightPoint System Demand Reduction Results: Circuit Level Analysis

Lighting Circuit, % Circuit Power for LightPoint Fixtures*	Test Period	Average kW**	% Total Circuit Power	% LightPoint Fixture Power***	Average LPD****
Circuit 1, 27.3% LightPoint	Baseline	1.053	100.0%	100.0%	0.79
	Energy Efficiency	0.907	86.1%	49.2%	0.39
Circuit 3, 74.2% LightPoint	Baseline	1.152	100.0%	100.0%	1.02
	Energy Efficiency	0.645	56.0%	40.7%	0.41
Circuit 5, 68.3% LightPoint	Baseline	1.427	100.0%	100.0%	1.05
	Energy Efficiency	0.644	45.1%	19.7%	0.21
All Circuits, 54.4% LightPoint	Baseline	3.632	100.0%	100.0%	0.95
	Energy Efficiency	2.196	60.5%	27.4%	0.26

* The fraction of the lighting load controlled by Adura was estimated based on fixtures controlled by Adura over the total fixtures on the circuit (factoring in fixture wattages)

** Averages were based on power readings during regular office hours; Monday – Friday (8 – 5)

*** Calculated by subtracting average lighting power difference from Baseline to energy efficiency from the percent of circuit power dedicated to Adura Light Controller-controlled fixtures only.

**** Energy efficiency LPD based on applying calculated power reduction during energy efficiency period to entire Circuit Floor Area

Note that data loggers recorded power reduction, the percent savings of which can be extrapolated to represent energy efficiency since hours of operation are consistent for the baseline and monitoring periods.

[5] See Public Interest Energy Research Program Technical Brief Wireless Lighting Controls Make Retrofits Practical, September 2008.: http://www.energy.ca.gov/2008publications/

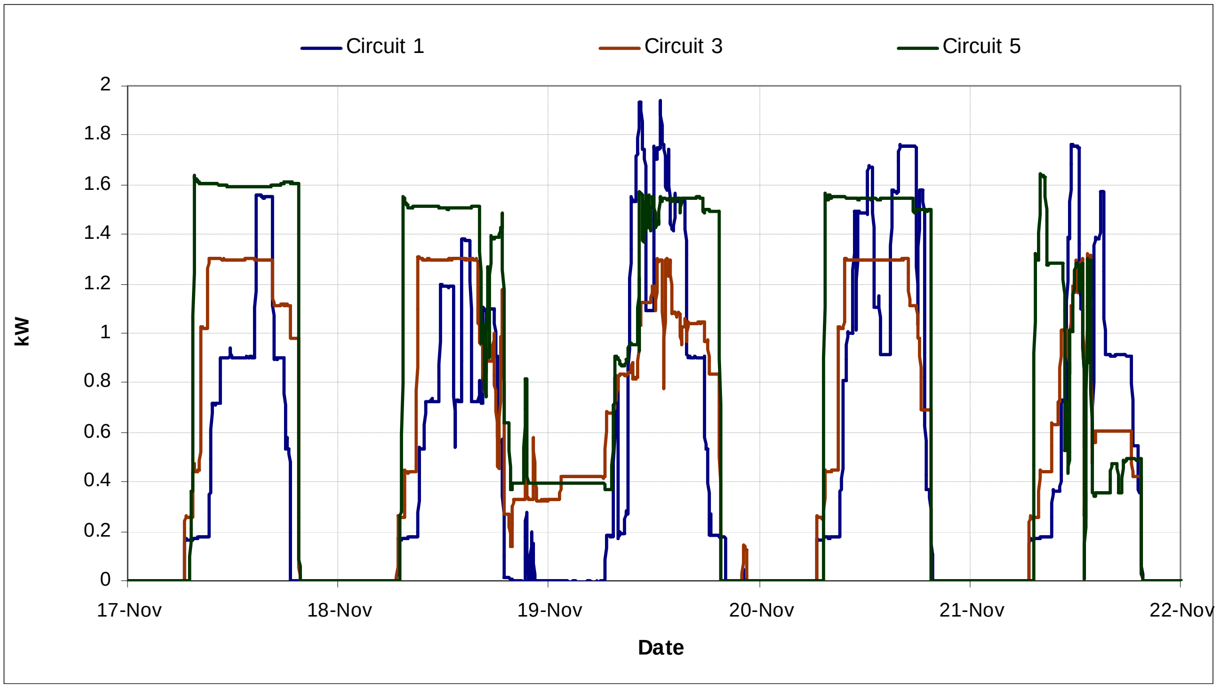


Figure 9: Sample Time Series of Pre-Light Controller Lighting Circuit Power

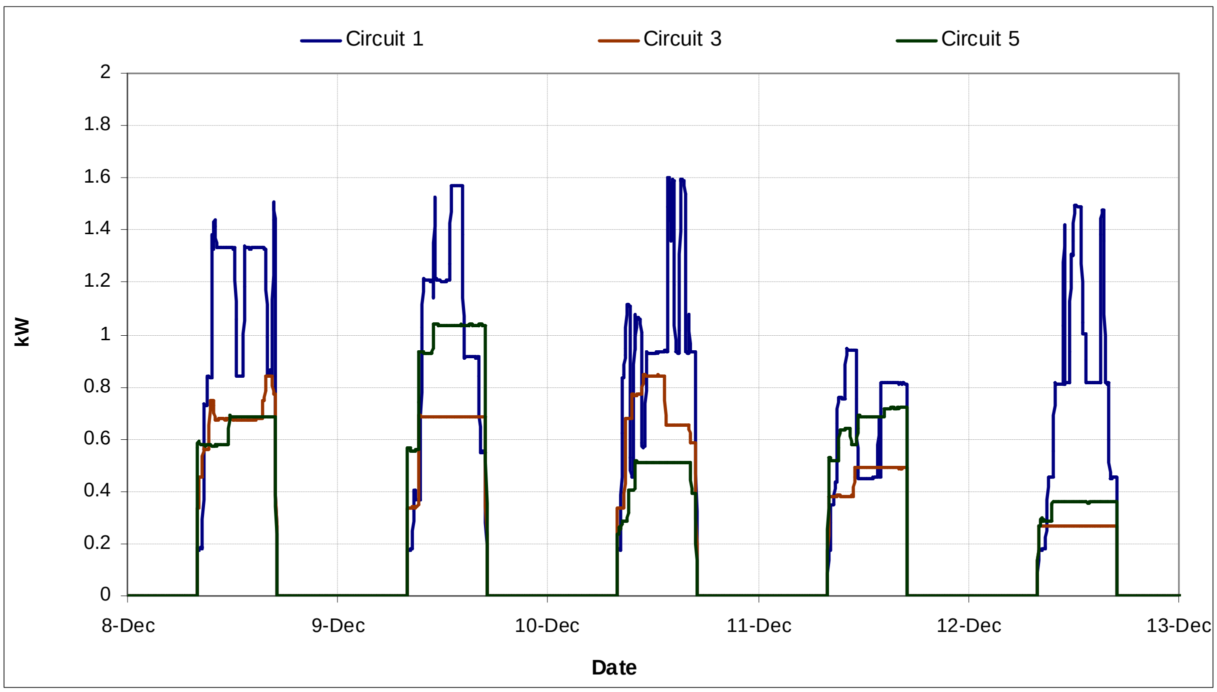


Figure 10: Sample Time Series of Post-Light Controller Lighting Circuit Power

Adura's LightPoint System technology allows each Light Controller to report back its status (on or off) to the system Gateway, which transmits fixture level changes of state to an Adura database. The database can calculate system lighting power based on assumed demand from individual fixtures. Because the measured power data at the circuit level included load outside the analysis, Adura was asked to provide power data for a period of time before and after the personal controls were commissioned. While power data in five minute averages was available for the period of time after personal control commissioning, December 1 - 18, baseline data was not available due to some data quality challenges with Adura's database. However, based on Adura's assumed wattages for each fixture and general occupancy information provided by facility contacts, it was possible to estimate average lighting power for the Light Controller-controlled fixtures before the personal controls were installed.

For this estimation, all open plan lighting was assumed to be on during normal business hours. Of the four individual offices in the Adura LightPoint System demonstration area (two fixtures per office), two were assumed occupied (lights on) 80% of normal business hours, and two were assumed occupied 60% of normal business hours.

Average lighting load under these conditions was calculated to be 2.52 kW, while average lighting load calculated from LightPoint System data following installation of the personal controls was 1.25 kW. This analysis shows a decrease in lighting power of 50%, or 1.27 kW.

Table 6: Adura Light Controller Demand Reduction Results: Calculated Baseline and Adura Light Controller Efficiency Period Data

Test Period	Average kW*	Average LPD	% Total Power
Baseline	2.52	1.25	100.0%
Energy Efficiency	1.25	0.70	49.6%

* Averages based on regular office hours; Monday – Friday (8 – 5)

Note that data loggers recorded power reduction, the percent savings of which can be extrapolated to represent energy efficiency since hours of operation are consistent for the baseline and monitoring periods.

Comparing the analysis of the circuit level logged data with the approach where lighting power reduction was estimated from a calculated baseline and using Adura LightPoint System data for the energy efficiency period, both analyses indicate significant savings potential from the wireless personal controls technology coupled with Adura's LightPoint System. Qualitatively, the time series plots above of lighting circuit power also clearly demonstrate the impact of personal controls.

ENERGY EFFICIENCY RESULTS

ACWD is billed for electric service at PG&E's E – 19 rate schedule[6] for 'Medium General Demand-Metered Time of Use Service' which includes energy charges ($/kWh) that are dependant on time of use, ranging from $0.08 to over $0.14 throughout the year, with an annual average kWh rate of $0.12836 for customers such as the host facility. Based on energy usage measurements from

[6] Available at: http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_E-19.pdf

Table 5 and assuming a 50% reduction in lighting power, energy savings for the Adura-controlled fixtures in this demonstration would be 2,964 kWh for 3,000 annual operating hours. For a 50,000 square foot space with the same baseline LPD as this demonstration, these savings would translate to 71,250 kWh annually, or $9,146.

Universal DCL System and DEMANDflex Ballasts

To evaluate the functionality and efficiency potential of the Universal DCL system, a data logger was installed on the lighting circuits retrofitted with DEMANDflex. The logger was programmed to record RMS volts, Amps, kW, and Power Factor at five minute intervals (averaged) for a period of over one month before the installation of the DCL system and for several weeks after the system was installed and commissioned for efficiency purposes. The data logging equipment, a Dent ElitePro Datalogger with CTs and voltage probes, was provided by the Pacific Energy Center's Tool Lending Library.

Using Universal's commissioning software, the DCL system was used to reset lighting power levels on each circuit to 90% of full power at Site 1 and 85% of full power at Site 2. The data logger served as both a check that the energy efficiency commissioning worked and to measure demand reduction over time.

ALAMEDA COUNTY WATER DISTRICT

Universal's DCL system was installed on Lighting Circuits 2, 3, and 5 of one of the host site's office areas. Lighting Circuit 3 served only open plan fixtures that were all switched together and consisted entirely of fixtures retrofitted with DEMANDflex and controlled by the DCL system. Portions of the lighting load on Circuits 2 and 5 were from private offices and conference rooms not retrofitted with DEMANDflex ballasts and switched independently of open plan fixtures. Though these fixtures were not controlled by DCL, they contributed load to the circuit level power measurements recorded by the data logger, which had to be factored out for data analysis.

Occupancy patterns for the private offices included in Lighting Circuits 2 and 5 varied and were not necessarily the same during baseline and energy efficiency monitoring. The cleanest comparison that could be made was the baseline and energy efficiency data for Circuit 3 only since all lights on the circuit were either on or off. However, power reductions could be accurately quantified for Circuits 2 and 5 by comparing baseline and energy efficiency power data that was sorted into bins according to load levels corresponding to groups of fixtures on, such as open plan only, open plan plus one office and so on. These bins, based on assumed number of fixtures on, were evident in the datasets. For example, on Circuit 2 during the baseline period (November 17 -30), the data showed roughly three load bins; open plan fixtures alone on roughly 3% of occupied time, open plan and one office on 52% of the time, and open plan fixtures and both offices were on 45% of the time. Sorting Circuit kW into designated bins for each monitoring period based on fixture number captured 97% - 99% of all kW readings in every case. For the bins that include lighting load from private offices not controlled by the DCL, office lights had to be factored out based on percent circuit power they represented in order to estimate average kW reductions from the DCL system.

The tables of efficiency results below compare average baseline and energy efficiency lighting power for each Circuit in the full load bin (all connected fixtures on). Results for other bins were consistent with these results in terms of demand reductions. The percent of readings in each bin is also shown in Table 7.

Changes in LPD, expressed as Watts/ft^2, were also calculated. Office area estimates were based on scaled lighting plans, and only the floor area under fixtures controlled by the DCL system was included in LPD calculations.

Though the system was commissioned on December 2 to reduce lighting power on each circuit to 90% baseline power, average power for the period from December 2 until data logger removal on December 18 indicate virtually no change as the table below demonstrates.

Table 7: Demand Reduction Results for Universal DEMANDflex at ACWD, Test 1

Circuit	Bin	Period	Bin Frequency*	Average kW**	Average LPD	% Total Power
2	Full Load: Open Plan + 4 Office Fixtures	Baseline	45.2%	1.519	1.69	100.0%
		Energy Efficiency	51.0%	1.521	1.69	100.1%
3	Full Load: Open Plan Only	Baseline	100%	1.704	1.27	100.0%
		Energy Efficiency	100%	1.707	1.27	100.2%
5	Full Load: Open Plan + 7 Office Fixtures	Baseline	30.7%	1.199	1.03	100.0%
		Energy Efficiency	54.1%	1.200	1.03	100.1%

* % kW readings within data bin during occupancy
** Average kW excludes load from fixtures not retrofit with DEMANDflex

Note that data loggers recorded power reduction, the percent savings of which can be extrapolated to represent energy efficiency since hours of operation are consistent for the baseline and monitoring periods.

The dataset does show that for a period of roughly 20 minutes (3:40 PM to 4:00 PM) during the efficiency commissioning visit, lighting system power was briefly reduced to the desired level. For example, total power for Circuit 3 was measured at 1.524 kW (89.3% of baseline average) during that time. However, the system reverted back to prior power levels when commissioning was complete.

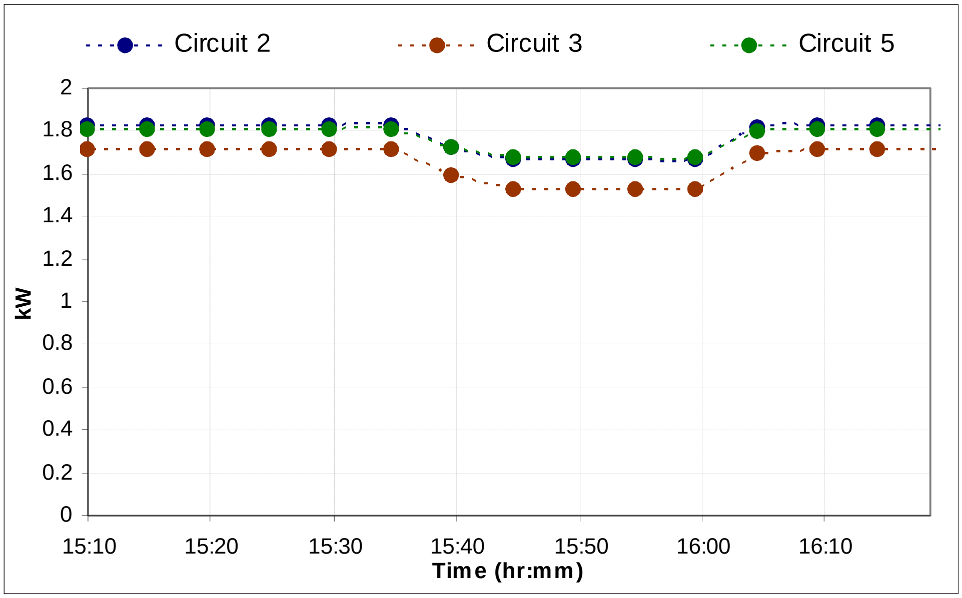


Figure 11: Time Series of Efficiency Commissioning on Universal DEMANDflex System

Discussions with the manufacturer clarified that in the commissioning software, desired circuit power levels (relative to 100%) must be set in two different program locations for the changes to persist after logging out of the system. It is possible that the levels were not set in one of these program locations the first time, and the manufacturer agreed to assist in a second efficiency commissioning effort to re-evaluate the system.

The second energy efficiency commissioning visit took place on February 4, 2009. Before this visit the data logger was again installed on the three affected circuits. To confirm system function during the commissioning visit, spot power readings were taken on each circuit through a series of power level settings in the DSM commissioning software. The measured lighting power levels agreed with the programmed levels in the software interface, confirming system function. The lighting power levels were then set to 90% for each circuit and data was collected for a period of almost three weeks (February 4 – 23, 2009). Data from the second efficiency period indicated that the desired reduction to 90% baseline power was achieved on Circuits 2 and 5, but again Circuit 3 remained virtually unchanged. This is thought to be due to another error during commissioning.

Table 8: Demand Reduction Results for Universal DEMANDflex at ACWD, Test 2

Circuit	Bin	Period	Bin Frequency*	Average kW**	Average LPD	% Total Power
2	Full Load: Open Plan + 4 Office Fixtures	Baseline	45.2%	1.519	1.69	100.0%
		Energy Efficiency	43.5%	1.362	1.51	89.6%
3	Full Load: Open Plan Only	Baseline	100%	1.704	1.27	100.0%
		Energy Efficiency	100%	1.683	1.26	98.8%
5	Full Load: Open Plan + 7 Office Fixtures	Baseline	30.7%	1.199	1.03	100.0%
		Energy Efficiency	37.0%	1.074	0.93	89.6%

* % kW readings within data bin during occupancy
** Average kW excludes load from fixtures not retrofit with DEMANDflex

Note that data loggers recorded power reduction, the percent savings of which can be extrapolated to represent energy efficiency since hours of operation are consistent for the baseline and monitoring periods.

ENERGY EFFICIENCY RESULTS

At full load for all three circuits, total kW demand from DEMANDflex fixtures equaled 4.422 kW, with an LPD of 1.27. If this were the constant load for 3,000 annual operating hours, a 10% reduction on all circuits would save the facility roughly 1,327 kWh. For a 50,000 square foot facility of equal LPD, energy savings would equal 19,050 kWh, or $2,445 using PG&E's E – 19 schedule average energy rate of $0.12836/kWh.

ANHEUSER-BUSCH

The lighting load at Anheuser-Busch consisted of two Circuits, labeled 13 and 15. Circuit 15 powered eight fixtures in the open floor plan and was wired with only one switch, so that all lights were either on or off. Circuit 13 served two groups of fixtures with each group on its own wall switch; two fixtures in a private office and five fixtures in the open area. Baseline data was collected for one month beginning February 5 and energy efficiency data was collected for three weeks beginning when the system was commissioned for the energy efficiency period on March 3, 2009. Data from the baseline period and the energy efficiency period showed Circuit 15 to consistently be on during business hours but showed high variability in lighting usage on Circuit 13's two switches. In order to compare the data sets to evaluate any power reduction, it was necessary to bin Circuit 13's power data according to which groups of fixtures were on. Three consistent levels of load were evident: for Bin 1 only the private office fixtures were on; for Bin 2 the lights in the private office and the open area were on; and for Bin 3 only the open area lights were on. The percent of data in each bin during baseline and energy efficiency periods is given below.

Table 9: Demand Reduction Results for Universal DEMANDflex at Anheuser-Busch site, Test 1

Circuit	Bin	Period	Bin Frequency*	Average kW**	Average LPD	% Total Power
13	1: Private Office Only	Baseline	95.3%	0.171	1.07	100.0%
		Energy Efficiency	77.8%	0.143	0.89	83.4%
13	2: Private Office and Open Plan	Baseline	0.8%	0.568	1.03	100.0%
		Energy Efficiency	2.6%	0.459	0.83	80.8%
13	3: Open Plan Only	Baseline	3.9%	0.432	1.10	100.0%
		Energy Efficiency	19.6%	0.349	0.89	80.9%
15	1: All Fixtures	Baseline	100%	0.672	1.14	100.0%
		Energy Efficiency	100%	0.549	0.93	81.8%

* % kW readings within each data bin during occupancy

** For Circuit 13, controls installed along with the DEMANDflex system were powered on the same circuit and added 0.02 kW constant load which was subtracted from averages.

Note that data loggers recorded power reduction, the percent savings of which can be extrapolated to represent energy efficiency since hours of operation are consistent for the baseline and monitoring periods.

Data logger readings during the energy efficiency commissioning visit confirmed that lighting power levels had been set to the programmed level of 85% full power. The time series data for both circuits also indicated that lighting power remained at the reduced level throughout the energy efficiency period. Results were within 2 - 4% of expectation.

ENERGY EFFICIENCY RESULTS

Weighting average kW by bin frequency, this facility's lighting demand equaled 0.857 kW. If a 15% reduction in lighting power were achieved on these lighting circuits for an entire year of 3,000 operating hours, the facility could expect to save roughly 385 kWh. For a 50,000 square foot facility with a weighted average LPD of 1.13 (the baseline weighted average floor area is roughly 760 square feet), energy savings would equal 25,425 kWh, or $3,264 using PG&E's E – 19 schedule average energy rate of $0.12836/kWh.

Echoflex

The Echoflex system was installed in the Energy Solutions office space laid out in the following plan view (not to scale) with offices labeled by number. Offices 1, 2 and 3 under the demonstration fixtures are approximately 160, 215 and 140 square feet, respectively. The rooms include a total of eight 2x4 lensed troffers with two lamps controlled by a single ballast in each fixture.

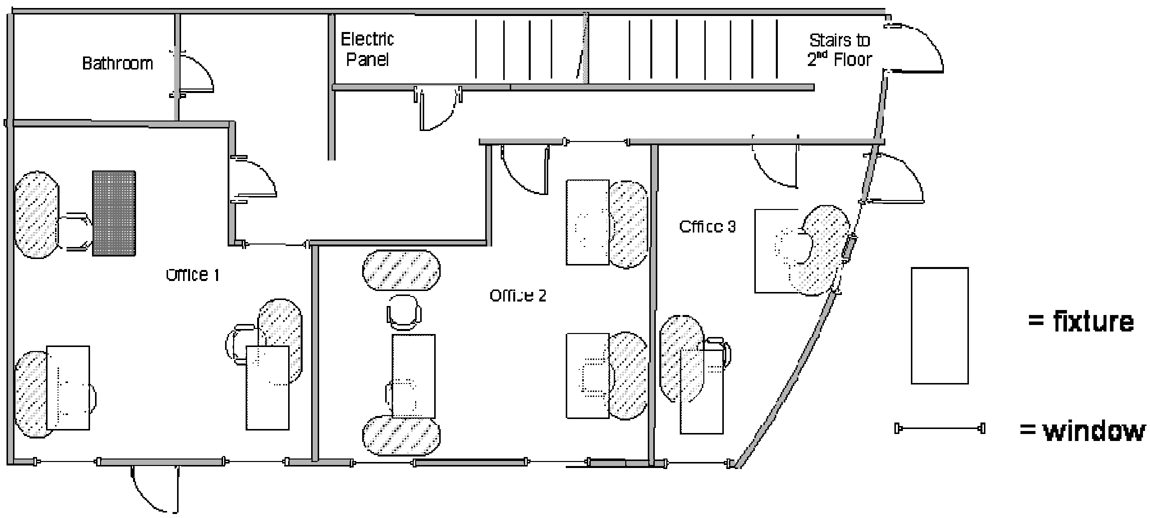


Figure 12: Plan View of Echoflex Site

To evaluate system function for the Echoflex technology, the lighting controllers were installed in each office and wired either to single or multiple fixtures, and wireless switches and photo sensors were located in each office as described previously. The wireless dimmer switches were installed in place of previous wired wall switches, and in the case of Office 2, where each fixture received its own controller, occupants were each given a wireless wall switch to control the fixture above their desk. Switches preformed as intended in all cases. Using the wireless switches as commissioning tools, the photo sensors and controllers were then programmed for daylight harvesting by setting target light levels in each zone according to occupant feedback. Desks and overhead fixtures in each office were within three to 15 feet of exterior windows so lighting power for all of the retrofitted fixtures had the potential to be reduced by taking advantage of natural lighting during sunny days through daylight harvesting. Observations verified that fixtures dimmed and turned off automatically throughout the day based on ambient light levels during the energy efficiency period.

As noted previously, occupants discovered that they could override the dimming by turning the fixture off and then back on using the wireless light switch. According to the manufacturer, the system has been improved to include photo set point defaults that can be locked in, so that they can not be reset by simply turning the system on and off.

To quantify energy reduction resulting from the wireless daylight harvesting system, a data logger was installed on the lighting circuits retrofitted with the technology. The logger was programmed to record RMS Volts, Amps, kW, and Power Factor at one minute intervals (averaged) for over one month before the installation of the system, and for a two week period after the system had been installed and the photo sensors and target light levels were fully commissioned (April 7 – 22, 2009). The data logging equipment, a Dent ElitePro Datalogger with CTs and voltage probes, was provided by the Pacific Energy Center's Tool Lending Library.

Because the demonstration space consisted of several small offices accommodating two to three employees each, with lights switched on manually, hours of usage per day were not necessarily consistent during baseline or energy efficiency monitoring periods. For example, occasionally individual offices were partially or wholly unoccupied for spans within the monitoring periods. In fact, lighting usage patterns in Office 3 varied so widely they had to be excluded from the data analysis. To provide a consistent basis of comparison, baseline and energy efficiency datasets were narrowed to the most consistent span of consecutive days to calculate average kW. The power data was also filtered to only consider typical business days for the site, 8:00AM to 5:00PM, excluding holidays, in order to estimate average daily lighting power levels. The best window of consistent baseline data was found to be the week of December 1 – 5. For the energy efficiency period, occupancy was generally consistent from April 8 - 17, excluding the weekend and April 13 for Office 3 and April 14 for Office 2.

Office dimensions were measured on site to calculate floor area, and only floor area under fixtures controlled by Echoflex was included in LPD (W/ft^2) calculations. Changes in LPD from the baseline condition to the efficiency case were also calculated.

The data for all three offices confirm that daylight harvesting with the photo sensors was an effective efficiency strategy, with a measured reduction of 63.3% in total lighting power.

Table 10: Demand Reduction Results for Echoflex; Office 2 and 3 Only

Timeframe	Period	Average kW	Average LPD	% Total Power
12/01/08 12/05/08	Baseline	0.277	0.74	100.0%
4/08/09 - 4/17/09	Energy Efficiency	0.102	0.27	36.7%

* Averages based on regular office hours; Mon – Friday (9 – 5)

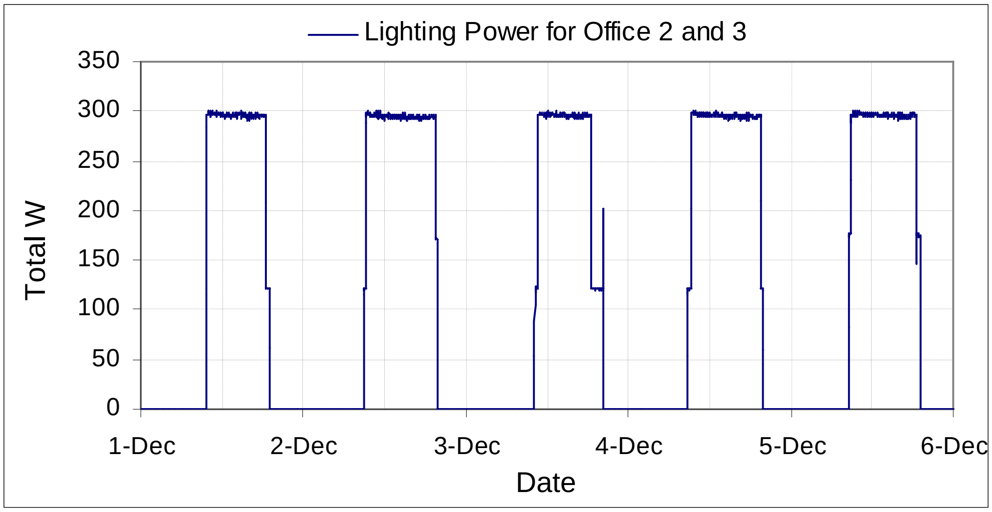
Note that data loggers recorded power reduction, the percent savings of which can be extrapolated to represent energy efficiency since hours of operation are consistent for the baseline and monitoring periods.

ENERGY EFFICIENCY RESULTS

If this reduction were achieved in the analyzed space for an entire year of 3,000 operating hours, the facility could expect to save roughly 526 kWh. For a 50,000 square foot facility with the same average LPD, energy savings would equal 70,165 kWh, or $9,006 using PG&E's E – 19 schedule average energy rate of $0.12836/kWh.

However, the savings measured here cannot easily be applied to all office spaces since exposure to daylight will vary greatly according to factors such as proximity to exterior windows, the direction such windows are facing, and local climate and shading. The energy efficiency period for this study consisted of mostly clear days, allowing for effective daylight harvesting, but this would not always be the case. Also, target light levels were commissioned at this site based on office occupant feedback regarding desired level of lighting to perform work tasks. This will also vary by occupant preference and the type of work performed[7].

[7] Indoor lighting guidelines such as IESNA's *Standard Practice for Office Lighting* (RP-1) offer recommendations for maintained task plane illuminance levels for various categories of work (Table 1). These types of guidelines may be considered during the commissioning of daylight harvesting controls and target light levels. Occupants in this demonstration generally requested levels lower than the 50 fc recommended by RP-1. In California, standards for daylight harvesting technologies and techniques are also addressed in the state's building energy efficiency code (Title 24) in section *§119(e)* and *(f)* and should be consulted for any permitted installations.



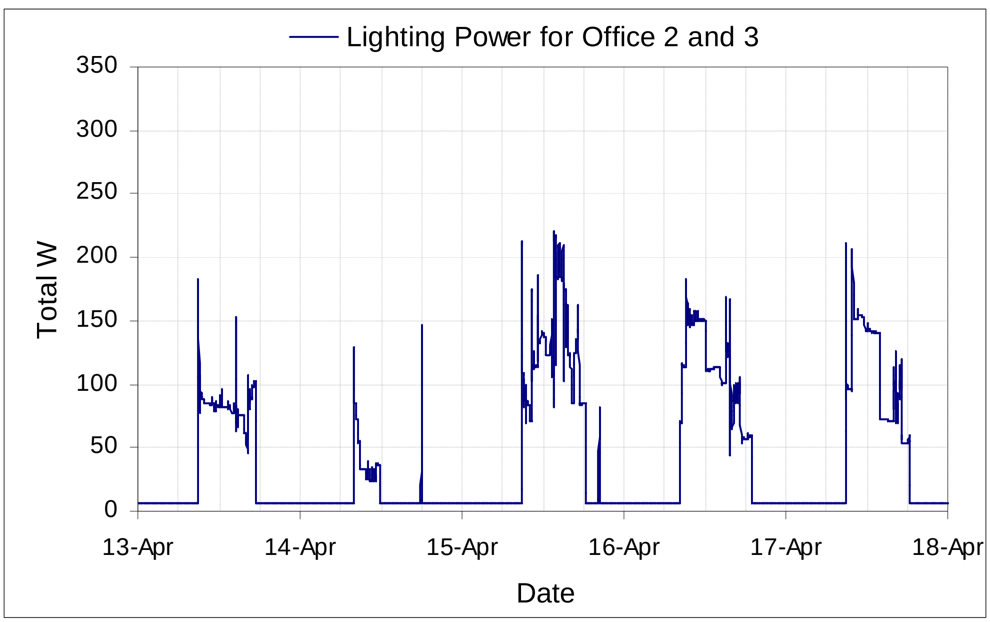


Figure 13: Sample Time Series of Post-Installation Lighting Circuit Power

Occupant and Host Satisfaction

Occupant and host satisfaction surveys were developed for most test sites and manufacturer products.

Table 11: Response to Customer Satisfaction Surveys

Manufacturer	Host Site	EE Surveys Requested	EE Surveys Returned
		Occupant Surveys	
Adura	Alameda County Water District (ACWD)	24	8
Universal	ACWD	0	0
Universal	Anheuser-Busch	3	3
Echoflex	Energy Solutions	5	4
		Host Surveys	
Adura	ACWD	1	1
Universal	ACWD	1	1
Universal	Anheuser-Busch	1	1
Echoflex	Energy Solutions	1	1

Occupant surveys focused on the ability of users to detect and accept reduced light levels during the energy efficiency monitoring period (which was about two weeks long for all technologies). For the Adura evaluation, occupants were asked specifically about their use of the personal remote light switch. For the Echoflex evaluation, occupants were asked specifically about the rate of dimming as well as the acceptability of dimmed light levels in response to daylighting conditions.

Host surveys queried the main point of contact at the host site regarding ease of installation of the system, any changes in lighting quality that followed installation of the demonstration system, and the site contact's level of understanding regarding the system's potential to facilitate participation in utility energy efficiency programs.

A sampling of survey results are summarized here. Detailed survey results are provided in Appendices 2-8.

OCCUPANT FEEDBACK

Occupant surveys were circulated after the energy efficiency monitoring periods concluded at each of the following locations:

- Adura system at ACWD
- Universal system at Anheuser-Busch
- Echoflex system at Energy Solutions

In general, occupants noticed dimming and were somewhat accepting of it, although there were exceptions. Proximity to natural daylighting (windows and skylights) affected peoples' responses. Some respondents also noted that dimmed levels were acceptable while working on the computer, but were not adequate when they needed to read documents. The addition and use of a task light would seem like a reasonable solution in such cases. (It is not known whether these respondents had task lights).

Of note was the popularity of the Adura wireless personal light switches. The majority of respondents commented that the switches were easy to use, and that they were using them to control their overhead inboard/outboard light fixtures with frequency. Of the eight survey respondents, almost all indicated that they were using the switches to turn lights on at the beginning of the workday, and off at the end of the workday. Five were using the switches to turn on one to two lamps instead of three during the workday, and two used it to turn off lights each time they left their workspace. All respondents indicated that the personal light switch was easy to use, and when asked about their preference for the personal light switch over the old system of controlling overhead lights, 75% said they preferred the personal light switch, 12.5% said they preferred the old system, and 12.5% indicated they had no preference.

We only received feedback from one occupant present during the energy efficiency evaluation of the Universal system. According to the survey, this occupant did not notice the reduced light levels and therefore was not affected by them and did not indicate a preference for the new versus previous light levels. This is not surprising considering that the lighting was tuned to just 15% below previous light levels. However, additional surveying, especially in the context of more aggressive tuning strategies, is recommended for future evaluations.

We encountered some challenges commissioning the Echoflex system to work with the wireless photo sensors. Of the four respondents surveyed and present for the majority of the two-week evaluation period, all indicated that their office space received significant daylighting. 75% of respondents said the light levels were sometimes too low, 100% said the light levels were sometimes too high, and 100% responded that the dimming rate was unsatisfactory. The dimming rate was deemed to be too rapid for occupants, especially on partly sunny/ partly cloudy days, which caused frequent and noticeable dimming.

HOST FEEDBACK

The following host surveys were received:

- Adura system installation at ACWD
- Universal system installation at ACWD
- Universal system installation at Anheuser-Busch
- Echoflex system installation at Energy Solutions

Hosts were queried about ease of use of the technology as well as perceived energy efficiency benefits. In general, host site facility managers recognized the potential energy efficiency benefits of all control strategies, their responses indicate mixed success regarding installation and commissioning of the systems.

Each host was asked the following questions regarding ease of use:

- On a scale of 1 to 5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this lighting control system would interface with your existing lighting system?
- On a scale of 1 to 5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of installation of this lighting control system?
- On a scale of 1 to 5, with 1 being the easiest and 5 being the most difficult, how would you characterize the design of this lighting control system, including its ability to integrate well with your existing lighting system?
- If this technology met your minimum cost-effectiveness requirements, would you be inclined to implement it widely in your facility?

The host site of the Adura installation indicated that the system's interface with the host site's existing lighting system was relatively easy to understand. Numerical feedback regarding ease of installation was lower than expected in light of our observations of the installation, which occurred quickly and seamlessly. The host subsequently confirmed that he "reversed" the numerical rating, and meant to score Adura higher in this category.

The host provided these comments about the installation of the Adura system:

> It allows great flexibility. The individual lighting remote controls facilitate this ease of use and allow control down to the single fixture level.

And

> The installation went smoothly and the system has performed well. The only part that required extensive instruction was the Internet to wireless controller interface. I am still not clear on how this works.

The Universal system was installed at two host sites. One of the hosts gave Universal high marks for ease of installation, responding with "1" or "2" for the first three questions, and indicated he "might" install it widely if the technology met his organization's minimum cost-effectiveness requirements. (We received no comments from this respondent).

The second hose site was less enthusiastic, and responded with a "3" or "4" for the first three questions. This respondent also indicated he "might" install the technology widely if it met his organization's minimum cost-effectiveness requirements.

The host indicated:

> It took several times with various people offering explanations about how the Universal system would interface with our existing lighting system.

And

> I have pointed out several features of the hardware that are not user friendly. Otherwise, the system is modular and easy to adapt to different size facilities.

The Echoflex system received high marks for ease of installation, with the notable exception that commissioning was less than straightforward. The host site responded with a "1" or "2" for the first three questions, and indicated he would install it widely if the technology met his organization's minimum cost-effectiveness requirements.

We received this comment about the Echoflex system:

> The lighting contractor had no problems with the installation even though it was a system they had never seen; they commented that it was an easy job. Changing the levels with the wireless wall switches was effective but required a complicated set of actions and a few calls to the manufacturer to get it right.

And

> The system functioned as intended and the light sensors did allow us to cut back significantly on lighting energy in the area where the controls were installed. An automatic sweep to ensure that lights weren't left on overnight would be important for long term usage.

Conclusions

Advanced lighting controls represent a significant energy efficiency opportunity in the commercial sector. Technologies such as those evaluated in this report present an excellent opportunity to penetrate the retrofit building market due to their lower installation cost relative to wired solutions.

Market and Energy Efficiency Potential

At 19,265 GWh/year, commercial lighting energy use represents roughly 29% of total statewide energy use. Lighting in the large and small office sector represents 4,331 GWh/year statewide. The types of advanced lighting controls evaluated in this report better enable customers to install lighting controls due to ease of installation and decreased costs relative to wired controls. These benefits could increase market penetration of lighting controls from less than 1% to something on the order of 10%.

Currently, market penetration of lighting controls technologies such as those evaluated here is low, particularly in the retrofit market, but our results demonstrate that effective technologies are available to capture savings potential in commercial lighting. Utility energy efficiency planners should consider supporting these or similar controls for deployment in appropriate market sectors where system performance and cost-effectiveness meet program requirements.

Cost

For the evaluated technologies, system cost estimates including materials and labor were provided by each manufacturer for a hypothetical 50,000 square foot commercial office space. Material costs included system hardware and, where applicable, software, commissioning and/or dimming ballast costs. The cost estimate for the Adura system was $1.58 per square foot. For the Echoflex system, a cost of $1.82 per square foot was estimated for a system with perimeter daylight harvesting and wireless switching for individual perimeter offices and groups of interior cubicles. The Universal system was estimated to cost $0.79 per square foot. Because the system controls are upstream of the fixtures, the Universal system may present the best potential for economies of scale for larger installations. These estimates provide a general cost comparison basis for the technologies but are not meant to be taken as actual quotes. Costs will vary based on building type and use, and prospective customers should consult with distributors or sales representatives for product pricing.

Technology Performance

As stated in the introduction to this paper, the three technologies generally performed as expected. However, they achieve similar results through various means; as such, they present differing opportunities and barriers.

ADURA LIGHTPOINT SYSTEM

The Adura Lightpoint System product was quickly and easily installed at the host site. This quality was further enhanced by the proximity of the manufacturer's headquarters to the host site, allowing for good design and commissioning support throughout the system installation. Because Adura controls the lighting system on a ballast-by-ballast basis, it is very flexible, allowing customizable energy efficiency strategies based on user input, even as cubicles and other workspaces are altered over time.

The Adura system we evaluated does have a few limitations. The system installed for this evaluation did not include a user interface for commissioning after initial set up with Adura; any modifications to the settings would have to be done by Adura. At the time of this evaluation, Adura did not yet have a Light Controller compatible with a dimmable ballast, and was therefore limited to stepped dimming in an inboard/outboard switched fixture, or turning on or off entire fixtures where inboard/outboard switching is not available. Our understanding from Adura is that they have recently released a product that is compatible with continuously dimming ballasts, which will increase the product's energy efficiency potential. The California Lighting Technology Center (CLTC) and Adura are developing a Wireless Integrated Photosensor and Motion Sensor (WIPAM) system that uses wireless communications to facilitate the potential for automated demand response, and reduce installation and commissioning time by as much as 50% over standard industry practice for competing technologies. More information is available on the CLTC website (http://cltc.ucdavis.edu/content/view/117/141/) and Adura website (http://www.aduratech.com/news.php).

UNIVERSAL DCL SYSTEM AND DEMANDFLEX BALLAST

The Universal DCL system and the continuously dimming DEMANDflex ballast provide an integrated package for energy efficiency and demand response. Although the DCL system provides dimming control to DEMANDflex ballasts only, non-dimming ballasts may be connected to DCL controlled circuits. The DCL system provides on-off control for all connected loads.

The system allows individual circuits to be commissioned separately, allowing greater flexibility in customizing a load shed strategy. The usefulness of this feature at a given location will depend on how lighting circuits are laid out to serve different types of space served (e.g., daylit perimeter areas vs. interior areas; individual workstations vs. common areas); however, our experience shows that circuits are not necessarily organized in such a convenient fashion in existing buildings. Universal is currently developing an extended DCL system that will provide sub-circuit control for up to three zones per circuit. Commissioning can be accomplished by the host site through a software package.

The Universal system requires the most space for bulkhead mounted control hardware, but provides controllability with no requirement for fixture level control wiring, or additional in-fixture devices. The DCL system controls require a different skillset than in-fixture controls, which can make the installation more challenging for an electrical contractor unfamiliar with the system and accustomed to working at the fixture level. To address this, Universal uses trained Certified Contractors to install the DCL system.

ECHOFLEX

The Echoflex system worked with a third party dimming ballast and delivered the expected energy efficiency results. The Echoflex product offered a full suite of wireless controls, including photocell, personal wall switches, and occupancy sensors. The controls are unique in that they do not require batteries.

The system appeared to be well suited to retrofits on lighting circuits that already include low voltage wiring and dimmable ballasts. Because the system works with third party ballasts, the load shed capability will be influenced by the dimming ballast configuration. The low voltage to power output relationship was not linear in the case of the ballast we used to evaluate the Echoflex controls, and may vary from one ballast manufacturer to the next.

One disadvantage was that occupants felt the dimming occurred too quickly, and the fluctuating light levels—exacerbated by a partly cloudy/ party sunny day—were a distraction. One office even went so far as to cover the photo sensor with paper in order to prevent the lights levels from fluctuating.

Recommendations for Future Work

Advanced lighting controls have excellent potential for cost-effectively advancing energy efficiency in existing building stock in California and elsewhere. The three products evaluated in this study could help customers participate in energy utility energy efficiency programs. However, current California investor-owned utility (IOU) rebates for controls require that they be hard-wired to ensure persistence, so this restriction needs to be addressed before IOU rebates can contribute to the penetration of many advanced lighting controls.

Incorporating the advanced lighting control technologies evaluated here into energy utility efficiency efforts might be best accomplished through integration of the technologies into existing energy efficiency and demand response programs. Because the load shedding and energy saving potential of the systems will vary based on each customer's lighting needs and location parameters, programs with high levels of customer support and feedback to the utility may be best suited for deployment of these technologies. Catalogue rebates or other deemed rebate offerings for these systems may be difficult to implement due to the variable nature of dimming and associated energy impacts and system costs for each installation.

To maximize market penetration, energy utilities and other stakeholders may also want to consider opportunities for partnerships with advanced lighting controls manufacturers to better understand technical market potential and organize outreach to market actors. Partnership activities could include joint marketing or co-branding efforts or third party proposals from manufacturers for integration of advanced lighting control systems in new and existing commercial buildings.

A number of other emerging products have entered the market and could be evaluated for energy efficiency potential as shown in the table below.

Table 12. Partial List of Advanced Lighting Controls Outside of this Study

Technology Name	Manufacturer	Description	Communication Protocol
Amanda	Philips	Wireless occupancy and light sensor communicating via ZigBee to wallbox dimmer	Powerline control of Mark X ballasts
ILLUMRA	AD HOC Electronics	Wireless controls communicate to System Controller; Ethernet Gateway DR System Controller also available	EnOcean
Intu!	Light Corporation	Mesh network w/wireless controls	Zigbee
LMCS (Lighting Management Control System)	LUMEnergi	Central LMCS Remote Server and one or more LMCS Controllers (photocells, occupancy sensors, DR, etc.)	DALI
Lutron	Maestro	Wireless occupancy and light sensor communicating via Lutron's proprietary wireless system to wallbox dimmer	Powerline control of TuWire ballasts

In addition, the manufacturers of the products evaluated in this report have developed or are developing next generation products that will increase flexibility and energy efficiency potential. These improvements include:

- A Light Controller from Adura that will communicate with dimming ballasts
- A photocell from Universal that will allow ballasts on multiple "zones" of a circuit to respond differently to daylighting conditions
- A dual channel controller from Echoflex that will allow each controller to drive two offices, a two-ballast set up, or handle both 0-10 volt dimming if the ballast are available

Future evaluations of advanced lighting controls would be strengthened through inclusion of cost-effectiveness calculations. A more rigorous economic analysis would provide quantification of the value of "wireless" technologies relative to wired solutions, particularly when these control strategies are designed with energy efficiency and demand reduction benefits and incentives in mind.

Also, datalogging of illuminance levels during photocell/ dimming evaluations would provide better context for occupants' survey responses regarding changing light levels over a period of days to weeks. In addition, this evaluation was not successful in getting significant occupant feedback regarding the ballast tuning strategy employed by the Universal Lighting Technologies system.

Lastly, the use of RF or PLC makes these controls an elegant and cost-effective option for energy efficiency – as well as demand response – in existing buildings. Market actors, including lighting designers and contractors, facility managers and building owners, need to be educated about the great strides in advanced controls that have occurred. The marketplace will benefit from outreach to trade professionals and groups with information and training on advanced lighting control systems, including instruction on system design, integration, and installation. An example of this type of extension effort is the California Lighting Technology Center's Professional Resources program, which including trade courses on daylighting, advanced interior lighting systems, technology specifications, efficiency code compliance, and more, as well as an online "Lighting Portal" resource for information on current lighting research activities, design, codes, and new technologies.[8]

[8] http://cltc.ucdavis.edu/index.php

Appendix 1

Universal DemandFlex EE Test 1 - Site 1

Site and Test Information

Baseline Period 11/1708 - 11/30/08
EE Period 12/01/08 - 12/18/08

	Circuit 2			Circuit 3	Circuit 5			
	Bin A	Bin B	Bin C	Bin A	Bin A	Bin B	Bin C	Bin D
Area, sq. ft.[1]	900			1340	1160			
Bin Description[2]	All open plan fixtures + 4 office fixtures	All open plan fixtures + 2 office fixtures	All open plan fixtures, no office fixtures	All open plan fixtures	All open plan fixtures + 7 office fixtures	All open plan fixtures + 5 office fixtures	All open plan fixtures + 4 office fixtures	All open plan fixtures + 2 office fixtures
Total Fixtures 'On' [3]	24	22	20	23	22.6	20.6	19.6	17.6
% Circuit Power to DemandFlex[4]	83.3%	90.9%	100.0%	100.0%	66.5%	72.9%	76.6%	85.4%
Baseline Period								
Bin Frequency[5]	45.2%	52.0%	2.8%	100.0%	30.7%	15.6%	23.9%	29.8%
Avg Circuit kW[6]	1.823	1.654	1.472	1.704	1.804	1.612	1.558	1.367
DemandFlex kW[7]	1.519	1.504	1.472	1.704	1.199	1.176	1.194	1.167
LPD[8]	1.69	1.67	1.64	1.27	1.03	1.01	1.03	1.01
EE Period								
Bin Frequency	51.0%	42.0%	7.0%	100.0%	54.1%	4.8%	33.1%	8.0%
Avg Circuit kW	1.825	1.658	1.474	1.707	1.805	1.623	1.559	1.393
DemandFlex kW	1.521	1.508	1.474	1.707	1.200	1.186	1.195	1.193
% Baseline[9]	**100.1%**	**100.3%**	**100.2%**	**100.2%**	**100.1%**	**100.6%**	**100.1%**	**101.9%**
LPD	1.69	1.68	1.64	1.27	1.03	1.02	1.03	1.03

1 Area estimate from scaled ceiling plan; includes only floor area under each lighting circuit corresponding to DemandFlex fixtures

2 See ceiling plan for fixture locations, Circuit 5 includes a hallway U-lamp fixture not controlled by DemandFlex (.57 power of 3 lamp T8 fixture)

3 Includes DemandFlex fixtures and non- DemandFlex fixtures on each Circuit (mostly prive office fixtures)

4 DemandFlex Fixture Power / Total Circuit Fixture Power; private office fixtures and Circuti 5 U lamp were not retrofit with DemandFlex ballasts

5 % of business hour data records corresponding to Bin fixture count (8AM to 5PM, Mon. - Fri., excluding holidays)

6 Average of all binned data records for Circuit during business

7 Average binned Circuit kW * % Circuit Power to DemandFlex

8 DemandFlex kW * 1000 / Area (see note 1)

9 Baseline DemandFlex kW - (Baseline Avg Circuit kW - EE Avg Circuit kW); the absolute reduction in avg. kW from Baseline to EE Period is attributed entirely to DemandFlexfixture recommissioning

Universal DemandFlex EE Test 2 - Site 1

Site and Test Information

Baseline Period 11/1708 - 11/30/08

EE Period 02/04/09 - 02/23/09

	Circuit 2			Circuit 3	Circuit 5			
	Bin A	Bin B	Bin C	Bin A	Bin A	Bin B	Bin C	Bin D
Area, sq. ft.[1]	900			1340	1160			
Bin Description[2]	All open plan fixtures + 4 office fixtures	All open plan fixtures + 2 office fixtures	All open plan fixtures, no office fixtures	All open plan fixtures	All open plan fixtures + 7 office fixtures	All open plan fixtures + 5 office fixtures	All open plan fixtures + 4 office fixtures	All open plan fixtures + 2 office fixtures
Total Fixtures 'On' [3]	24	22	20	23	22.6	20.6	19.6	17.6
% Circuit Power to DemandFlex[4]	83.3%	90.9%	100.0%	100.0%	66.5%	72.9%	76.6%	85.4%
Baseline Period								
Bin Frequency[5]	45.2%	52.0%	2.8%	100.0%	30.7%	15.6%	23.9%	29.8%
Avg Circuit kW[6]	1.823	1.654	1.472	1.704	1.804	1.612	1.558	1.367
DemandFlex kW[7]	1.519	1.504	1.472	1.704	1.199	1.176	1.194	1.167
LPD[8]	1.69	1.67	1.64	1.27	1.03	1.01	1.03	1.01
EE Period								
Bin Frequency	43.5%	47.0%	3.7%	100.0%	37.0%	16.0%	28.5%	18.5%
Avg Circuit kW	1.666	1.495	1.336	1.683	1.679	1.498	1.431	1.263
DemandFlex kW	1.362	1.345	1.336	1.683	1.074	1.062	1.067	1.063
% Baseline[9]	**89.6%**	**89.5%**	**90.7%**	**98.8%**	**89.6%**	**90.3%**	**89.4%**	**91.1%**
LPD	1.51	1.49	1.48	1.26	0.93	0.92	0.92	0.92

1 Area estimate from scaled ceiling plan; includes only floor area under each lighting circuit corresponding to DemandFlex fixtures

2 See ceiling plan for fixture locations, Circuit 5 includes a hallway U-lamp fixture not controlled by DemandFlex (.57 power of 3 lamp T8 fixture)

3 Includes DemandFlex fixtures and non- DemandFlex fixtures on each Circuit (mostly prive office fixtures)

4 DemandFlex Fixture Power / Total Circuit Fixture Power; private office fixtures and Circuti 5 U lamp were not retrofit with DemandFlex ballasts

5 % of business hour data records corresponding to Bin fixture count (8AM to 5PM, Mon. - Fri., excluding holidays)

6 Average of all binned data records for Circuit during business

7 Average binned Circuit kW * % Circuit Power to DemandFlex

8 DemandFlex kW * 1000 / Area (see note 1)

9 Baseline DemandFlex kW - (Baseline Avg Circuit kW - EE Avg Circuit kW); the absolute reduction in avg. kW from Baseline to EE Period is attributed entirely to DemandFlexfixture recommissioning

Universal DemandFlex EE Test - Site 2

Site and Test Information

Baseline Period 02/05/09 - 03/03/09

EE Period 03/03/09 - 03/26/09

	Circuit 13			Circuit 15
	Bin A	Bin B	Bin C	Bin A
Area, sq. ft.[1]	160	392	552	588
Bin Description[2]	Private office fixtures only	Open plan fixtures only	Office and open plan fixtures	All fixtures
Total Fixtures On	2	5	7	8
Baseline Period				
Bin Frequency[3]	95.3%	3.9%	0.8%	100.0%
Avg Circuit kW[4]	0.171	0.432	0.568	0.672
LPD	1.07	1.10	1.03	1.14
EE Period				
Bin Frequency	77.8%	19.6%	2.6%	100.0%
Avg Circuit kW	0.143	0.349	0.459	0.549
% Baseline	**83.4%**	**80.9%**	**80.8%**	**81.8%**
LPD	0.89	0.89	0.83	0.93

[1] Area estimate from scaled ceiling plan; includes only floor area under fixtures in Bin

[2] See ceiling plan for fixture locations

[3] % of business hour data records corresponding to Bin fixture count (8AM to 5PM, Mon. - Fri., excluding holidays)

[4] Average of all binned data records for Circuit during business hours, 20W load from AC plug for CLIR device subtracted from Circuit 13 Avg

Adura EE Data Analysis

Site Information					
3 - Lamp Fixture Amp Draw[1]	0.32				
2 - Lamp Fixture Amp Draw	0.215				
U - Lamp Fixture Amp Draw	0.114				
		Circuit			
		1	3	5	All
Adura Controlled Fixtures		6	12	13.67	31.67
Total Fixtures[2]		22	16.17	20.02	58.18
% Circuit Power to Adura Test Fixtures		27.3%	74.2%	68.3%	54.4%
Total Area, sq. ft.[3]		1340	1130	1360	3830

	Circuit			
EE Results	*1*	*3*	*5*	*All*
Baseline Avg. kW (9/25/08 - 11/25/08)	1.053	1.152	1.427	3.632
Baseline Avg. kW for Adura Test Fixtures	0.287	0.855	0.975	1.977
Baseline LPD	0.79	1.02	1.05	0.95
EE Avg. kW (12/01/08 - 12/18/08)	0.907	0.645	0.644	2.196
EE Avg. kW for Adura Test Fixtures[4]	0.141	0.348	0.192	0.541
EE % Total Power [5]	49.2%	40.7%	19.7%	27.4%
EE LPD [6]	0.39	0.41	0.21	0.26

[1] Amp draw based on Adura estimates for 3 and 2 lamp fixture types and on standard fixture wattage assumption / system votlage of 280 for U lamp fixture

[2] Total T8 equivalent fixtures (in terms of power) ; fixtures served by circuits included 3 and 2 lamp T8s and 2X2 U-lamps

[3] Total estimated square feet under all fixtures powered by circuit

[4] Baseline avg. kW for Adura Fixtures, minus the absolute difference from Baseline to EE avg. kW

[5] EE avg. kW for Adura Fixtures / Baseline avg. kW for Adura Fixtures

[6] This is calculated as [(EE % total power * Baseline avg. kW) / Total Area]

Appendix 2

Appendix 2: Occupant Feedback Survey (EE)- Adura LightPoint

	Respondents	Responses
GENERAL INFORMATION		
Please choose one of the following options to characterize the amount of natural daylighting in your office.	8	
My office space is directly adjacent to a window or directly below a skylight…………		3
My office space is located near enough to a window and/or skylight to receive significant daylighting………… (but is not adjacent to a window or directly below a skylight)		1
My office space is in the interior of the office and does not receive significant daylighting…………		4
Other (please describe in terms of availability of daylight)…………		0
LIGHTING SURVEY		
In the last several months, were you provided with a Personal Light Switch to control your overhead lights?	8	
Yes…………		8
No…………		0
(If you answered "yes", please continue with the Lighting Survey below. If you answered "no", you will not be able to complete the survey.)		
Since receiving your Personal Light Switch, have you used it to control the lamps in the fixture(s) above your work area?	8	
Yes…………		8
No…………		0
Please indicate the ways you have used the Personal Light Switch to control your overhead lights (check all that apply):	8	
Turn on lights at the beginning of the workday…………		8
Turn on 1-2 lamps instead of all 3 when I am working…………		5
Turn off lights each time I leave my workspace…………		2
Turn off lights at the end of each workday…………		7
Turn on/off individual lamps in the fixture throughout the day in response to daylight conditions…………		0
Turn on/off individual lamps in the fixture throughout the day in response to my worktasks…………		1
Other (please describe):		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how easy has it been to use the Personal Light Switch to control your overhead lights?	8	
1…………		3
2…………		5
3…………		0
4…………		0
5…………		0

Comments:

- Have to press the controller several times to turn the lamps full on or full off.
- Have to point the remote directly at the light for it to work.
- It has been very easy. The device is very simple and the instructions are clear. The only issue is that the buttons are not as responsive sometimes, and you really have to push down hard.
- One of my light fixtures does not turn off automatically.

	Respondents	Responses
Do you generally prefer having a Personal Light Switch to control your overhead lights over the old system of controlling the overhead lights?	8	
Yes…………		6
No…………		1
(write in: "no preference")		1

Please feel free to provide additional comments:

- While I don't really care if I have a personal light switch, or if I just use the switch on the wall, I do enjoy the feeling that I can get all my normal work done (without even noticing a difference in lighting) and know that I am conserving energy.
- I do not have to walk all the way over to the switch! Plus, If I am working late, I can keep my lights on without having to go to the switch when they automatically shut down.
- Old wall switch provided me with the capability to turn on/off 1-2 lamps in each fixture with a single press of the switch.
- Obviously, this saves a lot of electricty. The lights used to be very bright in all areas. This may seem just like a toy to play with, but in fact is a very effective tool in the workplace.

Appendix 3: Host Feedback Survey (EE/DR)- Adura LightPoint

EASE OF USE OF TECHNOLOGY	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would interface with your existing lighting system?	1	
1…………………………………………………………………………………………		
2…………………………………………………………………………………………		1
3…………………………………………………………………………………………		
4…………………………………………………………………………………………		
5…………………………………………………………………………………………		
Comments: The only part that required extensive instruction was the Internet to wireless controller interface. I am still not clear on how this works.		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of installation of this wireless lighting control system?	1	
1…………………………………………………………………………………………		
2…………………………………………………………………………………………		
3…………………………………………………………………………………………		
4…………………………………………………………………………………………		1
5…………………………………………………………………………………………		
Comments: The hardest part was coordination w/District staff to allow access for the installers.		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the design of this lighting control system, including its ability to integrate well with your existing lighting system?	1	
1…………………………………………………………………………………………		
2…………………………………………………………………………………………		
3…………………………………………………………………………………………		
4…………………………………………………………………………………………		1
5…………………………………………………………………………………………		
Comments: We have a system that was designed and installed in the mid-1980s. The installation went smoothly and the system has performed well.		
If this technology met your minimum cost-effectiveness requirements, would you be inclined to implement it widely in your facility?	1	
Yes………………………………………………………………………………………		1
No…………………………………………………………………………………………		
Being a public agency, we would have to review the initial cost very closely. Currently there are no funds allocated for this type of project, but could be in later years.		

DEMAND RESPONSE

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to "shed load" (i.e., kW) during a demand response event?	1	
1…………………………………………………………………………………		
2…………………………………………………………………………………		
3…………………………………………………………………………………		
4…………………………………………………………………………………		1
5…………………………………………………………………………………		
unsure/ not enough information…………………………………………………		

Comments:

> Although the system allows easy response to a DR event the internal education required to inform staff why they may not have the quantity of lighting available that they want would be the most difficult part.

	Respondents	Responses
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, demand response programs?	1	
1…………………………………………………………………………………		1
2…………………………………………………………………………………		
3…………………………………………………………………………………		
4…………………………………………………………………………………		
5…………………………………………………………………………………		
unsure/ not enough information…………………………………………………		

Comments:

(none)

ENERGY EFFICIENCY

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to reduce day-to-day energy consumption (i.e., kWh) during a demand response event?	1	
1…………………………………………………………………………………		1
2…………………………………………………………………………………		
3…………………………………………………………………………………		
4…………………………………………………………………………………		
5…………………………………………………………………………………		
unsure/ not enough information…………………………………………………		

Comments:

> It is easy to see how, when the variety of staff turns on or off lights to accomodate their individual needs.

	Respondents	Responses
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, energy efficiency programs?	1	
1…………………………………………………………………………………		
2…………………………………………………………………………………		1
3…………………………………………………………………………………		
4…………………………………………………………………………………		
5…………………………………………………………………………………		
unsure/ not enough information…………………………………………………		

Comments:

> It allows great flexibility. The individual lighting remote controls facilitate this ease of use and allow control down to the single fixture level.

	Respondents	Responses
LIGHTING QUALITY		
Did you notice any change in lighting quality after the wireless lighting controls were installed?	1	
Yes………………………………………………………………………………………………		1
No………………………………………………………………………………………………		
If "yes", please characterize the lighting quality relative to pre-retrofit conditions:		
Before there was relatively uniform lighting in the space where this pilot was conducted. Now with everyone having their own conrols there are light and dark areas that are contrary to what your impressions of an open office area should be.		
Did you receive any comments or complaints from occupants about the new system once it was installed, either during the energy efficiency or demand response monitoring and evaluation period?	1	
Yes………………………………………………………………………………………………		1
No………………………………………………………………………………………………		
If "yes", please explain:		
Only (1) complaint: that the evening sweep "off" of the lights was not happening as expected. This was investigated and the problem determined and corrected. Numerous staff have been intrigued by this technology and have repidly grown accustomed to using it. Most like it.		

Appendix 4: Occupant Feedback Survey- Echoflex- Energy Solutions

	Respondents	Responses
GENERAL INFORMATION		
Please choose one of the following options to characterize the amount of natural daylighting in your office.	5	
My office space is directly adjacent to a window or directly below a skylight……………		3
My office space is located near enough to a window and/or skylight to receive significant daylighting……………… (but is not adjacent to a window or directly below a skylight)		2
My office space is in the interior of the office and does not receive significant daylighting…………………		0
Other (please describe in terms of availability of daylight)………………		0
LIGHTING SURVEY		
Were you at your desk during the weekdays for the majority of the evaluation period, April 8 - 17, 2009?	5	
Yes………………		4
No………………		1
(If you answered "yes", please continue with the Lighting Survey below. If you answered "no", you will not be able to complete the survey.)		
Were you notified in advance that the lighting in your offices would be different between April 8 and 17?	4	
Yes………………		4
No………………		0
During the period between April 8 and 17, the light fixtures in your office were set to dim in response to natural daylighting, while maintaining a minimum level of lighting. Was this change noticeable to you?	4	
Yes………………		4
No………………		0
If you answered "yes" above, plese indicate what you noticed:	4	
Light levels were sometimes too low		3
Light levels were sometimes too high		4
Dimming rate (i.e., how quickly or slowly the lights dimmed in response to daylighting)		4

Respondents could check all that apply, above, and all respondents indicated they noticed all three situations.

Comments:

The dimming of the lights was very noticeable and distracting. It would often not respond quickly enough to the change in natural light levels, and when it did decide to change the light levels, the dimming was done abruptly with too drastic a change such that often there was either too little or too much artificial light.
Dimming did not occur frequently enough to adjust for temporary changes in ambient conditions (e.g., cloud cover). When dimming occurred, it was too quick to be comfortable. Dimming also seemed to over-correct, leaving light levels either too low or too high. This could be the result of infrequent and short sensing of conditions.
There is a lag time between when the lights should dim and when they actually dim. I believe they readjust every minute or so. If a cloud moves and the sun comes out, or vice versa, it takes a minute to notice the changes in the lights. Therefore, at times it seemed the lights were too dim or too bright, but they soon adjusted. The lights do change quite a bit, but it was never a distraction.
Light level fluctuations were too frequent and occurred too quickly. Light levels also changed without noticeable changes in the ambient light.

Please feel free to provide additional comments:

Generally dissatisfied with system. Lack of control beyond set conditions led me to manually override the system by covering the sensor when more light was needed, or when dimming became an irritation.
On a bright day, when I return to my office from outside, it would often seem dark. The lights had dimmed to compensate for the extra daylight. For the first few minutes I wished it were a bit brighter in the office; however, I reminded myself that it was set to a level that I approved (and liked) and my eyes soon recalibrated.

Appendix 5: Host Feedback Survey (EE/DR)- Echoflex

EASE OF USE OF TECHNOLOGY

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would interface with your existing lighting system?	1	
1………………………………………………………..		
2………………………………………………………..		1
3………………………………………………………..		
4………………………………………………………..		
5………………………………………………………..		

Comments:

> Generally, system operation was easy to understand. Though the switches were wireless, the interconnection of the controllers with the dimmable ballasts still required some low voltage wiring. This was not really problematic, but ran counter to my expectation that this would be a completely wireless system.

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of installation of this wireless lighting control system?	1	
1………………………………………………………..		1
2………………………………………………………..		
3………………………………………………………..		
4………………………………………………………..		
5………………………………………………………..		

Comments:

> The lighting contractor had no problems with the installation even though it was a system they had never seen; they commented that it was an easy job.

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the design of this lighting control system, including its ability to integrate well with your existing lighting system?	1	
1………………………………………………………..		
2………………………………………………………..		1
3………………………………………………………..		
4………………………………………………………..		
5………………………………………………………..		

Comments:

> The design allowed us to easily choose to control one or several lights with each wireless wall switch and in some cases to give individual office occupants control over their overhead lights. The battery-less switches and light sensors are impressive and effective.
> Occupants have expressed that they would prefer a slower dim rate and less fluctuation during daylight harvesting. Also, the ability to reset target light levels and DR dimming levels with the wireless wall switches is handy, but the process for clicking through commissioning options and the instructions for these processes are somewhat confusing.

	Respondents	Responses
If this technology met your minimum cost-effectiveness requirements, would you be inclined to implement it widely in your facility?	1	
Yes………………………………………………………		1
No……………………………………………………….		
Maybe……………………………………………………		

Comments:

> The individual control option for lights that were originally wired to switch in groups is great but requires additional costs (one controller per fixture) that may make the system less cost-effective.

	Respondents	Responses
DEMAND RESPONSE		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to "shed load" (i.e., kW) during a demand response event?	1	
1……………………………………………………………………………………………		
2……………………………………………………………………………………………		
3……………………………………………………………………………………………		1
4……………………………………………………………………………………………		
5……………………………………………………………………………………………		
unsure/ not enough information………………………………………………………………		

Comments:

> We had problems with the lighting power levels that the system was originally set to dim to during moderate and critical demand response events, as they were less than our preference. Changing the levels with the wireless wall switches was effective but required a complicated set of actions and a few calls to the manufacturer to get it right. Also, to get the power levels where we wanted them, we had to install meters on the lighting circuits during re-commissioning since the only user feedback during commissioning is the fixture light level; some type of display, computer interface, or even blink sequence on the controller LEDs to indicate power level settings would have been very helpful. The process also requires too many clicks!

	Respondents	Responses
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, demand response programs?	1	
1……………………………………………………………………………………………		
2……………………………………………………………………………………………		1
3……………………………………………………………………………………………		
4……………………………………………………………………………………………		
5……………………………………………………………………………………………		
unsure/ not enough information………………………………………………………………		

Comments:

> Once the system was installed and programmed (lighting power levels reset to our preferences) it was ready to go.

	Respondents	Responses
ENERGY EFFICIENCY		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to reduce day-to-day energy consumption (i.e., kWh) during a demand response event?	1	
1……………………………………………………………………………………………		
2……………………………………………………………………………………………		1
3……………………………………………………………………………………………		
4……………………………………………………………………………………………		
5……………………………………………………………………………………………		
unsure/ not enough information………………………………………………………………		

Comments:

> Understanding what the light sensors would do to reduce energy usage was no problem (dim lights when enough daylighting is available) but setting the target light level for the light sensors took some trial and error and a call to the manufacturer to clarify the process. Also, it is a bit of a guessing game choosing the best location for the photo sensors (wall, ceiling, proximity to desk or window).

	Respondents	Responses
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, energy efficiency programs?	1	
1……………………………………………………………………………………………		
2……………………………………………………………………………………………		1
3……………………………………………………………………………………………		
4……………………………………………………………………………………………		
5……………………………………………………………………………………………		
unsure/ not enough information………………………………………………………………		

LIGHTING QUALITY	Respondents	Responses
Did you notice any change in lighting quality after the wireless lighting controls were installed?	1	
Yes…………………………………………………………………………………………		1
No…………………………………………………………………………………………		
If "yes", please characterize the lighting quality relative to pre-retrofit conditions:		
The daylight harvesting strategy resulted in office lights responding actively to light levels and dimming/ turning off during the brightest periods of the day. This did not necessarily mean a reduction in quality; only that the condition was different than before.		
Did you receive any comments or complaints from occupants about the new system once it was installed, either during the energy efficiency or demand response monitoring and evaluation period?	1	
Yes…………………………………………………………………………………………		1
No…………………………………………………………………………………………		
If "yes", please explain:		
After the light sensors were installed for the energy efficiency testing, two occupants in one office were not very pleased with the cycling of the light levels throughout the day due to outdoor light fluctuations and would have preferred a slower dim rate. These occupants indicated they wold prefer manual control of light levels in their office. One other occupant felt that the target light level had been set too low for her desk space and requested a higher light level.		

Appendix 6: Occupant Feedback Survey (EE)- Universal DCL- Anheuser-Busch

	Respondents	Responses
GENERAL INFORMATION		
Please choose one of the following options to characterize the amount of natural daylighting in your office.	3	
My office space is directly adjacent to a window or directly below a skylight……………………………………………………		1
My office space is located near enough to a window and/or skylight to receive significant daylighting………………………… (but is not adjacent to a window or directly below a skylight)		0
My office space is in the interior of the office and does not receive significant daylighting……………………………………		2
Other (please describe in terms of availability of daylight)…………………………………………………………………		0
LIGHTING SURVEY		
Were you at your desk anytime between March 2 and March 13?	3	
Yes…………………………………………………………………………………………		1
No…………………………………………………………………………………………		2
(If you answered "yes", please continue with the Lighting Survey below. If you answered "no", you will not be able to complete the survey.)		
During the weeks of March 2-6 and March 9-13, the light fixtures were adjusted to use 15% less power and provide 82% of previous light output. Was this change noticable to you?	1	
Yes…………………………………………………………………………………………		0
No…………………………………………………………………………………………		1
Were you notified in advance that the lighting would change the weeks of March 2-6 and March 9-13?	1	
Yes…………………………………………………………………………………………		0
No…………………………………………………………………………………………		1
At any point during those two weeks, were the new light levels too low to allow you to comfortably do your work?	1	
Yes…………………………………………………………………………………………		0
No…………………………………………………………………………………………		1
How did you find the reduced light levels relative to the previous light levels?	1	
Prefer the reduced light levels………………………………………………………………		0
Prefer the previous light levels………………………………………………………………		0
No opinion…………………………………………………………………………………		1
Would prefer a light level between the previous light levels and the reduced light levels……………………		0

Appendix 7: Host Feedback Survey (EE / DR)- Universal DCL- Anheuser-Busch

EASE OF USE OF TECHNOLOGY	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would interface with your existing lighting system?	1	
1……………………………………………………………………………………………….		
2……………………………………………………………………………………………….		1
3……………………………………………………………………………………………….		
4……………………………………………………………………………………………….		
5……………………………………………………………………………………………….		
Comments:		
(no comments)		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of installation of this wireless lighting control system?	1	
1……………………………………………………………………………………………….		
2……………………………………………………………………………………………….		1
3……………………………………………………………………………………………….		
4……………………………………………………………………………………………….		
5……………………………………………………………………………………………….		
Comments:		
(no comments)		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the design of this lighting control system, including its ability to integrate well with your existing lighting system?	1	
1……………………………………………………………………………………………….		1
2……………………………………………………………………………………………….		
3……………………………………………………………………………………………….		
4……………………………………………………………………………………………….		
5……………………………………………………………………………………………….		
Comments:		
(no comments)		
If this technology met your minimum cost-effectiveness requirements, would you be inclined to implement it widely in your facility?	1	
Yes………………………………………………………………………………………………		
No………………………………………………………………………………………………		
Maybe……………………………………………………………………………………………		1
Comments:		
(no comments)		

	Respondents	Responses
DEMAND RESPONSE		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to "shed load" (i.e., kW) during a demand response event?	1	
1………………………………………………………………………………………………		
2………………………………………………………………………………………………		1
3………………………………………………………………………………………………		
4………………………………………………………………………………………………		
5………………………………………………………………………………………………		
unsure/ not enough information……………………………………………………………………		
Comments: (no comments)		
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, demand response programs?	1	
1………………………………………………………………………………………………		1
2………………………………………………………………………………………………		
3………………………………………………………………………………………………		
4………………………………………………………………………………………………		
5………………………………………………………………………………………………		
unsure/ not enough information……………………………………………………………………		
Comments: (no comments)		
ENERGY EFFICIENCY		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to reduce day-to-day energy consumption (i.e., kWh) during a demand response event?	1	
1………………………………………………………………………………………………		1
2………………………………………………………………………………………………		
3………………………………………………………………………………………………		
4………………………………………………………………………………………………		
5………………………………………………………………………………………………		
unsure/ not enough information……………………………………………………………………		
Comments: (no comments)		
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, energy efficiency programs?	1	
1………………………………………………………………………………………………		1
2………………………………………………………………………………………………		
3………………………………………………………………………………………………		
4………………………………………………………………………………………………		
5………………………………………………………………………………………………		
unsure/ not enough information……………………………………………………………………		
Comments: (no comments)		

LIGHTING QUALITY	Respondents	Responses
Did you notice any change in lighting quality after the wireless lighting controls were installed?	1	
Yes…………………………………………………………………………………………		
No…………………………………………………………………………………………		1
If "yes", please characterize the lighting quality relative to pre-retrofit conditions:		
Did you receive any comments or complaints from occupants about the new system once it was installed, either during the energy efficiency or demand response monitoring and evaluation period?	1	
Yes…………………………………………………………………………………………		
No…………………………………………………………………………………………		1
If "yes", please explain:		

Appendix 8: Host Feedback Survey (EE/DR)- Universal DCL- Alameda County Water District

EASE OF USE OF TECHNOLOGY	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would interface with your existing lighting system?	1	
1…………………………………………………………………………………………………		
2…………………………………………………………………………………………………		
3…………………………………………………………………………………………………		
4…………………………………………………………………………………………………		1
5…………………………………………………………………………………………………		
Comments: It took several times with various people offering explanations about how the Universal system would interface with our existing lighting system.		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of installation of this wireless lighting control system?	1	
1…………………………………………………………………………………………………		
2…………………………………………………………………………………………………		
3…………………………………………………………………………………………………		1
4…………………………………………………………………………………………………		
5…………………………………………………………………………………………………		
Comments: The hardest part was Understanding how it would be installed and then the overall disruption of installing new dimmable ballasts in each lighting fixture.		
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the design of this lighting control system, including its ability to integrate well with your existing lighting system?	1	
1…………………………………………………………………………………………………		
2…………………………………………………………………………………………………		
3…………………………………………………………………………………………………		1
4…………………………………………………………………………………………………		
5…………………………………………………………………………………………………		
Comments: I have pointed out several features of the hardware that are not user friendly. Otherwise, the system is modular and easy to adapt to different size facilities.		
If this technology met your minimum cost-effectiveness requirements, would you be inclined to implement it widely in your facility?	1	
Yes…………………………………………………………………………………………………		
No…………………………………………………………………………………………………		
Maybe………………………………………………………………………………………………		1
Comments: It is not my decision. Throughout this whole pilot installation, cost has never been discussed. I would need to gather cost information and then prpeare a cost/benefit analysis to determine if it is worthwhile to implement this technology further.		

DEMAND RESPONSE

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to "shed load" (i.e., kW) during a demand response event?	1	
1……………………………………………………………………………………………………		
2……………………………………………………………………………………………………		1
3……………………………………………………………………………………………………		
4……………………………………………………………………………………………………		
5……………………………………………………………………………………………………		
unsure/ not enough information…………………………………………………………………………		

Comments:

This was the easiest part of the system to understand.

	Respondents	Responses
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, demand response programs?	1	
1……………………………………………………………………………………………………		1
2……………………………………………………………………………………………………		
3……………………………………………………………………………………………………		
4……………………………………………………………………………………………………		
5……………………………………………………………………………………………………		
unsure/ not enough information…………………………………………………………………………		

Comments:

It allows us to implement a widespread response but also tailor it to specific needs within the organization.

ENERGY EFFICIENCY

	Respondents	Responses
On a scale of 1-5, with 1 being the easiest and 5 being the most difficult, how would you characterize the ease of understanding how this wireless lighting control system would facilitate your ability to reduce day-to-day energy consumption (i.e., kWh) during a demand response event?	1	
1……………………………………………………………………………………………………		
2……………………………………………………………………………………………………		1
3……………………………………………………………………………………………………		
4……………………………………………………………………………………………………		
5……………………………………………………………………………………………………		
unsure/ not enough information…………………………………………………………………………		

Comments:

(no comments)

	Respondents	Responses
On a scale of 1-5, with 1 being the most useful and 5 being the least useful, how useful do you feel this wireless lighting control system would be in helping your facility participate in, and benefit from, energy efficiency programs?	1	
1……………………………………………………………………………………………………		
2……………………………………………………………………………………………………		1
3……………………………………………………………………………………………………		
4……………………………………………………………………………………………………		
5……………………………………………………………………………………………………		
unsure/ not enough information…………………………………………………………………………		

Comments:

(no comments)

	Respondents	Responses
LIGHTING QUALITY		
Did you notice any change in lighting quality after the wireless lighting controls were installed?	1	
Yes……………………………………………………………………………………………		1
No……………………………………………………………………………………………		
If "yes", please characterize the lighting quality relative to pre-retrofit conditions:		
At 100% power levels no difference, but as power/lighting levels are reduced the type of lamp becomes more apparent. Some lamps have a rose hue to them and others are still white.		
Did you receive any comments or complaints from occupants about the new system once it was installed, either during the energy efficiency or demand response monitoring and evaluation period?	1	
Yes……………………………………………………………………………………………		1
No……………………………………………………………………………………………		
If "yes", please explain:		
Mostly comments: Some staff enjoyed the overall reduced light levels. Lighting was less harsh. Other members of staff depending on their location were more impacted than others. Therefore, the reduced light levels impacted their ability to perform their work effectively.		

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