PACIFIC GAS AND ELECTRIC COMPANY
EMERGING TECHNOLOGIES PROGRAM

APPLICATION ASSESSMENT REPORT #0826

ADVANCED LIGHTING CONTROLS FOR DEMAND SIDE MANAGEMENT

(DEMAND RESPONSE ASSESSMENT)

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Acknowledgements

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Executive Summary

Energy Solutions evaluated the functional performance and demand response (DR) 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 these events, a moderate and critical price signal was sent to the control system, which was commissioned to decrease lighting power by a specific percentage (e.g., moderate price would result in decreasing power to 80% of baseline level, and high price would result in decreasing power to 60%). The price signal was sent via either a Gateway device (in the case of the Adura evaluation) or a Client and Logic with Integrated Relay (CLIR) device (in the case of the Universal and Echoflex demonstrations) installed at the host site.

Power measurements were taken using Dent Instruments Elite Pro Data Loggers (Line Powered, Extended Memory) with 20 amp CTs before and during the test. In some instances, illuminance readings were taken in the test space before and during DR testing to evaluate lighting impacts.

Onsite verification and monitoring showed that all three technologies generally performed as expected and have good potential to shed lighting load during DR events. The Adura and Universal off-the-shelf products were easily integrated with a control that allowed the technologies to receive DR signals; the Echoflex product required customization to do so.

Objectives

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

The technologies were also evaluated in regards to ability to deliver energy efficiency savings relative to the previous lighting technology at the site. Those results are summarized in a separate report to PG&E and are available on the Emerging Technologies Coordinating Council website.

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 table on the following page summarizes the attributes of each product.

Table 1. Comparison of Evaluated Advanced Lighting Control Technologies

Product	System-level Controllability	Communication	Method of Field Commissioning	Dimming Capability	Integrated Wireless Controls
Adura LightPoint	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	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	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-free 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 Controls

Product	Ease of Installation	Ease of Commissioning	Design/ Ease of Integration
Adura LightPoint	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.	Integration smooth; however, system limited to stepped dimming via inboard/ outboard lamp control, at time of evaluation.
Universal DCL + Universal DEMAND-flex ballast	Installation requires trained or manufacturer-certified Contractors.	Manufacturer commissioned system successfully.	Integration went smoothly. Host pointed out several aspects of hardware design that could improve installation/ integration.
Echoflex	Contractor found it easy to install even though they had no experience with system.	Field commissioning was eventually successful, but required a complicated set of actions.	System required customized solution in order to receive and interpret DR signals.

DEMAND REDUCTION

The Project Findings section details results from the DR tests for each technology and location. Table 2 summarizes the results in terms of power reductions at two DR price levels: moderate price and high price. Each technology's control method and interface with utility automated DR equipment was slightly different, and in some instances manufacturer and/or field modifications were necessary to allow the controls to receive and respond accurately to the DR price signals.

It is important to note that the power settings chosen for the DR levels could be modified for any of the three technologies, and power reductions are generally more a reflection of user preference than savings potential. In other words, expected versus actual demand reductions within a technology, as presented below, is more relevant than demand reductions among the various technologies. In terms of achieving expected demand reduction levels, the final results of each tested system fall within a few percentage points of expectations, though some systems required modifications after initial testing to achieve these results. Each control technology could be adjusted in the field, but the ability to make adjustments after installation varied from technology to technology. Test expectations and achievements will be discussed in more detail later in this report.

Ease of installation, user interface, and cost are several other considerations that differentiate DR-enabled advanced lighting systems. This evaluation also includes our impressions based on installing pilot-scale systems for evaluation in the field; however, these characteristics should be further investigated (e.g., through manufacturer/ distributor bids, pilot-scale installations, etc.) by prospective users before investing in a system at their facility.

Table 3. Summary of Demand Reduction Findings for the Three Technologies

<table>
<tr><th>Technology</th><th>Date of Test</th><th colspan="3">Expected Moderate Demand Reduction (% below baseline)</th><th colspan="3">Actual Moderate Demand Reduction (% below baseline)</th><th colspan="3">Expected Critical Demand Reduction (% below baseline)</th><th colspan="3">Actual Critical Demand Reduction (% below baseline)</th></tr>
<tr><td>Adura LightPoint-Test 1*</td><td>7/3/08</td><td colspan="3">33%</td><td colspan="3">29%</td><td colspan="3">48%</td><td colspan="3">52%</td></tr>
<tr><td>Adura LightPoint-Test 2*</td><td>7/8/08</td><td colspan="3">33%</td><td colspan="3">33%</td><td colspan="3">48%</td><td colspan="3">50%</td></tr>
<tr><td>Universal DCL/ DEMANDflex - Site 1, Test 1</td><td>10/22/08</td><td colspan="3">10%</td><td colspan="3">10%</td><td colspan="3">30%</td><td colspan="3">32%</td></tr>
<tr><td>Universal DCL/ DEMANDflex - Site 1, Test 2</td><td>10/24/08</td><td colspan="3">10%</td><td colspan="3">11%</td><td colspan="3">30%</td><td colspan="3">32%</td></tr>
<tr><td>Universal DCL/ DEMANDflex - Site 1, Test 3**</td><td>11/7/08</td><td>10%</td><td>20%</td><td>30%</td><td>12%</td><td>22%</td><td>31%</td><td>30%</td><td>40%</td><td>50%</td><td>33%</td><td>42%</td><td>49%</td></tr>
<tr><td>Universal DCL/ DEMANDflex - Site 2, Test 1</td><td>2/18/09</td><td colspan="3">20%</td><td colspan="3">22%</td><td colspan="3">40%</td><td colspan="3">41%</td></tr>
<tr><td>Echoflex- Test 1</td><td>2/13/09</td><td colspan="3">35%</td><td colspan="3">10%</td><td colspan="3">70%</td><td colspan="3">50%</td></tr>
<tr><td>Echoflex- Test 2</td><td>2/26/09</td><td colspan="3">35%</td><td colspan="3">31%</td><td colspan="3">70%</td><td colspan="3">69%</td></tr>
</table>

* For Adura LightPoint, expected demand reductions are calculated reductions based on assumed fixture wattages and checkerboard plan of fixtures turned off during DR price signals.

**For Universal DCL/ DEMANDflex - Site 1, Test 3, unique demand reductions were programmed for each of three circuits.

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 DR 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 DR opportunity in the commercial sector. Commercial lighting demand is responsible for roughly 7.5% of total statewide demand[1] and is largely coincident with total Statewide peak demand. During peak periods on summer days, lighting represents a staggering 30% of demand, compared to 32% for HVAC.[2]

Presently, lighting controls are not widely used because it is expensive to retrofit a building with wired controls. Previous generations of controls have also had a limited ability to decrease peak load. However, the increased prevalence of the Internet and the development of wireless and PLC technologies have created new opportunities for installing lighting controls that deliver DR as well as energy efficiency benefits, particularly in existing buildings. In addition, the efficacy of the latest generation of dimming ballasts, at full light output, is within 2% of program start ballast efficacy and 8% instant-start ballasts.

There are a number of lighting application-specific controllers on the market that can operate dimming ballasts and multi-level lighting using various industry-accepted communication protocols. These protocols include:

- low-voltage analog (0-10 volt DC)
- low-voltage digital (e.g., Digital Addressable Lighting Interface- DALI)
- powerline control (e.g., voltage regulation, wave-chopping, low level signal injection, etc.)
- wireless/radio communications (e.g., WiFi, ZigBee, Z-wave, 802.15.4 low-power radio, EnOcean)

These types of lighting controls, used in conjunction with bi-level lighting in California's commercial buildings, are estimated to represent 1 GW of demand shed potential.[3] The commercial building sector represents around 30%, or 6 GW, of the PG&E service area's estimated 20 GW of peak demand[4]. Interior commercial lighting, at roughly 1.45 GW, makes up around one quarter of the commercial building peak demand. If DR controls could reduce peak commercial lighting power by 25% in 50% of commercial buildings in PG&E's territory, that would result in a 180 MW reduction in load during the peak demand period[5]. The use of dimming ballasts could increase this potential.

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[1] Peak demand estimates based on California Commercial End-Use Survey data, queried April 22, 2009 (http://capabilities.itron.com/CeusWeb/Chart.aspx), and California Energy Commission Staff Forecast of 2008 Peak Demand: http://www.energy.ca.gov/2007publications/CEC-200-2007-006/CEC-200-2007-006-SD.PDF for PG&E, SCE, SDG&E and SMUD service territories only.

[2] F. Rubinstein, S. Kiliccote. 2007. "Demand Responsive Lighting: A Scoping Study". Lawrence Berkeley National Laboratory. (LBNL-62226)

[3] See note 2.

[4] According to California Energy Commission Staff Forecast of 2008 Peak Demand: http://www.energy.ca.gov/2007publications/CEC-200-2007-006/CEC-200-2007-006-SD.PDF

[5] See note 1, above.

Descriptions of Technologies Evaluated

ADURA LIGHTPOINT SYSTEM (ALPS)

The Adura LightPoint System consists of wireless switching and dimming controllers (Light Controllers) that connect to the ballast to provide precise control of individual light fixtures or rows of fixtures. Because Adura controls the lighting system on a ballast-by-ballast basis, it is very flexible, allowing customizable load-shed 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. The Adura system can also be commissioned to respond to a DR signal sent via the Internet to their onsite gateway device that communicates the signal wirelessly to the Light Controllers, turning individual ballasts and the associated lamps on or off. Light Controllers also enable personal occupant controls using Adura wireless light switches, which operate on batteries with an estimated useful life of 10 years.

Figure 1. Adura Light Controller

The Adura system is currently well suited to control fixtures enabled for bi-level switching. For example, the system can be commissioned to turn off the inboard lamp (33% demand reduction) during a moderate price event, and turn off the outboard lamps and turn on the inboard lamp (66% demand reduction) during a critical price event. 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 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, 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 continuously 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 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 and can be used with the Demand Control Lighting (DCL) system, including a Relay Sensing Module (RSMDCL), and Single Circuit Controllers (SC20s), to create an energy management system that has DR and energy efficiency capability.

The RSM inputs include sensing circuits for eight external contacts. The RSM 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. The RSMDCL provides several operating modes. A combination of the power level control mode (see Table 4) and the scene recall control mode were used for these DR tests.

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	

When the DEMANDflex ballasts are used in conjunction with the DCL and individual circuit controllers, the system allows the user to receive a DR signal and dim ballasts accordingly, as well as respond to wireless 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 currently includes wired controls for scheduling, daylighting and other controls; and can be configured to work with third party controls, such as the CLIR box, as was done for this DR evaluation. This study did not evaluate the DCL system controls for scheduling or daylighting.

Figure 2. Universal DCL System

ECHOFLEX

The Echoflex wireless lighting control system evaluated in this report is comprised of Echoflex wireless/battery-free switches and controllers that receive wireless switch signals and DR 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 – 10v) wired to a dimmable ballast. The system is designed to perform day-to-day lighting control functions, including switching, daylighting and occupancy controls.

For DR purposes, the controllers can be commissioned to turn on or off a single ballast, group of ballasts, or an entire circuit, or dim one or multiple ballasts in response to a wireless signal broadcast in the office space. For this evaluation, this functionality required a customized (by Lawrence Berkeley National Laboratory) CLIR box equipped with a transceiver to broadcast price signals. In addition, Echoflex developed customized controllers programmed to receive the price signals. In other words, this was a spec product developed for this evaluation.

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.

The wireless switches also serve as a permanent, on-site commissioning tool for setting the controllers' DR power levels. The process for adjusting DR levels with the wireless switches is described in the methodology section. The switches also 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. These benefits are not evaluated here; an energy efficiency evaluation of the technology coupled with a wireless photo sensor option was carried out and is summarized in a separate report.

Figure 3. Echoflex Wireless Switch 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 DR programs.

To estimate demand reduction resulting from the use of the various advanced lighting controls, monitoring included collection of power data before, during, and after the DR test. Current transformers (CTs) and a data logger were situated at the proper electrical circuit box to record electric power through time at a given interval for the designated time period.

Power measurements were taken using Dent Instruments Elite Pro Data Loggers (Line Powered, Extended Memory) with 20 amp CTs. In some instances, illuminance readings were taken in the test space before and during DR testing to evaluate lighting impacts. These measurements were made with a Wattstopper FX-200 Illuminometer.

The “test” DR signal was scheduled and initiated by Lawrence Berkeley National Laboratory. The signals may be PUSHed into a facility, which requires an opening of a port in the firewall to access a facility’s network, or PULLed by a facility, where the client polls the server periodically to receive DR related data. PUSHing data into the facility reduces latencies. However, due to security concerns from consumers, PULL method is currently preferred in California’s Automated DR programs between the Demand Response Automation Server (DRAS) and its clients.

The DR signal was received via either a Gateway (in the case of the Adura evaluation) or a Client and Logic with Integrated Relay (CLIR) device (in the case of the Universal and Echoflex demonstrations) installed at the host site. The CLIR is a secure, self-configuring Internet relay. The CLIR utilizes PULL method and enables a lighting control system to receive DR signals over the Internet. These signals are translated into relay contacts that are sensed by the lighting controller, which then communicates on/off or dimming levels to the ballasts on fixtures equipped with the control technology. More information about the CLIR device is available at: http://drrc.lbl.gov/pubs/CLIR-UserGuide_6-R3.pdf.

Adura's technology uses a secure Internet server instead of a CLIR box in order to respond to a DR signal. It routes these signals to their lighting network Gateways where they are translated directly into RF mesh network commands to Light Controllers which are programmed with the logic to turn off or dim when price signals are received.

Adura LightPoint System

SITE DESCRIPTION: ALAMEDA COUNTY WATER DISTRICT

The Adura demonstration occurred at an Alameda County Water District office building located in Fremont, CA. The area chosen for the evaluation of the Adura product is approximately 2,000 square foot 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.

At the time of the DR test, the three-lamp fixtures contained a single ballast and inboard/outboard switching capability was not present. (Prior to the energy efficiency test—described in a separate report-- the three-lamp fixtures were retrofitted with two ballasts in order to allow inboard/outboard switching capability.) 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 Light Controllers due to space constraints; therefore, they were excluded from the study.

This site was chosen, in part, because the agency already participates in PG&E’s Automated Critical Peak Pricing program through their HVAC system operations during DR events.

DR TEST DESCRIPTION

The DR test aimed to determine if Adura wireless lighting controls could receive and respond to a DR signal by turning certain fixtures off. The first step was to install and commission the Adura Lightpoint System. A Light Controller (LC-2R) was connected to the ballast in each of the 33 fixtures in the study and Adura commissioned the system to turn off certain fixtures during a moderate price DR event, and to turn off additional fixtures during a critical price event. Because the fixtures in the Operations area at ACWD did not have two ballasts with inboard/outboard switching capability, the Adura system turned off entire fixtures, creating a checkerboard pattern of fixtures on/off.

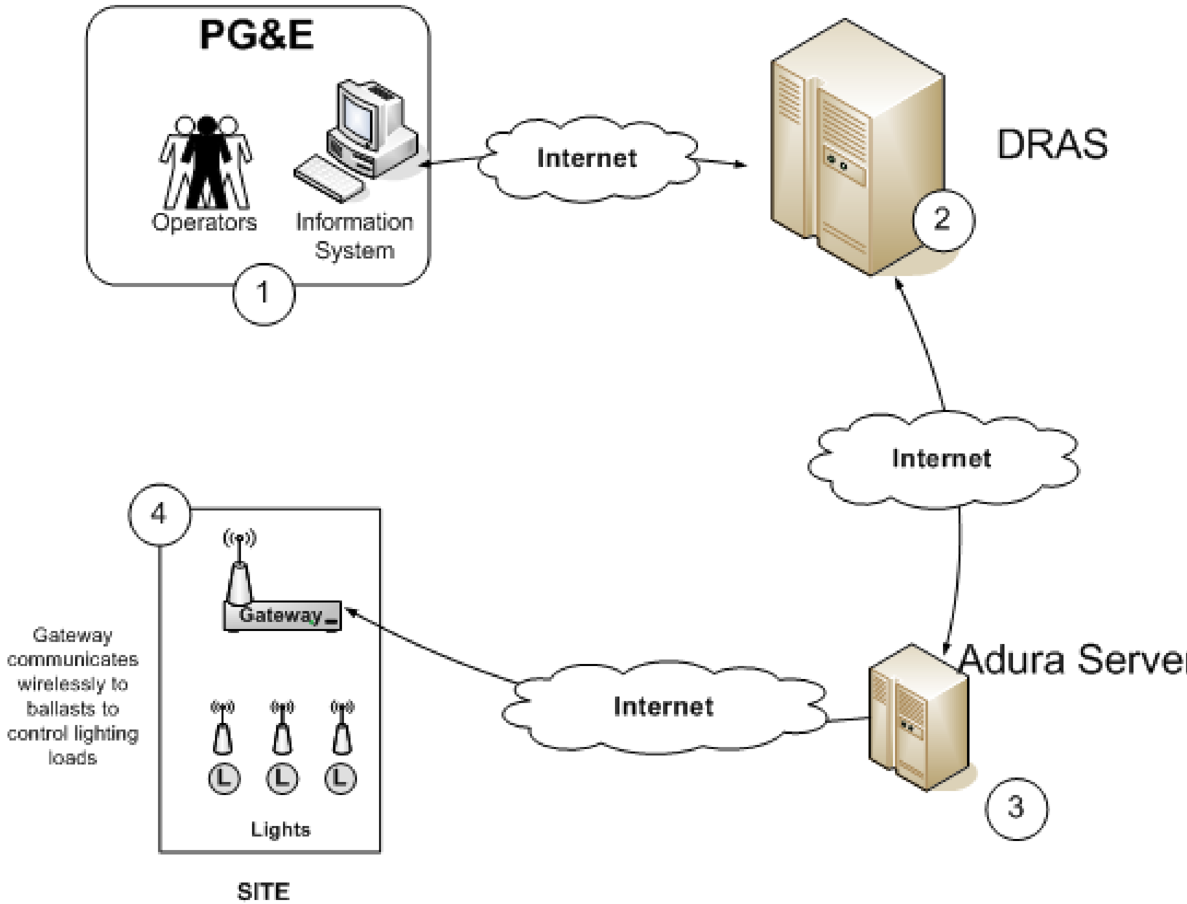

Figure 4. Adura LightPoint System Diagram

PG&E utilized the DRAS to send price signals via Internet to Adura's server, which routes these signals to a Gateway device at the site. Two simulated DR test events were conducted: The first on Thursday, July 3, 2008 and the second on Tuesday, July 8, 2008. During the test events, a signal was sent via the Internet to the system Gateway, which broadcast the signal wirelessly causing fixtures to turn off based on price level. Price signals included three levels: normal, moderate, and critical. At normal price, all fixtures were on; at moderate price, nine fixtures turned off; at critical price, seven additional fixtures turned off (the nine turned off during the moderate price event remained off). A graphic representation of the specific fixtures affected by each price signal is included in the Project Results section.

Adura's Gateway collected and stored state-change (i.e., on/off) information for controlled lights on a fixture-by-fixture basis. This information was multiplied by assumed fixture wattages to determine total lighting power, which was stored in the system database. Actual electric power monitoring equipment was not installed on the controlled lighting circuits at the time of the DR test, so lighting power reductions are based on data reported by the Adura Gateway. Fixture condition and control (on/off) was visually verified by Energy Solutions staff during the DR events by comparing actual results with the commissioning plan provided by Adura, which showed which fixtures should turn off during normal, moderate, and critical price conditions. Along with visual confirmation, data was cross-checked with calculated wattage reductions based on controlled fixture wattages. Illuminance readings were taken at several locations in the test area before and after the DR event (i.e., at normal price levels), and while the moderate and critical price signals were in effect. The DR settings are summarized below; power and lighting reductions are presented in Project Results.

Figure 5. Photos of Adura LightPoint Demonstration at Normal, Moderate, and Critical Settings at ACWD

Table 5. Summary of Adura DR Test Settings

Date	Price Signal	Fixtures Off	Calculated Power Relative to 100% Baseline
7/3/08 and 7/8/08	Moderate	10 of 33	67%
	Critical	16 of 33	52%
	Normal (test ends)	0 of 33	100%

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 they already participate 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 4,000 square feet of open office space in the Engineering Department. The evaluation area is located in a single-story building and has an open floorplan with cubicles with some private perimeter offices. The lighting fixtures in the area are predominantly 2' x 4' recessed, lensed troffers, with three lamps controlled by a single ballast. There are a total of 68 fixtures powered by three lighting circuits. 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, which is discussed further in Project Results.

DR TEST DESCRIPTION

The DR test aimed to determine if the DCL system could receive and respond to DR signals by dimming lighting circuits to user defined levels during load shedding events. The DCL system- including DR signal receivers, power line carrier controls, and dimmable ballasts- was installed and commissioned on the three lighting circuits serving the test area. A CLIR device was installed and connected to the local network in order to receive DR signals over the Internet and relay these to the DCL system. The system components, integrated with the CLIR, are shown below. Although the SC20s (power line carrier controls) do monitor power levels and other data suitable for diagnostic and analytical purposes, the control set selected for this test did not access this feature.

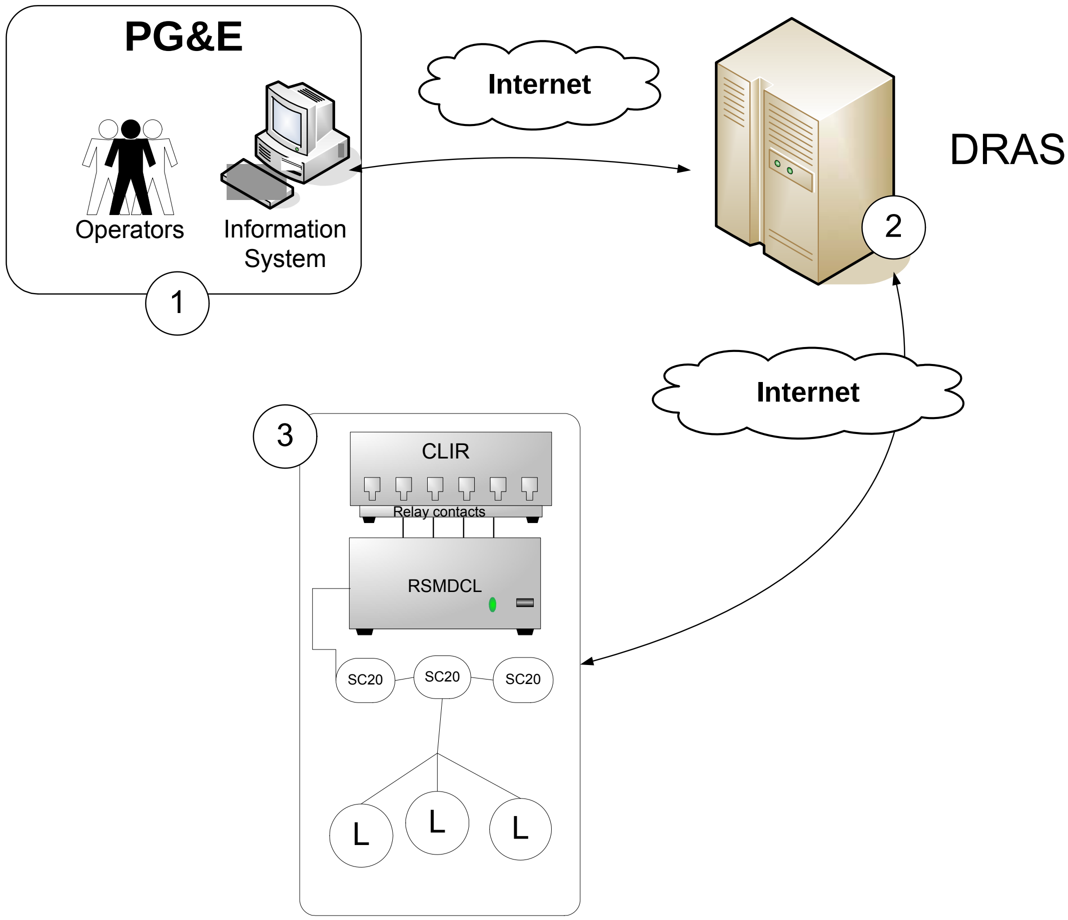

Figure 6. Universal DCL System Diagram

To evaluate the DR capability of the DCL system, baseline power on each of the affected lighting circuits was measured for several weeks prior to installation of the dimming ballasts and controls, again following the system installation but prior to DR testing; and, lastly, during the simulated DR events.

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

Following installation of the DEMANDflex dimmable ballasts and DCL system, three test DR events were dispatched to the site over the course of three business days via the CLIR box. Because the DCL system has the capability to control each circuit individually through the single circuit controllers, the final test was designed so that each circuit dimmed to a unique ballast power level relative to the other two circuits. The DR test settings are summarized below. Measured power reductions are summarized in the Projects Result section.

Table 6. Summary of DCL/ DEMANDflex DR Test Settings at ACWD

Date	Price Signal	Ballast Power Output (% relative to 100%)		
		Circuit 2	**Circuit 3**	**Circuit 5**
10/22/08 and 10/24/08	Moderate	90%		
	Critical	70%		
	Normal (test ends)	100%		
11/7/08	Moderate	90%	80%	70%
	Critical	70%	60%	50%
	Normal (test ends)	100%		

SITE DESCRIPTION: ANHEUSER-BUSCH

The second host site at which Universal's technology was evaluated was the Anheuser-Busch company in Fairfield, CA. The evaluation area is comprised of a small open office area with cubicles (~980 square feet), as well as one private office (~160 square feet). The lighting system consists of 15 2' x 4' recessed troffers, each with three lamps controlled by one ballast. Two of the 15 fixtures are 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. A reflected ceiling plan with circuits labeled is included in Project Results.

DR TEST DESCRIPTION

To evaluate the DR capability of the DCL system, baseline power on each of the affected lighting circuits was measured for several weeks before, during, and after the DCL installation and DR test period. A CLIR box was installed with the system and connected to the Internet through a local DSL line. One DR test event was scheduled to determine whether the system responded to the price signals and reduced lighting power to defined levels. The system components were similar to the previous installation, though due to space constraints at the circuit breaker location, the controls equipment and CLIR had to be installed in the drop ceiling above the open office area. The programmed DR power levels are summarized below; measured results are presented in Project Results.

Table 7. Summary of DCL/ DEMANDflex DR Test Settings at Anheuser-Busch

Date	Price Signal	Ballast Power Output (% relative to 100%)	
		Circuit 13	**Circuit 15**
2/18/09	Moderate	80%	80%
	Critical	60%	60%
	Normal (test ends)	100%	100%

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.

The controllers set light levels through a 0 – 10 volt dimming circuit that can be wired to control one or more dimmable ballasts. All test fixtures had to be retrofitted with dimmable ballasts. The installation was designed to test controllers that were wired to single and multiple fixtures. In two of the offices, a single controller was installed to switch and dim two fixtures together. In the remaining office, a controller was installed at each overhead fixture to dim each fixture independently.

The modified CLIR box with RF transceiver was placed in one of the demonstration offices and connected to the local Internet. The CLIR received DR signals from the DRAS and converted this information into radio transmissions that were broadcast throughout the offices by the transceiver.

DR TEST DESCRIPTION

The DR test aimed to determine if the Echoflex system could receive and respond to wireless DR signals transmitted by the modified CLIR by dimming fixtures to a pre-set power level. The Echoflex controllers had to be factory-configured to receive DR transmissions as this is not yet an off-the-shelf feature of the product. The CLIR used for the test was modified with a RF transceiver adapted to the CLIR's serial output in order to transmit wireless 14 byte DR messages to the controllers. The transceiver itself also had to be modified to broadcast at the system frequency of 315 MHz, rather than 868 MHz as originally built (for European/ Canadian communication protocols).

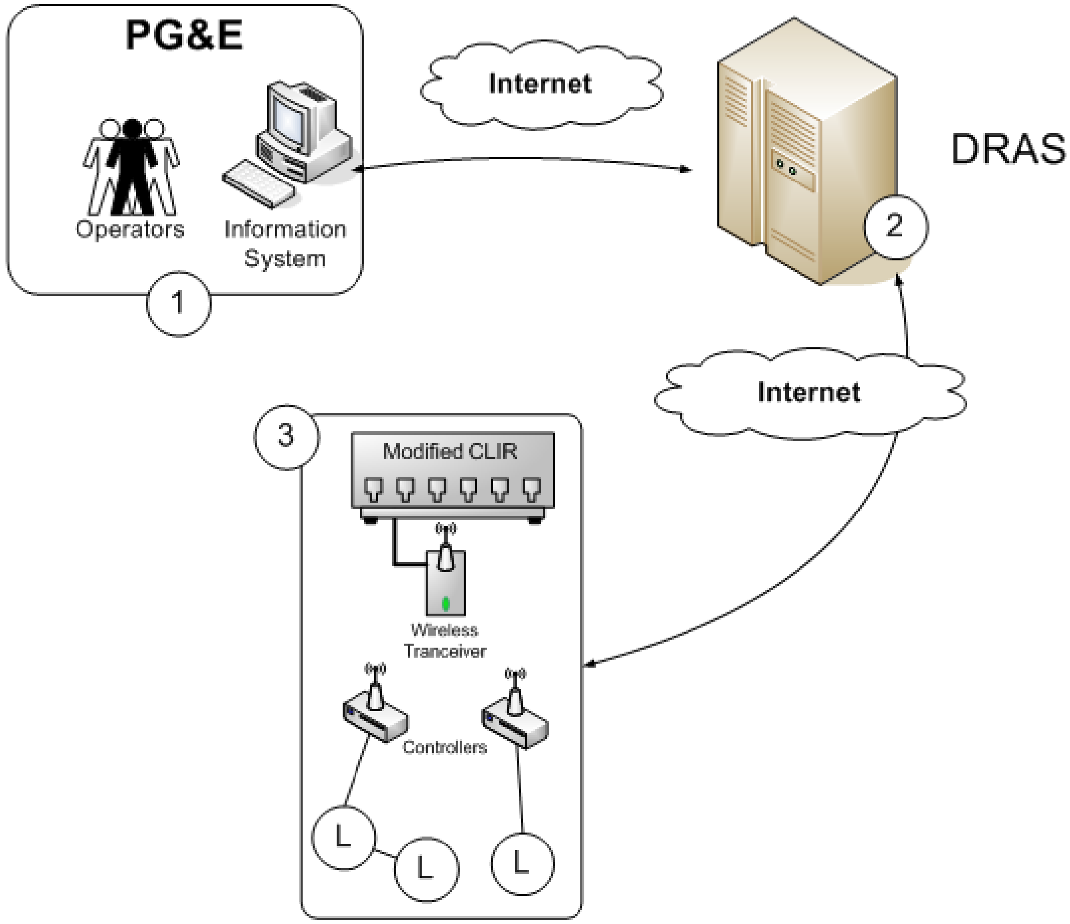

Figure 8. Echoflex System Diagram

All controlled lighting loads were preset to dim to 65% power at the moderate price signal and 30% power at the critical price signal, though the settings were adjustable in the field. The first DR test results indicated that the lighting power levels did not reduce to the intended levels. The controllers had been programmed to set the low voltage dimming output to 6.5 volts and three volts during the moderate and critical DR periods, but measurements showed that these signal voltage levels did not correspond to the desired lighting power levels for the dimmable ballasts used in the demonstration. Recommissioning of the controller settings was carried out by Energy Solutions staff to set the DR levels within the desired ranges, and further DR tests were performed.

Figure 9. Photos of Echoflex Demonstration at Energy Solutions, Showing Light Levels during Normal and Moderate Price Signals

To evaluate the DR capability of the Echoflex technology, baseline power on each of the affected lighting circuits was measured for several weeks prior to installation of the dimming ballasts and controls. Following installation of the system (controllers, wireless switches, dimmable ballasts and low voltage wiring, which was run between the ballasts and controllers), a DR event was dispatched via a CLIR box modified to transmit DR events wirelessly. Because the initial test did not yield the expected results (this is explained in more detail in the Project Results section), field commissioning of the controllers using the wireless wall switches was carried out to re-set DR lighting power levels and two more DR tests were staged. The intended DR power reduction levels were as follows:

Table 8. Summary of Echoflex DR Test Settings

Date	Price Signal	Ballast Power Output (% relative to 100%)		
		Circuit 2	**Circuit 3**	**Circuit 5**
2/18/09 and 2/26/09	Moderate	65%		
	Critical	30%		
	Normal (test ends)	100%		

Project Results

Adura LightPoint System

As discussed in the DR Test Description above, this system was installed to turn off a grid pattern of selected light fixtures at moderate and critical DR price signals. DR testing for Light Controllers occurred on July 3 and 8, before power logging commenced on the three circuits serving the affected lights. However, the technology was programmed so that each individual fixture level Light Controller instantly reported changes of state from "on" to "off" to the system Gateway during DR events. This information was recorded throughout the test period in an Adura database, which automatically calculated total system wattage based on system voltage and assumed ballast amp draw for "on" fixtures. The system level wattage data was organized and reported by Adura in five minute intervals for simplicity. Lighting Power Density (LPD) was then calculated by dividing reported system wattage by floor area under the Light Controller-controlled fixtures (area estimates were based on scaled lighting plans).

Figure 11 presents a schematic of the fixtures controlled by Light Controllers during the DR events; all numbered fixtures were programmed to the "on" state during normal price signal, while the yellow shaded fixtures turned off during the moderate price signal, and both yellow and red shaded fixtures were programmed to "off" for the critical price signal.

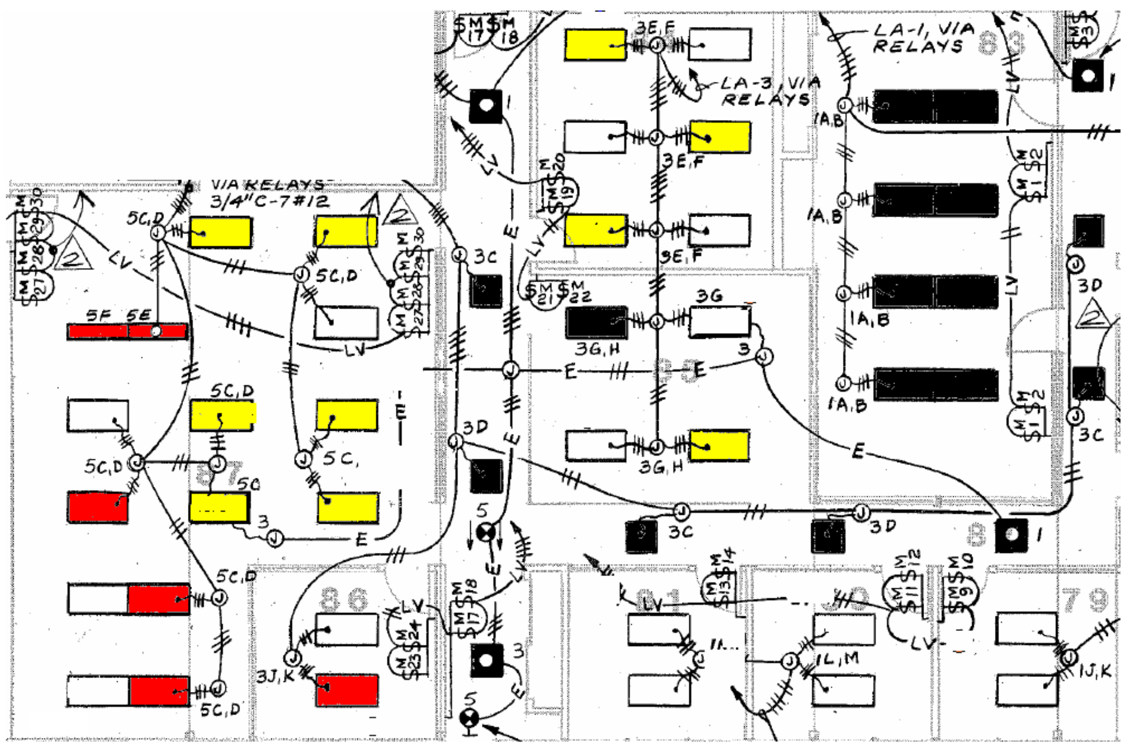

Figure 10: Diagram of Adura LightPoint DR Control Strategy

Observation during the DR testing periods indicated that the intended DR strategies were successful. Lighting power data from Adura for the demonstration system were evaluated and results indicated that during the DR testing on July 3, total system power load dropped to 71.0% of baseline (system wattage with all fixtures on) during the moderate period and 48.4% during the critical period. A summary of system wattages from the data set at the different DR levels is given in Table 8. Note that the system did not return to full system wattage after the return to normal signal was received. The discrepancy is based on an 88.64 W difference, the assigned wattage for one three-lamp fixture. This indicates that a fixture Light Controller did not report back a return to "on" state or that a fixture remained off after the test. On the other hand, the DR test on July 8 did return to full system power upon return to normal price signal.

Comparing the dataset results with calculated system wattages based on fixture wattages reported by Adura and the DR control strategy diagram above, the baseline system wattage agrees perfectly, but we would have expected about 100 W less during the moderate period and about 100 W more during the critical period. No ready explanation for these differences during the DR events is available, but they seem to point to issues with the Adura dataset for the test period since system function (fixtures turning off and on at appropriate times) was observed in the field.

The data also appears to indicate that system wattage did not recover to baseline levels immediately after the "return to normal" received, post- DR test. In actuality, the Light Controllers were programmed to turn on immediately upon receiving the signal (which was confirmed in the field); therefore the gradual step up in system wattage over almost an hour long period in the Adura data is an artifact of the controllers not reporting back state change from off to on immediately when they responded to the return to normal signal. Whether or not a DR event is taking place, the Light Controllers transmit an hourly "heartbeat" message on their current state (i.e., on/off) to the Gateway, so even though they did not immediately report turning back on at the end of the DR test, within an hour the system wattage recorded by the system had returned to expected levels.

Table 9: Adura LightPoint DR Results – July 3

Date	DR Signal	System Wattage	LPD	% Total
7/3/2008	Normal	2747.8	1.54	100.0%
	Moderate	1950.1	1.10	71.0%
	Critical	1329.6	0.75	48.4%
	Return to Normal	2659.2	1.49	96.8%

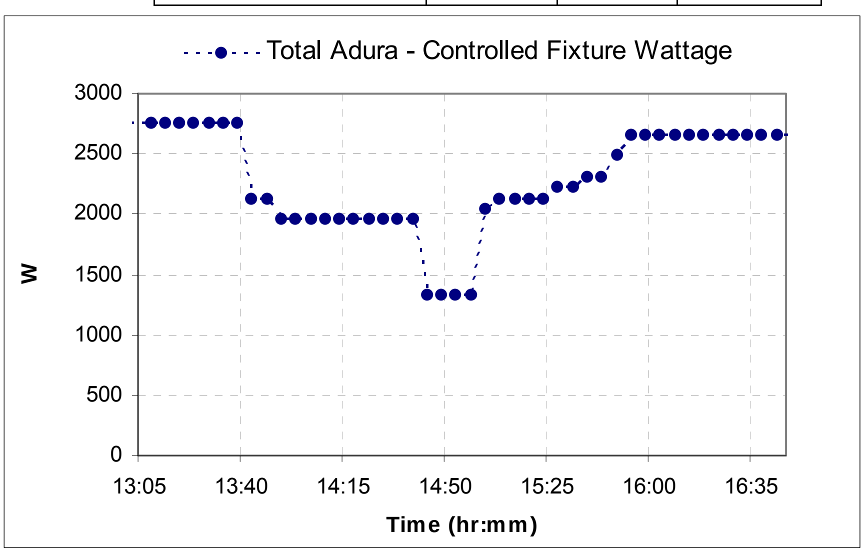

Figure 11: Time Series of Reported System Power for Adura LightPoint DR Test - July 3

Results for July 8 indicated that during the DR testing, total system power dropped by 1/3, to 66.7%, during the moderate period and by ½, to 50.0%, during the critical period, with a post DR return to 100% full power. The baseline system wattage on July 8 is about one fixture (89 W) lower than on July 3, indicating that one of the fixtures was off, or at least reported itself off, throughout the test period. Accounting for this one off fixture in the calculated approach, July 8 system wattages at normal, moderate, and critical levels agree with calculated system wattages within 1 to 14 W at each level. See appendix for calculated wattage values.

Table 10: Adura LightPoint DR Results – July 8

Date	DR Signal	System Wattage	LPD	% Total
7/8/2008	Normal	2659.2	1.49	100.0%
	Moderate	1772.8	1.00	66.7%
	Critical	1329.6	0.75	50.0%
	Return to Normal	2659.2	1.49	100.0%

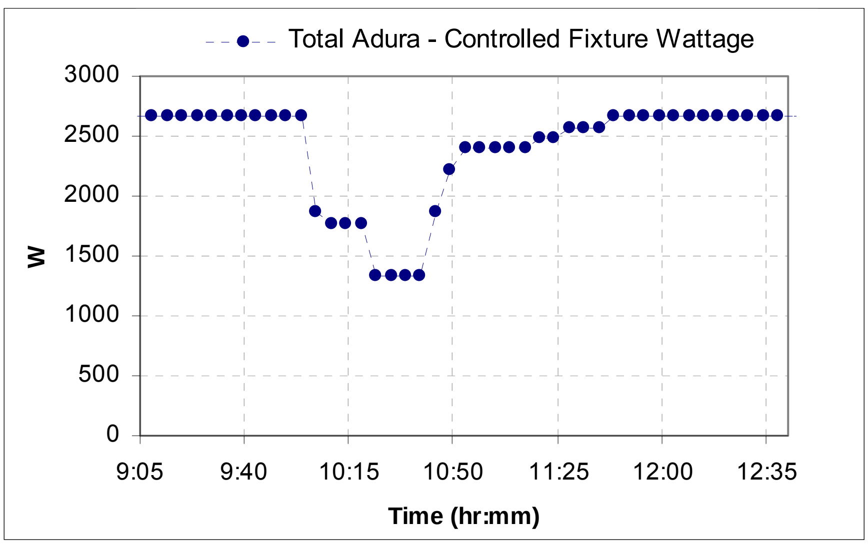

Figure 12: Time Series of Reported System Power for Adura DR Test - July 8

TECHNOLOGY RESPONSE TIME

Adura indicates that the system was designed to switch fixtures immediately upon receiving DR signals for the moderate and critical price scenarios, and visual observations during the tests confirm that this was the case. From Adura data for the DR tests on July 3, the Gateway system clock appeared to differ by roughly 15 minutes with the times recorded for the DR signal transmissions. On the other hand, the July 8 times appear to correspond closely. Adura lighting system wattage data was compiled by running a query of system data that summed Light Controller states on a five minute interval, so the exact time the system switched from normal to moderate, and moderate to critical is not known. Nonetheless, comparing the recorded times at which the DR signals were communicated to the Light Controllers with the times at which demand reductions are observed in the data (correcting for the system time difference on July 3), it appears in general that the system responded to moderate and critical signals in five minutes or less. Data for the system's return from critical to normal mode was inconclusive for the DR tests because, as described previously, the Light Controllers were not programmed to immediately report change of state from off to on during a return to normal signal.

The current generation of Adura controls improves upon the system of data collection by including fixture level power sensors, as opposed to assigning assumed fixture power based on Light Controller reported states. The current generation LightPoint System also stores this instantaneous power data for later retrieval[6].

LIGHTING LEVELS

Along with power measurements, sample illuminance readings were taken (in foot candles) during the DR events on July 3 to characterize lighting impacts at locations in the demonstration area. A complete set of illuminance measurements throughout the office to quantify average illuminance at normal, moderate, and critical levels was not possible, but the sample points give some indication of DR impacts on light levels.

IESNA's Standard Practice for Office Lighting (RP-1) Table 1 recommends maintained task plane illuminance levels for various categories of work. For the types of work performed at this site, 30-50 foot candles is an appropriate illuminance range.

The locations of the measurement points are described in the following table, with fixtures referred to by the DR level at which they were programmed "off". Note that the outdoor lighting conditions were clear and sunny, affecting readings near windows and skylights. Because the load shedding strategy was a checkerboard of on / off fixtures rather than dimming throughout the space, lighting impacts were highly dependant upon location and how nearby fixtures were controlled during the DR events.

[6] The current generation of controls was released after this evaluation concluded and these features were not tested or confirmed.

Table 11: Illuminance Impacts of Adura DR Event

Location Label	Measurement Location Description	Event Pending Illuminance (fc)	Moderate Price Illuminance (fc)	Normal to Moderate % Baseline	Critical Price Illuminance (fc)	Normal to Critical % Baseline
A	Interior cubicle with nearby skylight, directly under Normal fixture, surrounded by two Moderate fixtures and two Critical fixtures	98.0	85.7	87.4%	55.6	56.7%
B	Hallway between cubical and hardwall offices, directly under Moderate fixture, adjacent to one Moderate and one Normal fixture	53.8	19.0	35.3%	21.2	39.4%
C	Interior cubicle under Normal fixture, adjacent to two Moderate fixtures and one other Normal fixture	75.3	57.8	76.8%	57.9	76.9%
D	Interior cubicle under Normal fixture adjacent to one Moderate fixture and two other Normal fixtures	46.0	42.3	92.0%	41.5	90.2%

Universal DEMANDflex

ALAMEDA COUNTY WATER DISTRICT

The DCL system was configured to dim lighting circuit ballasts to preset levels upon receiving DR signals from the internet-connected CLIR device. To evaluate lighting power reductions during the DCL system's DR testing at ACWD, a data logger was placed on the lighting circuits where the technology was installed. The logger was programmed to record RMS volts, Amps, kW, and Power Factor at five minute intervals (averaged) throughout the DR periods. A sample of the daily lighting power cycle monitored by the data logger for the three lighting circuits retrofitted with Universal's DCL technology is provided in Figure 14.

The data logging equipment, a Dent ElitePro Datalogger with current transformers and voltage probes, was provided by the Pacific Energy Center's Tool Lending Library. Changes in LPD during the DR tests were also calculated. Office area estimates were based on scaled lighting plans and only the floor area under fixtures equipped with DEMANDflex ballasts was included in LPD calculations.

Universal's DCL system was installed on lighting Circuits 2, 3, and 5 at Site 1. DR tests occurred on October 22 and 24 and November 7, and included transmission of moderate, critical and normal price signals from the DRAS to the DCL system through the CLIR box installed at the host facility.

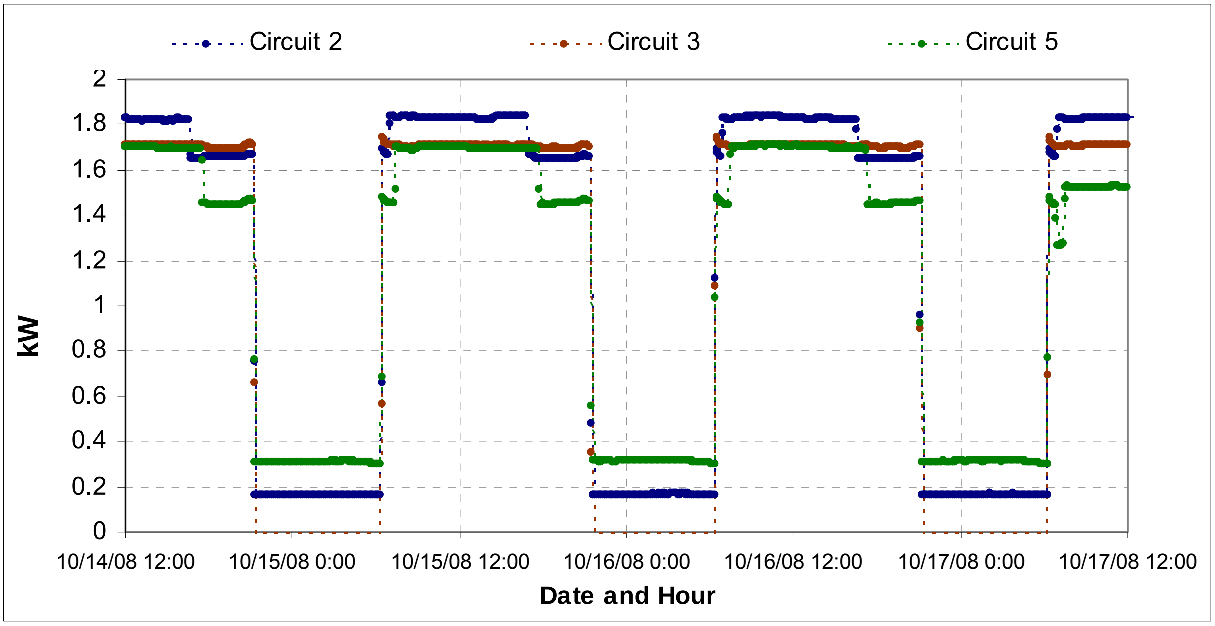

Figure 13: Sample Lighting Power Time Series - ACWD Engineering Offices

Lighting Circuit 3 consisted entirely of fixtures equipped with DEMANDflex ballasts and controlled by the DCL system. A small fraction of the lighting load on Circuits 2 and 5 was not retrofitted with DEMANDflex ballasts and therefore was not controlled by the DCL system during DR testing. Fixtures not retrofitted for the study included private office and conference room fixtures. Though these fixtures were not controlled during the DR tests, those that were on during the tests added load to the circuit level measurements, so the total lighting power recorded for each circuit was multiplied by a factor (DCL– controlled fixtures on Circuit/ Total Fixtures on Circuit) in order to isolate the fraction of lighting power controlled by the DCL system. A contact at the host site also provided information on occupancy during the test periods for the private offices and conference rooms so that the total number of "on" fixtures for each circuit was known.

Measured power results for the DR events on October 22 show that during the intended moderate price signal period, total kW dropped to 68.2%, while lighting power was reduced to 89.6% during the intended critical price period. These levels indicate that the system either received the moderate and critical DR signals in reverse of the intended order or misinterpreted the signals it received on this date. The data have been arranged in proper order in the table below, but the plot in Figure 15 illustrates the reversal of the two DR events. Aside from the order of the events, the power reductions agree with design levels and with subsequent DR test results. The data below factor out the fraction of measured lighting load not controlled by the DCL system, but the following data plots include all measured kW for each circuit, including fixtures equipped with both DEMANDflex and non- DEMANDflex ballasts). Appendix data tables include total kW readings and calculations of the amount controlled by the DCL system.

Table 12: Universal DEMANDflex DR Results - October 22

Date			**Circuit 2**	**Circuit 3**	**Circuit 5**	**All Circuits**	**Demand Flex Settings**
	% of monitored lighting load controlled by DEMANDflex		83.3%	100.0%	69.5%	**84.6%**	
10/22/08	Baseline	Total DEMANDflex kW	1.51	1.71	1.18	**4.40**	**100%**
		LPD	1.68	1.27	0.95	**1.26**	
		% Baseline	100.0%	100.0%	100.0%	**100.0%**	
	Moderate	Total DEMANDflex kW	1.37	1.52	1.06	**3.94**	**90%**
		LPD	1.52	1.13	0.85	**1.13**	
		% Baseline	90.3%	89.0%	89.6%	**89.6%**	
	Critical	Total DEMANDflex kW	1.04	1.15	0.81	**3.00**	**70%**
		LPD	1.15	0.86	0.65	**0.86**	
		% Baseline	68.6%	67.4%	68.7%	**68.2%**	

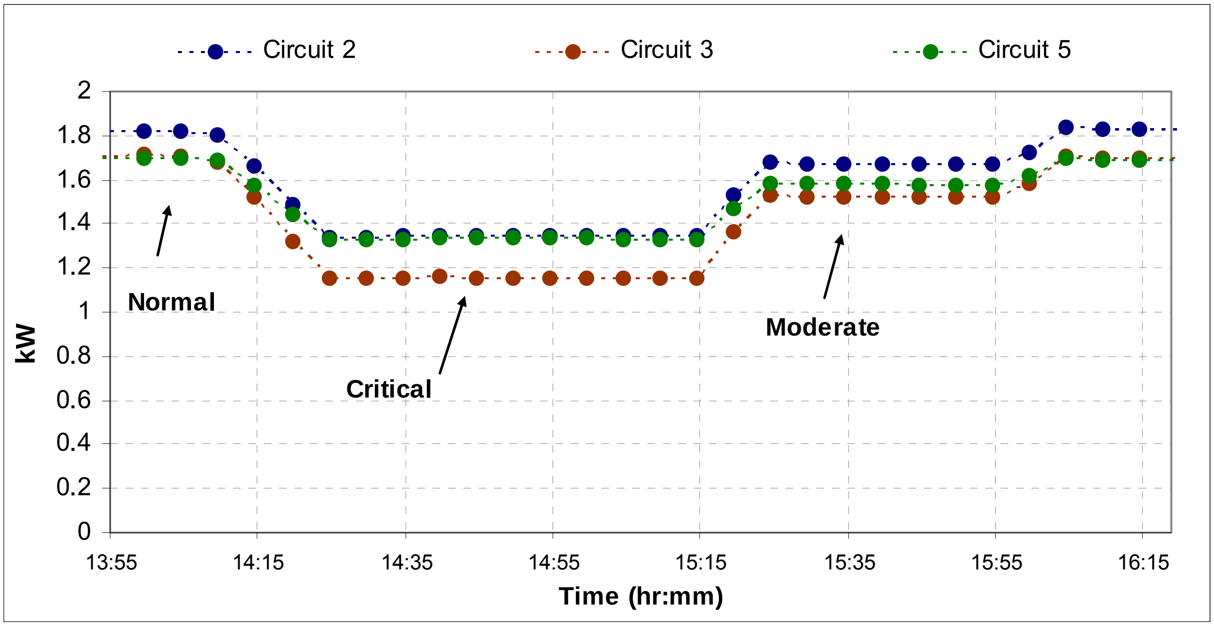

Figure 14: Time Series of Lighting Circuit Power for Universal DEMANDflex DR Test - October 22

Measured total lighting power results for the DR events on October 24 correspond closely with expected reductions at the moderate and critical price signal periods, at 89.4% and 68.0% respectively.

Table 13: Universal DEMANDflex DR Results - October 24

Date			Circuit 2	Circuit 3	Circuit 5	All Circuits	Demand Flex Settings
	% of monitored lighting load controlled by DEMANDflex		83.3%	100.0%	76.6%	**87.1%**	
10/24/08	Baseline	Total DEMANDflex kW	1.52	1.71	1.16	**4.39**	**100%**
		LPD	1.69	1.27	0.94	**1.26**	
		% Baseline	100.0%	100.0%	100.0%	**100.0%**	
	Moderate	Total DEMANDflex kW	1.36	1.52	1.04	**3.93**	**90%**
		LPD	1.52	1.14	0.84	**1.13**	
		% Baseline	89.5%	89.2%	89.6%	**89.4%**	
	Critical	Total DEMANDflex kW	1.04	1.15	0.80	**2.99**	**70%**
		LPD	1.16	0.86	0.64	**0.86**	
		% Baseline	68.2%	67.5%	68.5%	**68.0%**	

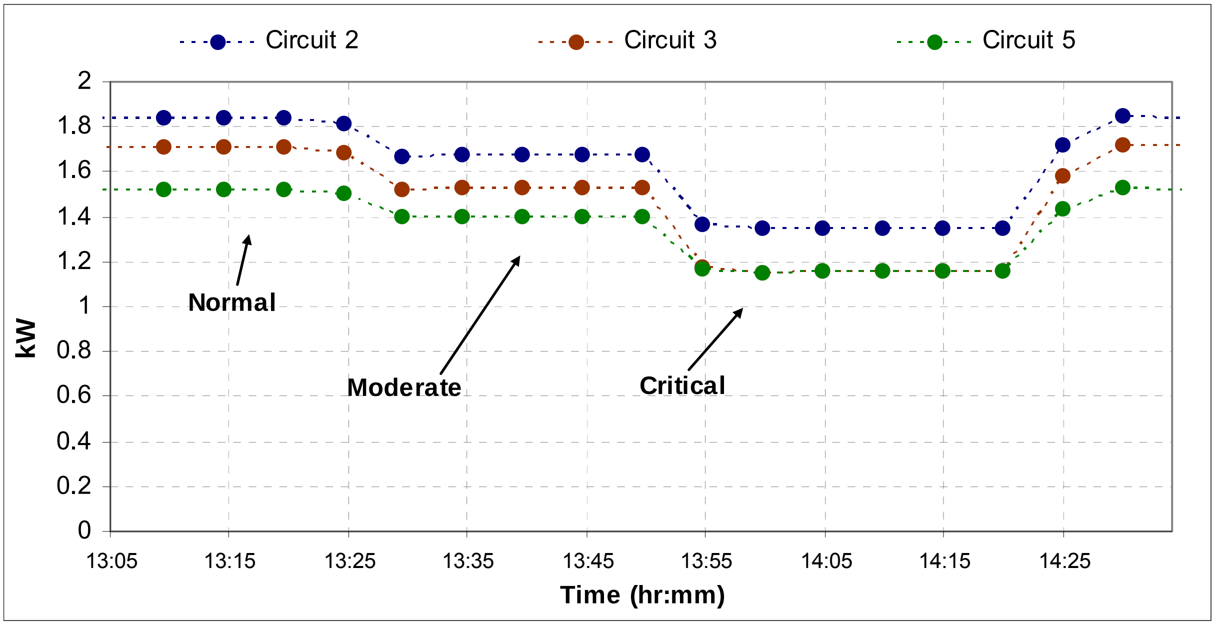

Figure 15: Time Series of Lighting Circuit Power, Universal DEMANDflex DR Test - October 24

As opposed to the previous tests, for the DR test on November 7, the Universal controls were set to reduce lighting power to different levels on each circuit, with levels on Circuits 3 and 5 being programmed to more aggressive reductions.

Table 14: Universal DEMANDflex DR Unique Circuit Settings – November 7

DR Level	Circuit 2	Circuit 3	Circuit 5
Moderate	90%	80%	70%
Critical	70%	60%	50%

Results from the DR tests on November 7 agree well with the programmed reductions; measured power reductions are within a few percent of expectations in each case and total lighting power experienced a more significant reduction than in previous tests, at 79.1% of baseline power during the moderate price period and 59.0% power during the critical price period.

From Figure 17, it is evident that on Circuit 2, some lights were actually turned off while DR testing was underway (moderate period), dropping power measurements on the circuit by 154 W, likely corresponding to the load of two fixtures. This change is accounted for in DEMANDflex kW and % Baseline calculations in Table 14.

Table 15: Universal DEMANDflex DR Results – November 7

Date		Circuit 2	Circuit 3	Circuit 5	All Circuits
	% of monitored lighting load controlled by DEMANDflex	90.9%	100.0%	76.6%	**87.1%**

11/07/2008	Baseline	Total DEMANDflex kW	1.52	1.70	1.17	**4.39**
		LPD	1.69	1.27	0.94	**1.26**
		% Baseline	100.0%	100.0%	100.0%	**100.0%**
	Moderate	Total DEMANDflex kW	1.34	1.33	0.80	**3.49**
		LPD	1.51	0.99	0.64	**1.00**
		% Baseline	88.4%	78.1%	68.6%	**79.1%**
	Critical	Total DEMANDflex kW	1.02	0.98	0.59	**2.44**
		LPD	1.13	0.73	0.48	**0.70**
		% Baseline	67.0%	57.6%	50.7%	**59.0%**

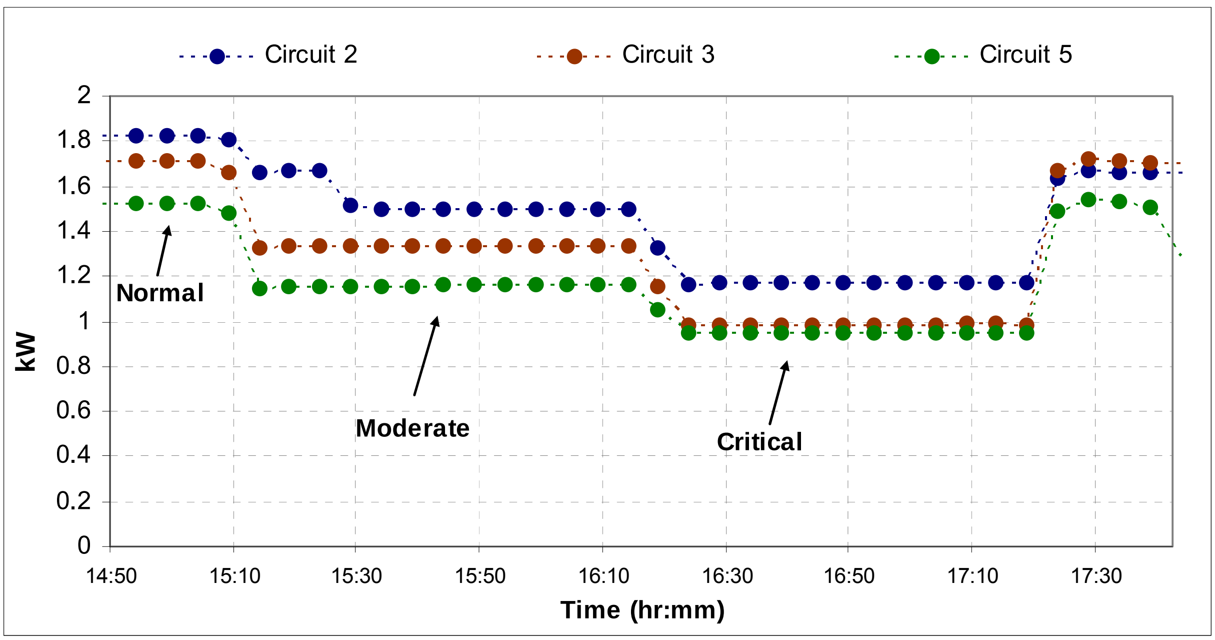

Figure 16: Time Series of Lighting Circuit Power, Universal DEMANDflex DR Test – November 7

ANHEUSER-BUSCH

As was done at ACWD, lighting power reductions during DR testing at Anheuser-Busch were evaluated by placing a data logger on the lighting circuits where the Universal system technology was installed. The logger was programmed to record RMS volts, Amps, kW, and Power Factor at five minute intervals (averaged) throughout the DR periods. The data logging equipment consisted of a Dent ElitePro Datalogger with current transformers and voltage probes. LPD was calculated based on office area estimates from a scaled lighting plan.

Universal's DEMANDflex system was installed on lighting Circuits 13 and 15, shown in the reflected ceiling plan below. The DR test occurred on February 18, 2009 and included transmission of moderate, critical and normal price signals from the DRAS to the DEMANDflex system through the CLIR box installed at the host facility. During the test, both rows of fixtures powered by Circuit 15 were on. Only the private office fixtures served by Circuit 13 were on during the test; the center row of fixtures in the open plan and single corner fixture powered by Circuit 13 were off before, during, and after the test. Circuit 13 power data indicates that for the majority of time during the weeks surrounding the DR test, only the private office lights were turned on.

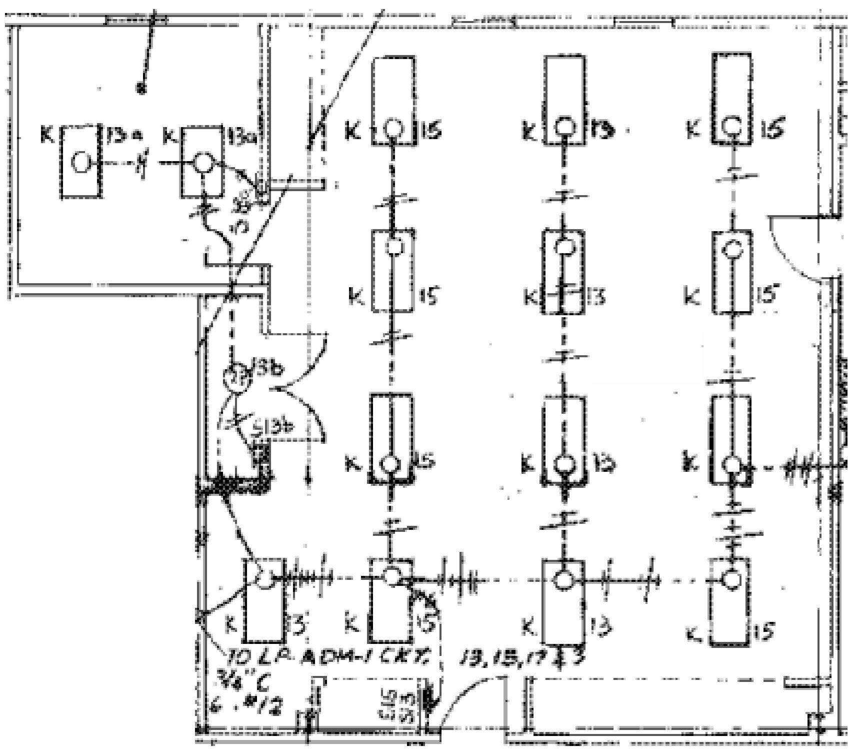

Figure 17: Reflected Ceiling Plan for Universal DEMANDflex Installation at Anheuser-Busch

Results from DR testing at Site 2 are shown in the following graph and table. The measurements indicate that the system achieved the expected reductions during moderate and critical DR periods. Note that when the DCL controls and CLIR box were installed, Circuit 13 was tapped with a 120 V outlet downstream of the logger to power the devices. This resulted in an average additional 20 W power recorded for this Circuit during the test period. The wattage attributed to powering these devices was subtracted from the power totals in the presented results.

Table 16: Universal DEMANDflex DR Results – February 18

Date			Circuit 13	Circuit 15	Both Circuits	DEMANDflex Settings
2/18/09	Baseline	Total DEMANDflex kW	0.174	0.676	**0.850**	**100%**
		LPD	1.088	0.690	**0.746**	
		% Baseline	100.0%	100.0%	**100.0%**	
	Moderate	Total DEMANDflex kW	0.134	0.524	**0.658**	**80%**
		LPD	0.840	0.534	**0.577**	
		% Baseline	77.2%	77.5%	**77.4%**	
	Critical	Total DEMANDflex kW	0.102	0.392	**0.494**	**60%**
		LPD	0.637	0.400	**0.433**	
		% Baseline	58.6%	58.0%	**58.1%**	

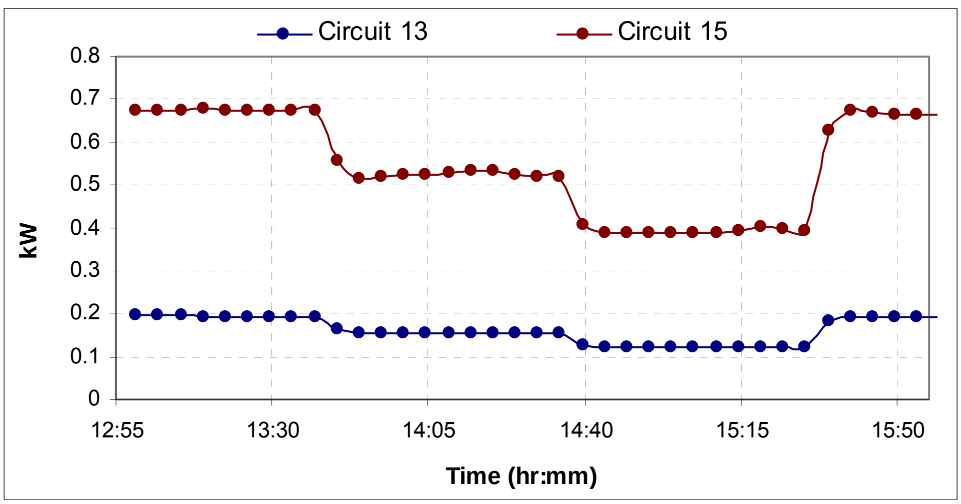

Figure 18: Time Series of Lighting Circuit Power, Universal DEMANDflex DR Test – February 18

TECHNOLOGY RESPONSE TIME

Field observations and communications with the manufacturer confirm that dimming occurred immediately upon receipt of DR signals. For ACWD and Anheuser-Busch, the time stamped lighting power reductions from the DR data can be compared with the times at which the DR signals were communicated to the DEMANDflex system. However, due to equipment data storage limitations, time stamped circuit kW values were averaged over five minute intervals, so instantaneous power reductions or reductions occurring in under five minutes cannot be directly observed in the data. In the data, average lighting power was drawn down for the five minute intervals during which DR signals were received and typically reached steady state at the reduced level in the following five minute average. As such, the data indicates that the system response time to reach programmed reductions was at most five minutes.

LIGHTING LEVELS

Along with power measurements, sample illuminance readings were taken (in foot candles) during the DR events on October 24 at ACWD to characterize lighting impacts at locations in the demonstration area. A complete set of illuminance measurements throughout the office to quantify average illuminance at normal, moderate, and critical levels was not possible, but the sample points give some indication of DR impacts on light levels.

IESNA's Standard Practice for Office Lighting (RP-1) Table 1 recommends maintained task plane illuminance levels for various categories of work. For the types of work performed at this site, 30-50 foot candles is an appropriate illuminance range.

Light levels at location A and B show agreement with power reductions, while C and D show less relationship between DR levels and light levels. It is likely that an outside factor influenced the recorded light levels at these points, such as local task lamps or other light sources not controlled by the DEMANDflex system.

Table 17: Illuminance Impacts of Universal DEMANDflex DR Event at ACWD

Location Label	Measurement Location Description	Event Pending Illuminance (fc)	Moderate Price Illuminance (fc)	Normal to Moderate % Baseline	Critical Price Illuminance (fc)	Normal to Critical % Baseline
A	Perimeter cube, next to window	40.7	37.0	90.9%	29.8	73.2%
B	Interior cube, some daylight	78.2	69.7	89.1%	50.4	64.5%
C	Interior, minimal daylight	46.6	47.9	102.8%	34.7	74.5%
D	Group cube, some daylight	51.5	54.9	106.6%	48.8	94.8%

No lighting levels were taken during the DR test at Anheuser-Busch.

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 2' x 4' lensed troffers with two lamps controlled by a single ballast in each fixture.

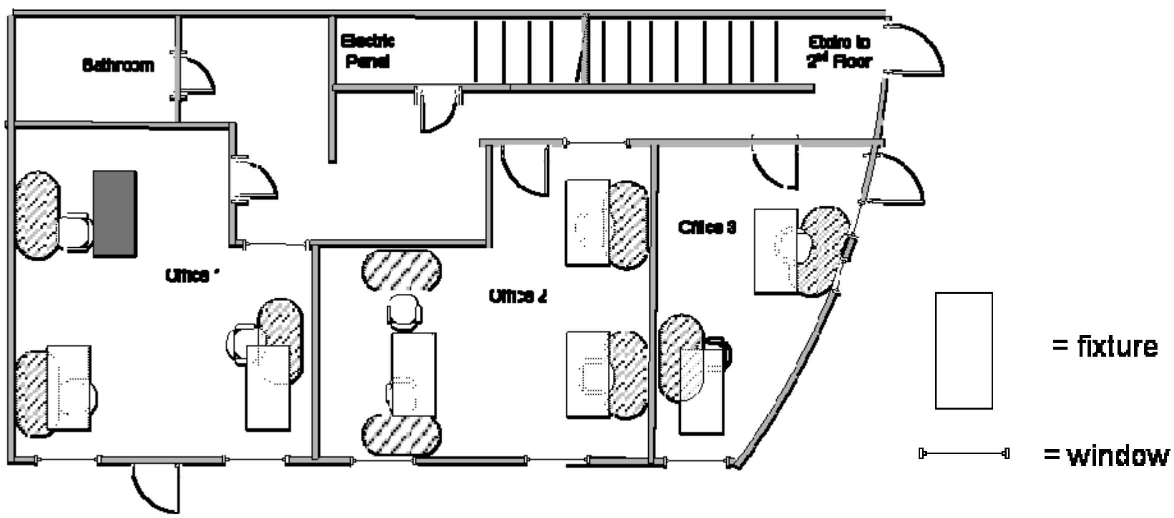

Figure 19: Plan View of Echoflex Site

To evaluate lighting power reductions during Echoflex DR testing, data loggers were placed on three lighting circuits serving the demonstration fixtures. The data logging equipment consisted of two Dent ElitePro Dataloggers with current transformers and voltage probes. The loggers were programmed to record RMS volts, Amps, kW, and Power Factor at 30 second to one minute intervals (averaged) throughout the DR periods. The grayed out fixture in Office 1 was wired to a fourth circuit that was not accessible for monitoring and was therefore excluded from the evaluation.

Changes in LPD during the DR tests were also calculated. Office area estimates were based on hand measurement of the office dimensions. For Office 1 the area used in LPD calculations excluded the area under the fixture that was not retrofitted for the demonstration.

A DR test was dispatched on February 13 and included transmission of moderate, critical and normal price signals from the DRAS to the Echoflex system through the modified CLIR box. Cumulative results for the seven fixtures in the study are shown in the following table. As the table shows, the power reductions recorded during this DR test differed from the intended levels of 65% power (moderate) and 30% power (critical).

Table 18: Echoflex DR Results – February 13

Date	DR Level		All Circuits	Echoflex Settings
2/13/2009	Baseline	Total Echoflex kW	**0.473**	**100.0%**
		LPD	**0.92**	
		% Baseline	**100.0%**	
	Moderate	Total Echoflex kW	**0.426**	**65%**
		LPD	**0.83**	
		% Baseline	**90.1%**	
	Critical	Total Echoflex kW	**0.237**	**30%**
		LPD	**0.46**	
		% Baseline	**50.1%**	

Discussions with the controls manufacturer indicated that the Echoflex controllers were programmed assuming that the dimmable ballasts were designed to reduce power in proportion to signal voltage. In other words, the controllers were programmed to reduce the signal voltage output from 10 volts (full power) to 6.5 volts at moderate signal, and to three volts at critical signal. The power data proved that lighting load was not shed in proportion to the drop in low voltage signal, as power levels dropped to roughly 90% at the 6.5 volt signal output and 50% at the three volt signal output.

Following this discovery, lighting power was measured through a range of signal voltage levels to determine the relationship between the two (no published data or curves from the ballast manufacturer were found describing this relationship). It was determined that 4.5 volts and 1.5 volts corresponded to 65% and 30% lighting power, respectively. The controllers were then reconfigured in the field to set the proper signal voltage for DR moderate and critical periods.

The process for reconfiguring the controllers' DR levels was explained by the manufacturer and a short guide for commissioning was also provided. The process consisted of a series of "clicks" and "holds" on the wireless switches that initiated a configuration mode for the individual controllers. It was then possible to set the low voltage signal output by clicking up and down through the range of incremental voltages. It was found that one click corresponded to roughly 1/5 of 1 decivolt (i.e., reducing the moderate level signal voltage from 6.5 volts to 4.5 volts required 100 clicks!). Since the only system feedback to the user in this process was the incremental dimming of light output from the fixtures, we found it necessary to connect a volt meter to the signal voltage circuit during commissioning to enter precise settings.

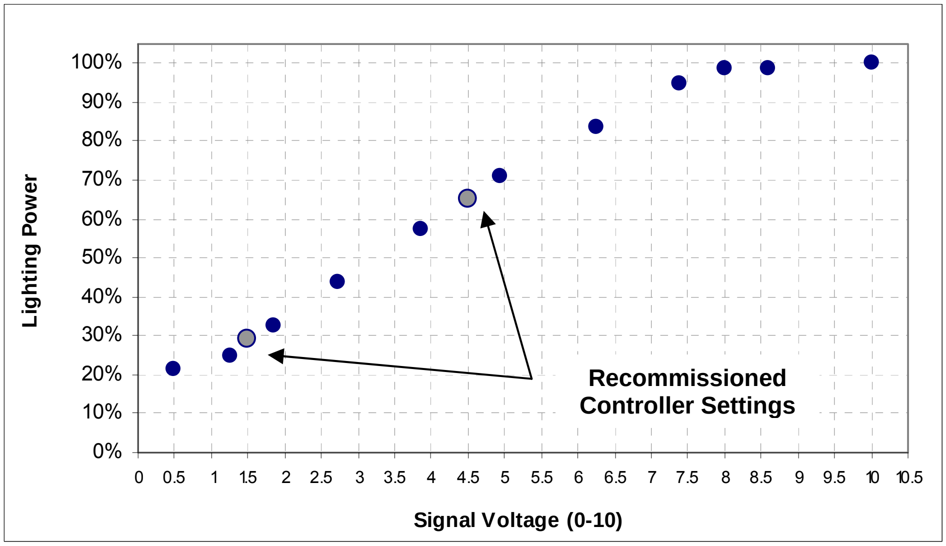

Figure 20: Echoflex Dimmable Ballast Control: Measured Power Levels for Range of Signal Voltages

Once the signal voltage levels had been field-commissioned, another DR test event was scheduled to re-evaluate the system. Results from the second DR event showed that the recommissioning exercise had been largely successful; lighting power levels were reduced to 69.3% and 31.1% during the moderate and critical periods. The moderate level reduction was still slightly less than expected but within a reasonable range. Because the process for field commissioning the DR levels required so many clicks and holds, this could easily be due to operator error.

Table 19: Echoflex DR Results – February 26

Date	DR Level		All Circuits	Echoflex Settings
2/26/2009	Baseline	Total Echoflex kW	**0.466**	**100.0%**
		LPD	**0.91**	
		% Baseline	**100.0%**	
	Moderate	Total Echoflex kW	**0.323**	**65%**
		LPD	**0.63**	
		% Baseline	**69.3%**	
	Critical	Total Echoflex kW	**0.145**	**30%**
		LPD	**0.28**	
		% Baseline	**31.1%**	

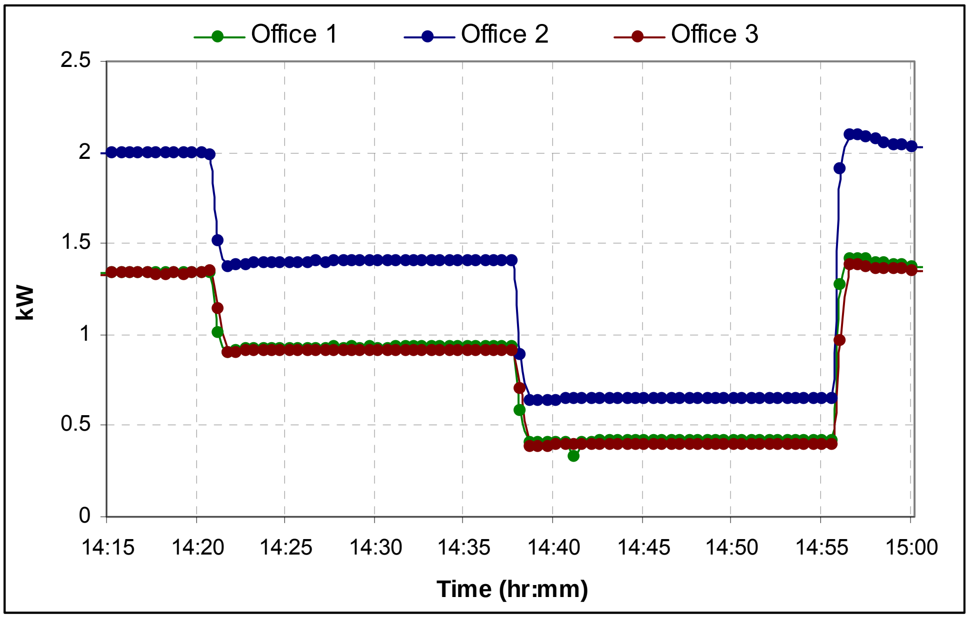

Figure 21: Time Series of Lighting Circuit Power, Echoflex DR Test

TECHNOLOGY RESPONSE TIME

Observations during the DR test indicated that lights dimmed immediately upon receiving wireless DR signals from the modified CLIR. The kW readings were averaged over a shorter interval at this site (30 seconds to one minute, versus five minute averages) to further evaluate technology response time. The data confirms that within 30 seconds to one minute, lighting load reached steady state at the new level.

LIGHTING LEVELS

For the February 26 DR test, in which lighting power reductions were within expected ranges, illuminance readings were taken on task planes in each office. Results show general agreement between power reductions and corresponding light levels, though points with high amounts of daylighting showed less reduction in light levels, especially during the critical period.

IESNA's Standard Practice for Office Lighting (RP-1) Table 1 recommends maintained task plane illuminance levels for various categories of work. For the types of work performed at this site, 30-50 foot candles is an appropriate illuminance range.

Table 20: Illuminance Impacts of Echoflex DR Event

Location Label	Measurement Location Description	Event Pending Illuminance (fc)	Moderate Price Illuminance (fc)	Normal to Moderate % Baseline	Critical Price Illuminance (fc)	Normal to Critical % Baseline
Office 1	Desk under fixture and across from window	48.8	35.8	73.4%	18.8	38.5%
Office 2	Interior desk under fixture, minimal daylighting	43.2	30.3	70.1%	13.0	30.1%
Office 2	Desk under fixture and adjacent to window	60.9	42.2	69.3%	28.3	46.5%
Office 3	Center desk, some daylighting – blinds drawn	37.8	24.0	63.5%	7.0	18.5%

Occupant and Host Satisfaction

Occupant and host satisfaction surveys were developed for most sites and manufacturer products. Occupants were not surveyed regarding the DR test of the Adura system because the test was completed prior to the ET team's decision to survey occupants. (However, the host was surveyed).

Table 21: Response to Occupant and Host Satisfaction Surveys

Manufacturer	Host Site	DR Surveys Requested	DR Surveys Returned
	Occupant Surveys		
Adura	Alameda Co. Water District (ACWD)	0	0
Universal	ACWD	26	16
Universal	Anheuser-Busch	3	3
Echoflex	Energy Solutions	4	4
Host Surveys			
	Host Surveys		
Adura	ACWD	1	1
Universal	ACWD	1	1
Universal	Anheuser-Busch	1	1
Echoflex	Energy Solutions	1	1

Occupant surveys focused on ability of users to detect and accept reduced light levels during the simulated DR events. Host surveys queried the main point of contact at the host site regarding ease of installation of the system, and their level of understanding regarding the system's potential to facilitate the host site's participation in utility DR programs.

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 DR 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 DR monitoring periods concluded at each of the following locations:

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

In general, occupants noticed dimming and were 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 intermittent use of a task light would seem like a reasonable solution in such cases.

When asked about complaints or comments received from occupants, host facilities noted mixed feedback. For example:

> 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.

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 DR benefits. 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?

In general, host sites found the technologies reasonably easy to understand and recognized the potential DR benefits. Occupant education and field commissioning were noted as areas that could be improved to deliver better results.

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

Wireless lighting controls represent a significant demand reduction opportunity in the commercial sector. Commercial lighting demand is responsible for 7.5% of total statewide demand[7]. However, lighting controls are not widely used because it is expensive to retrofit a building with wired controls. Previous generations of controls have also had a limited ability to decrease peak load. However, the technologies 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 DR Potential

The commercial building sector represents around 30%, or 6 GW, of the PG&E service area's estimated 20 GW of peak demand[8]. Interior commercial lighting, at roughly 1.45 GW, makes up around one quarter of the commercial building peak demand. If DR controls could reduce peak commercial lighting power by 25% in 50% of commercial buildings in PG&E's territory, that would result in a 180 MW reduction in load during the peak demand period[9]. The use of dimming ballasts could increase this potential.

Currently, market penetration of demand responsive lighting controls technologies such as those evaluated here is low, but our results demonstrate that effective technologies are available to capture demand savings potential in commercial lighting. Utility DR 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. Cost estimates for the Adura and Echoflex systems were between $1.50 and $1.75 per square foot. The Universal system was estimated to cost less than $1.00 per square foot. Because the system DR 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.

For analysis of system paybacks and cost/ benefits, it would be necessary to quantify both the economic benefits of participation in utility DR programs, as well as the energy savings potential that these systems provide relative to baseline control options. Because these factors vary greatly, system paybacks are not calculated here.

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[7] See note 1.

[8] According to California Energy Commission Staff Forecast of 2008 Peak Demand: http://www.energy.ca.gov/2007publications/CEC-200-2007-006/CEC-200-2007-006-SD.PDF

[9] Peak commercial demand estimates based on California Commercial End-Use Survey data, queried April 22, 2009 (http://capabilities.itron.com/CeusWeb/Chart.aspx)

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 product was quickly and easily installed at the host site, and this was noted by the host site point of contact. 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. Adura provided a Gateway that easily facilitated receipt of DR signals and transmitted them to the Light Controllers on the ballasts. Because Adura controls the lighting system on a ballast-by-ballast basis, it is very flexible, allowing customizable load-shed 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. Future installations may allow the customer to modify the load shed strategy over time using a web interface in development by Adura. However, the system installed for this evaluation did not include a user interface for commissioning and modification of DR settings after initial set up with Adura; any modifications to the DR settings would need to be executed by Adura.

At the time of this evaluation, Adura did not yet have a Light Controller compatible with a dimming 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 was not available. Our understanding from Adura is that they have recently released a product that is compatible with dimming ballasts, which will increase the product's DR 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 DR, 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).

Lastly, the tested system did not record power usage, including any load shedding. In addition, as described earlier in the report, we noticed data quality issues in the way that the Light Controllers reported state changes and the Gateway managed data. According to Adura, these issues have been resolved in the current generation of the Light Controller, which will include actual power monitoring.

UNIVERSAL DCL SYSTEM AND DEMANDFLEX BALLAST

The Universal DCL system and the continuously dimming DEMANDflex ballasts provide an integrated package for DR and various other control measures. 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. During our demonstration, the system interfaced with the CLIR box and successfully transmitted dimming commands to the individual circuits.

The Universal system requires the most space for bulkhead mounted control hardware, but provides controllability with no requirement for fixture level control wiring nor 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 DR results in most cases-- albeit after some rather complex on-site commissioning. Field commissioning was accomplished by clicking a wireless personal switch, which is an elegant solution—one that does not require logging onto the web or loading a software program—except that instructions needed to be clarified with the manufacturers, and the process required an excessive number of clicks.

The Echoflex product offers a full suite of wireless controls, including photocell and personal wall switches. The controls are unique in that they do not require batteries. Since these controls are an energy efficiency strategy and did not play a role in the DR evaluation, they are not addressed here.

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.

A significant limitation for this technology currently is that it did not easily interface with a device for automated DR. The system required a customized CLIR box that could wirelessly transmit price signals to the Echoflex controls. (Note that Echoflex could manufacture a Gateway device similar to that used by the Audra system to wirelessly transmit reliability signals to the controls—a CLIR box is not necessary).

Also, the system was not initially commissioned correctly to produce the requested demand reductions, so the ET team re-commissioned the system in the field. The process consisted of a series of "clicks" and "holds" on the wireless switches that initiated a configuration mode for the individual controllers.

Recommendations for Future Work

Wireless lighting controls have excellent potential for cost-effectively advancing DR in existing building stock in California and elsewhere. The three products evaluated in this study could help customers participate in energy utility DR programs. For example, in PG&E's service territory, customers utilizing these controls may be appropriate candidates for the Enabling Technologies Incentive Program (e.g., Technology Incentive and Auto Demand Response).

Incorporating the advanced lighting control technologies evaluated here into energy utility DR 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, PG&E 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 DR-enabled lighting control systems in new and existing commercial buildings.

A number of other lighting control products have entered the market and could be evaluated for DR capability, as listed in the following table.

Table 22. 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, as mentioned earlier, the manufacturers of the products evaluated in this report have developed or are developing next generation products that will increase flexibility and DR 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.

Lastly, the use of RF or PLC makes these controls an elegant and increasingly cost-effective option for DR, as well as energy efficiency, in existing buildings. Market actors, including lighting designers and contractors, facility managers and building owners, need to be educated about the great strides in lighting controls that have occurred. The marketplace will benefit from outreach to trade professionals and groups with information and training on advanced lighting control systems and DR options, 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 includes 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.[10]

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

Appendix 1: Monitoring and Evaluation Data

Table A1: Adura DR Tests - Comparison of System Data and Calculated Lighting Load

Site Information and Lighting Load Calculations			
Total Area, sq. ft.	1780		
System Voltage[1]	280		
3 - Lamp Fixture Amp Draw	0.32		
2 - Lamp Fixture Amp Draw	0.215		
		DR Period[2]	
	Normal	Moderate	Critical
3 - Lamp Fixtures	30	20	16
2 - Lamp Fixtures	1	1	0
Total System Fixtures	31	21	16
Calc. System Wattage, July 3	2,748.2	1,852.2	1,433.6
Calc. System Wattage, July 8[3]	2,658.6	1,762.6	1,344.0

	3-Jul-08				8-Jul-08			
DR Period	*Adura W*	*Δ Calc.W*[4]	*% base*	*LPD*[5]	*Adura W*	*Δ Calc.W*[4]	*% base*	*LPD*[5]
Pre- test	2747.8	0.4	100.0%	1.54	2659.2	-0.6	66.7%	1.49
Moderate	1950.1	-97.9	71.0%	1.10	1772.8	-10.2	50.0%	1.00
Critical	1329.6	104.0	48.4%	0.75	1329.6	14.4	100.0%	0.75

[1] System voltage and amp draw assumptions for fixture types provided by Adura

[2] Fixtures on during DR Periods based on Checkerboard DR Plan, total wattages for each period based on fixture number X fixture voltage X fixture amp draw

[3] Data from July 8 indicated that one fixture was either off or reported off, so one fixture (3 - lamp) was subtracted from calculated totals

[4] Δ Calc. W refers to difference in W between Calculated System Wattage and Wattage taken from Adura data

[5] Total W / Area

Table A2: Universal DEMANDflex DR Test - Site 1, 10/22/2008

Site and Test Information	Circuit 2	Circuit 3	Circuit 5	Total
Date 10/22/2008				
Area, sq. ft.	900	1340	1240	3480
Total Fixtures 'On' during Test	24	23	21.57	68.57
Non DemandFlex Fixtures 'On'	4	0	6.57	10.57
DemandFlex Load, %[1]	83.3%	100.0%	69.5%	84.6%

	Circuit 2			Circuit 3			Circuit 5			Total			
DR Period[2]	*kW*	*% base*	*LPD*[5]	*kW*	*% base*	*LPD*[5]	*kW*	*% base*	*LPD*[5]	*kW*	*% base*	*LPD*[5]	*W/fixture*[6]
Pre- test 12:40 - 2:00PM	1.8156			1.7057			1.6985			5.2198			
DemandFlex Load[3]	1.5130	100.0%	1.68	1.7057	100.0%	1.27	1.1810	100.0%	0.95	4.3997	100.0%	1.26	75.9
Critical 2:30 - 3:15PM	1.3404			1.1500			1.3284			3.8188			
DemandFlex Load[4]	1.0378	68.6%	1.15	1.1500	67.4%	0.86	0.8109	68.7%	0.65	2.9987	68.2%	0.86	51.7
Moderate 3:25 - 3:55PM	1.6694			1.5189			1.5751			4.7634			
DemandFlex Load[4]	1.3668	90.3%	1.52	1.5189	89.0%	1.13	1.0576	89.6%	0.85	3.9433	89.6%	1.13	68.0

[1] (Total Fixtures 'On' During Test - Non DemanFlex Fixtures 'On') / Total Fixtures 'On' During Test; note that fractional value for Circuit 5 is due to U-tube T8, assuming 43W / 75W

[2] Average kW for given time period; note that this period excludes transition values between DR periods

[3] Pre- test DemandFlex Load is calculated as Average Total Circuit kW X % Load DemandFlex

[4] DemandFlex Load during DR periods is calculated as the Pre- test DemandFlex Load minus the difference between Total Pre- test kW and Total DR period kW

[5] Total W / Area

[6] Total DemandFlex Load / Total DemandFlex Fixtures

Table A3: Universal DEMANDflex DR Test - Site 1, 10/24/2008

Site and Test Information				
Date 10/24/2008				
	Circuit 2	Circuit 3	Circuit 5	Total
Area, sq. ft.	900	1340	1240	3480
Total Fixtures 'On' during Test	24	23	19.57	66.57
Non DemandFlex Fixtures 'On'	4	0	4.57	8.57
DemandFlex Load, %[1]	83.3%	100.0%	76.6%	87.1%

	Circuit 2			Circuit 3			Circuit 5			Total			
DR Period[2]	*kW*	*% base*	*LPD*[5]	*kW*	*% base*	*LPD*[5]	*kW*	*% base*	*LPD*[5]	*kW*	*% base*	*LPD*[5]	*W/fixture*[6]
Pre- test 12:30 - 1:25PM	1.8289			1.7068			1.5182			5.0538			
DemandFlex Load[3]	1.5241	100.0%	1.69	1.7068	100.0%	1.27	1.1634	100.0%	0.94	4.3943	100.0%	1.26	75.8
Moderate 1:30 - 1:50PM	1.6696			1.5228			1.3966			4.5890			
DemandFlex Load[4]	1.3648	89.5%	1.52	1.5228	89.2%	1.14	1.0419	89.6%	0.84	3.9295	89.4%	1.13	67.7
Critical 2:00 - 2:20PM	1.3450			1.1524			1.1522			3.6496			
DemandFlex Load[4]	1.0402	68.2%	1.16	1.1524	67.5%	0.86	0.7975	68.5%	0.64	2.9901	68.0%	0.86	51.6

[1] (Total Fixtures 'On' During Test - Non DemanFlex Fixtures 'On') / Total Fixtures 'On' During Test; note that fractional value for Circuit 5 is due to U-tube T8, assuming 43W / 75W

[2] Average kW for given time period; note that this period excludes transition values between DR periods

[3] Pre- test DemandFlex Load is calculated as Average Total Circuit kW X % Load DemandFlex

[4] DemandFlex Load during DR periods is calculated as the Pre- test DemandFlex Load minus the difference between Total Pre- test kW and Total DR period kW

[5] Total W / Area

[6] Total DemandFlex Load / Total DemandFlex Fixtures

Table A4: Universal DEMANDflex DR Test - Site 1, 11/07/2008

Site and Test Information	Circuit 2	Circuit 3	Circuit 5	Total
Date 11/7/2008				
Area, sq. ft.	900	1340	1240	3480
Total Fixtures 'On' during Test	22	23	19.57	64.57
Non DemandFlex Fixtures 'On'	2	0	4.57	6.57
DemandFlex Load, %[1]	90.9%	100.0%	76.6%	89.8%

	Circuit 2 [3]			Circuit 3			Circuit 5			Total			
DR Period[2]	*kW*	*% base*	*LPD*[6]	*kW*	*% base*	*LPD*[6]	*kW*	*% base*	*LPD*[6]	*kW*	*% base*	*LPD*[6]	*W/fixture*[7]
Pre- test 2:40 - 3:05PM	1.6692			1.7042			1.5207			4.8940			
DemandFlex Load[4]	1.5174	100.0%	1.69	1.7042	100.0%	1.27	1.1654	100.0%	0.94	4.3870	100.0%	1.26	75.6
Moderate 3:30 - 4:15PM	1.4926			1.3307			1.1550			3.9783			
DemandFlex Load[5]	1.3408	88.4%	1.49	1.3307	78.1%	0.99	0.7997	68.6%	0.64	3.4712	79.1%	1.00	59.8
Critical 4:25 - 5:20PM	1.1688			0.9813			0.9463			3.0963			
DemandFlex Load[5]	1.0170	67.0%	1.13	0.9813	57.6%	0.73	0.5910	50.7%	0.48	2.5893	59.0%	0.74	44.6

[1] (Total Fixtures 'On' During Test - Non DemanFlex Fixtures 'On') / Total Fixtures 'On' During Test; note that fractional value for Circuit 5 is due to U-tube T8, assuming 43W / 75W

[2] Average kW for given time period; note that this period excludes transition values between DR periods

[3] Note that for Circuit 2, a pair of lights was turned off during the test; these lights (153W) are subtracted from the Fixture count and pre- test kW average

[4] Pre- test DemandFlex Load is calculated as Average Total Circuit kW X % Load DemandFlex

[5] DemandFlex Load during DR periods is calculated as the Pre- test DemandFlex Load minus the difference between Total Pre- test kW and Total DR period kW

[6] Total W / Area

[7] Total DemandFlex Load / Total DemandFlex Fixtures

Table A5: Universal DEMANDflex DR Test - Site 2, 2/18/2009

Site and Test Information	
Date	2/18/2009
Total Area, sq. ft.	1140
Fixtures on During Test	10

		Circuit 13		Circuit 15		Total			
DR Period[1]		*kW*[2]	*% base*	*kW*	*% base*	*kW*	*% base*	*LPD*[3]	*W / fixture*[4]
Pre- test	1:00 - 1:40PM	0.1740	100.0%	0.6759	100.0%	0.8499	100.0%	0.75	85.0
Moderate	1:50 - 2:30PM	0.1343	77.2%	0.5236	77.5%	0.6579	77.4%	0.58	65.8
Critical	2:45 - 3:25PM	0.1019	58.6%	0.3918	58.0%	0.4937	58.1%	0.43	49.4
Return	3:40 - 4:50PM	0.1703	97.8%	0.6669	98.7%	0.8372	98.5%	0.73	83.7

[1] Average kW for given time period; note that this period excludes transition values between DR periods

[2] Avg Circuit kW - .02kW (load from controls + CLIR on same Circuit)

[3] Total W / Total Area

[4] Total W / Fixtures on During Test

Appendix 2- Host Survey Results- Adura LightPoint- ACWD

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.

	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…………		
2…………		
3…………		
4…………		1
5…………		

Comments:

> The hardest part was coordination w/District staff to allow access for the installers.

	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…………		
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.

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

> Being a public agency we would have to review the initial cost very closely. Currently there are no funds attached for this type of project 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 want would be the most difficule 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 accompdate 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 good 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 3- Occupant Survey Results- Universal DCL System, ACWD

	Respondents	Responses
GENERAL INFORMATION		
Please choose one of the following options to characterize the amount of natural daylighting in your office.	16	
My office space is directly adjacent to a window or directly below a skylight……………………………………………		5
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……………………………………		8
Other (please describe in terms of availability of daylight)………………………………………………………………		1
My office space is in the corner and does not receive significant daylighting.		
LIGHTING SURVEY		
Were you at your desk on Wednesday, February 4 between noon and 5pm?	16	
Yes………………………………………………………………………………………………		14
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.)		
On Wednesday, February 4, in response to simulated electricity price signals, the lights in your area were automatically dimmed.	14	
Did you notice that the light levels dimmed the afternoon of February 4th?		
Yes………………………………………………………………………………………………		11
No………………………………………………………………………………………………		3
Were you notified in advance that the lighting would be dimmed the afternoon of February 4th?	14	
Yes………………………………………………………………………………………………		13
No………………………………………………………………………………………………		1
At any point that afternoon, were the dimmed light levels too low to allow you to comfortably do your work?		
Yes………………………………………………………………………………………………		7
No………………………………………………………………………………………………		7
Comments:		
Did not notice any difference.		
The area would only be uncomfortable if a lot of reading on paper were being done (70% dimming).		
I prefer the lights be dimmed. The 50% level is very nice and allows ample light especially when working on the computer.		
Typically the lights are too bright for me to comfortably do my work. I loved the dimmed lighting, especially around 2:16pm, 4:14pm, and 4:25 pm. The lighting at 4:00 pm was also okay, but I prefer the dimmer level.		
My office is next to a window, and I do not need artificial lighting at all, as natural lighting is sufficient during summer months.		
It was very dark in my cubby.		
Dimming to 70% of full power was straining to the eyes.		
The lower light levels only bothered me when I'm reading a hard copy report, but not when I'm working on my computer.		
Test was conducted on a cloudy winter day. If lighting levels are reduced to the lowest level used during the test on a summer afternoon, there would be little impact on me.		
During the 90% light level I was able to do all my work. During the 70% light level I required task lights to read hard copies.		
Dimming lights in response to the price of electricity helps save money and helps the utility manage electric resources during periods of peak electricity demand (e.g., summer afternoons). In light of these benefits, would you consider the level of dimming that you experienced acceptable for 1-2 afternoons per month?	14	
Yes………………………………………………………………………………………………		12
No………………………………………………………………………………………………		2
Comments:		
Dimming the lunch area lights might also reduce energy consumption.		
I would be agreeable to have the lights dimmed every day.		
I would consider the level of dimming acceptable for all mornings and afternoons.		
During winter, even most cloudy days still provide enough natural light until ~4pm. In fact, the electric lights in my office are too harsh and I would prefer nothing but natural light during summer (until ~4pm), so I am totally in favor of all dimming.		

Appendix 4- Host Survey Results- Universal DCL System, ACWD

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 suze 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.		

Appendix 5- Occupant Survey Results- Universal DCL System, 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 on Wednesday, February 18 between noon and 4pm?	3	
Yes………………………………………………………………………………………………………		3
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.)		
On Wednesday, February 18, in response to simulated electricity price signals, the lights in your area were automatically dimmed in two stages, over a period of 2 hours before returning to normal.		
Did you notice that the light levels dimmed the afternoon of February 18th?	3	
Yes………………………………………………………………………………………………………		3
No………………………………………………………………………………………………………		0
Were you notified in advance that the lighting would be dimmed the afternoon of February 18th?	3	
Yes………………………………………………………………………………………………………		1
No………………………………………………………………………………………………………		2
Did you notice that the light levels were dimmed in two different stages, the first level being less dim and the second level being more dim?	3	
Yes………………………………………………………………………………………………………		2
No………………………………………………………………………………………………………		1
Were light levels adequate at the first, less dim, level, for you to do normal work?	3	
Yes………………………………………………………………………………………………………		3
No………………………………………………………………………………………………………		0
Were light levels adequate at the second, more dim, level, for you to do normal work?	3	
Yes………………………………………………………………………………………………………		3
No………………………………………………………………………………………………………		0
Dimming lights in response to the price of electricity helps the company save money and helps the utility manage electric resources during periods of peak electricity demand (e.g., summer afternoons). In light of these benefits, would you consider the level of dimming that you experienced acceptable for 1-2 afternoons per month?	3	
Yes………………………………………………………………………………………………………		3
No………………………………………………………………………………………………………		0

Appendix 6- Host Survey Results- Universal DCL System, 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 7- Occupant Survey Results- EchoFlex- Energy Solutions

	Respondents	Responses
GENERAL INFORMATION		
Please choose one of the following options to characterize the amount of natural daylighting in your office.	4	
My office space is directly adjacent to a window or directly below a skylight…………………………………………………		2
My office space is located near enough to a window and/or skylight to receive significant daylighting…………………………		2
(but is not adjacent to a window or directly below a skylight)		
My office space is in the interior of the office and does not receive significant daylighting……………………………………		
Other (please describe in terms of availability of daylight)……………………………………………………………………		
LIGHTING SURVEY		
Were you at your desk on Wednesday, February 18 between noon and 4pm?	4	
Yes………………………………………………………………………………………………		4
No………………………………………………………………………………………………		
(If you answered "yes", please continue with the Lighting Survey below. If you answered "no", you will not be able to complete the survey.)		
On Wednesday, February 18, in response to simulated electricity price signals, the lights in your area were automatically dimmed in two stages, over a period of 2 hours before returning to normal.		
Did you notice that the light levels dimmed the afternoon of February 18th?	4	
Yes………………………………………………………………………………………………		3
No………………………………………………………………………………………………		1
Were you notified in advance that the lighting would be dimmed the afternoon of February 18th?	4	
Yes………………………………………………………………………………………………		4
No………………………………………………………………………………………………		
Did you notice that the light levels were dimmed in two different stages, the first level being less dim and the second level being more dim?	4	
Yes………………………………………………………………………………………………		2
No………………………………………………………………………………………………		2
Were light levels adequate at the first, less dim, level, for you to do normal work?	4	
Yes………………………………………………………………………………………………		4
No………………………………………………………………………………………………		
Were light levels adequate at the second, more dim, level, for you to do normal work?	4	
Yes………………………………………………………………………………………………		4
No………………………………………………………………………………………………		
Dimming lights in response to the price of electricity helps the company save money and helps the utility manage electric resources during periods of peak electricity demand (e.g., summer afternoons). In light of these benefits, would you consider the level of dimming that you experienced acceptable for 1-2 afternoons per month?	4	
Yes………………………………………………………………………………………………		4
No………………………………………………………………………………………………		

Please feel free to provide comments:

I only noticed the light level change because I was expecting it and looking at the fixture. Otherwise, it would have been unlikely that I would have noticed the change.
The first dimmed light level was barely perceptible, which makes the full light level seem unneccessary.
Two questions were not as easy to provide a concrete answer: 1) First of all, my desk situation is somewhere between "near enough to a window and/or skylight to receive significant daylighting", and "in the interior of the office and does not receive significant daylighting". I put the first as my situation because at times, I do receive a significant amount of daylight, but a lot of the time I would not call it "significant". 2) At the second, more dim setting, the light levels were more than adequate for that time. However, if there were significant dark cloud cover and an extended period of dimness, it could become bother-some, but would not significantly affect my work.

Appendix 8- Host Survey Results- EchoFlex- Energy Solutions

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.

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…………		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.

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:

> 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…………		

	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:		
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 dut 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.		