Design & Engineering Services

DEMAND RESPONSE TESTS OF LIGHTING IN A TYPICAL COLLEGE CORRIDOR

DR11SCE1.05.2 Report

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Acknowledgements

Southern California Edison's (SCE's) Design & Engineering Services (DES) group is responsible for this project in collaboration with the Tariff Program & Services (TP&S) group. It was developed as part of SCE's Demand Response, Emerging Markets and Technology program under internal project number DR11SCE1.05.02. DES project manager Doug Avery conducted this project with overall guidance and management from Carlos Haiad of DES and Carl Besaw of TP&S. For more information on this project, contact: doug.avery@sce.com.

Disclaimer

ABBREVIATIONS AND ACRONYMS

ALCS	Advanced Lighting Controls Systems
FC	Footcandle
kW	kiloWatt
LPD	Lighting Power Density
M&V	Measurement and Verification
OTF	Office of the Future
SCE	Southern California Edison
sf	Square Feet
UCI	University of California, Irvine
W	Watts
W/sf	Watts per Square Foot

FIGURES

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EXECUTIVE SUMMARY

This report evaluates the lighting Demand Response (DR) technology installed at the Natural Sciences Building on the University of California, Irvine (UCI) campus. The DR study was conducted by Southern California Edison's (SCE) Design and Engineering Services Group.

The primary goals of this pilot project are to:

1. Determine whether the advanced lighting controls system allows for reliable control of corridor lighting loads from SCE or the facility manager as part of a Demand Response Program,
2. Examine demand reductions that can be achieved with a well-designed lighting system, and
3. Provide measured and technical data in support of the Smart Corridor and Stairwell concept.

The project site consists of several small areas in the Natural Sciences building. The total area of these spaces represents 2,000 square feet (sf) of a college classroom and laboratory building.

This DR pilot installed a new lighting control system consisting of 19 lighting fixtures. Three corridors and a small lab were retrofitted with Light Emitting Diode (LED) fixtures. The fixtures are fully controllable by a Redwood Systems' low-voltage LED lighting control. The fixtures provide full dimming capability, ranging from 1% to 100% using the Redwood Engine. Occupancy sensors provide on/off control of the lighting fixtures. In addition, all four areas have continuously illuminated security lighting that is not dimmable.

The occupancy control solution reduces demand on a regular basis. Occupancy sensors are an integral part of suspended fixtures, and the recessed fixtures use recessed occupancy sensors. Low voltage wires power the fixtures connected to the control engine.

Testing was conducted over four separate days in November of 2011. The testing involved changing the DR level to five different settings: 10% to 30% reductions (in 5% increments) in light output from the commissioned level (85% of the rated power), which is now the new 100% level. Each setting lasted for one hour after which it returned to the baseline DR level of 0%. Table 1 shows the planned schedule of the DR lighting tests. The fourth test day followed a different schedule and bypassed the occupancy sensors, causing all of the lights to stay on.

TABLE 1. LIGHTING DEMAND RESPONSE TEST SCHEDULE

DR LEVEL, %	CONTROL SYSTEM TIMING
10%	9:30 a.m. – 10:30 a.m.
0%	10:30 a.m. – 11:00 a.m.
15%	11:00 a.m. - 12:00 p.m.
0%	12:00 p.m. - 1:00 p.m.
20%	1:00 p.m. - 2:00 p.m.
0%	2:00 p.m. – 2:30 p.m.
25%	2:30 p.m. - 3:30 p.m.
0%	3:30 p.m. - 4:00 p.m.
30%	4:00 p.m. - 5:00 p.m.

Table 2 presents DR lighting average demand reduction in Watts per square foot (W/sf). The average DR reduction per square foot across the new commissioned Advanced Lighting Controls System (ALCS) is 0.031 W/sf at the 30% DR level. The average measured lighting density during the baseline period was (0.072 W/sf) and lighting density during the DR testing at the 30% level was (0.041 W/sf) during typical occupancy.

The demand reduction at DR level 30% is .031 Watts per square foot. Lighting systems achieved an average power savings of 43% when controlled during the DR test with control level at 30%. These values simulate typical operation, where many of the lights are off due to occupancy control. In the absence of occupancy control, more demand reduction is possible. With all lights continuously on, the average measured baseline lighting density was 0.218 W/sf and 0.100 W/sf during the DR testing at the 30% level. This results in a 0.118 W/sf (54%) demand reduction when all of the lights are on.

Figure 1 illustrates the relationship between the DR levels and DR lighting demand reduction. The figure shows a general upward trend between DR level setting and measured lighting power reductions, with the greatest savings being 0.031 W/sf at the 30% DR level. This is for the typical occupancy observed in the corridor area and in the occupied lab. A second dotted line is added to the figure representing reduction potential if the lights were not turned off via occupancy control.

TABLE 2. LIGHTING DEMAND REDUCTIONS

MEASUREMENT DESCRIPTION	DR LIGHTING VALUE	UNITS
Corridor Area	2,000	sf
Total Demand Response Savings at 30% DR (19 fixtures, typical)	62	W
Total Demand Response Savings at 30% DR (19 fixtures, no occupancy control)	236	W
Baseline Lighting Power Density (0% DR Level)	0.072	W/sf
Lighting Power Density at 30% DR Level	0.041	W/sf
Demand Reduction at 30% DR	0.031	W/sf

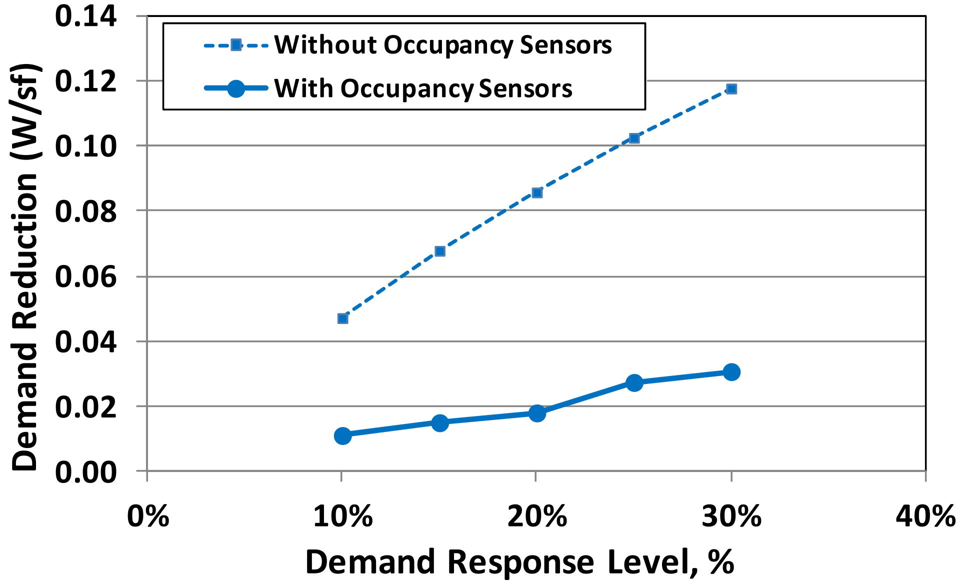

FIGURE 1. LIGHTING DEMAND REDUCTION PER SQUARE FEET AT VARIOUS LEVEL SETTINGS DURING DEMAND RESPONSE TESTING FROM BASELINE (0.072 W/SF)

The DR strategies tested in this study showed significant demand reduction with Advanced Lighting Controls Systems (ALCS) and recommends that there are future studies to address:

- Evaluation of DR strategies and their interaction with other controls such as occupancy sensors
- Evaluation of DR reductions available at various peak hours based on various lighting profiles

INTRODUCTION

The purpose of this study was to evaluate the Demand Response (DR) capability of Advanced Lighting Control System (ALCS) developed by Redwood Systems. Installation of this ALCS occurred on the ground floor of the Natural Sciences 1 building at the University of California, Irvine (UCI). This real-world setting permitted the researchers to verify that the technology proposed by the participating manufacturer performed to the published specifications by delivering the predicted reductions through reliable DR capabilities.

The building examined in this report also participated in the Smart Corridor concept. Southern California Edison (SCE) is developing such concepts in order to reduce energy and demand in spaces such as corridors and stairwells where occupancy is sparse and intermittent.

BACKGROUND

The following is an explanation of the need for demand reduction based on stress to the electric grid. This stress occurs when demand for electricity nears the capacity of the available power generation, an event that is typically most prevalent during hot summer afternoons. Weather forecasts are used to predict the need for demand reduction tactics and to provide a degree of planning for electric load curtailment. However, malfunctions in power generation, or to the electric grid, may result in immediate needs to reduce electricity consumption.

Various programs types, including very large customer participation in the following, have controlled peak electricity load.

- Demand Bidding,
- Critical Peak Pricing and Interruptible Rate programs, and
- Time-Of-Use rates for large commercial customers.

Residential customers participating in air conditioning cycling programs have also controlled peak demand.

SCE is investigating the potential for DR technologies on several projects this year to reduce the peak electric system load. In 2005, SCE implemented testing of a Universal lighting ALCS as well as one manufactured by General Electric.

SCE will benefit from fast and flexible responding to demand reduction systems. The larger the load that can be controlled, the more useful it is. Large load reductions can be achieved either by substantially reducing loads at a few major facilities, or by performing smaller load reductions at a large number of facilities. New technologies are providing ways to coordinate the DR program participation of larger and more varied customer groups.

GOAL OF THE PILOT PROJECT

SCE is testing the implementation of ALCS on the ground floor of the Natural Sciences 1 building, representing 2,000 square feet of corridor. The ALCS controls the level of light output via a controllable power source for the LED lights installed as part of this project.

The primary goals of this project are to:

1. Determine whether the advanced lighting controls system allows for reliable control of corridor lighting loads from SCE or business management as part of a Demand Response Program,
2. Examine demand reductions that can be achieved with a well-designed lighting system, and
3. Provide measured and technical data in support of the Smart Corridor and Stairwell concept.

POTENTIAL MARKET IMPACT

According to the California Commercial Energy Use Survey (CEUS), offices are the single largest commercial energy use in California. Offices represent 21% of the total commercial square footage and 25% of total commercial energy usage in California. In the SCE service territory, offices represent 18% of commercial square footage (385,110,000 sf) and have an interior lighting connected load of 1.16 W/sf.[1]. It follows that the connected interior lighting load in offices is 447 megawatts (MW). If 75% of the lighting was operating and DR could reduce 30% of the operating load, that would result the shedding of 100 MW.

The market impact of lighting improvements in existing office spaces is a discrete analysis and not a part of this study.

[1] Itron, 2010, California End Use Survey Results March 2006 prepared for the California Energy Commission retrieved 3/5/10 at http://capabilities.itron.com/CeusWeb/Chart.aspx.

THE UCI DEMONSTRATION PROJECT DESCRIPTION

Lighting demand use was monitored to quantify the demand reductions. A series of tests were conducted on the system to show the feasibility of this type of installed DR system.

SITE DESCRIPTION

This project consists of the corridor and teaching lab lighting on the ground floor of the Natural Sciences 1 building at UCI. The project area consists of four different adjoining spaces. Lights are located in typical straight corridors, a small mid-building lobby, a curved corridor, and a small teaching laboratory. The corridors and lobby occupy 1,440 square feet and the teaching lab occupies 560 square feet, for a total of 2,000 square feet. Some of the fixtures in the test areas are security lights that remain on continuously. The layout of the test areas displays in Figure 2.

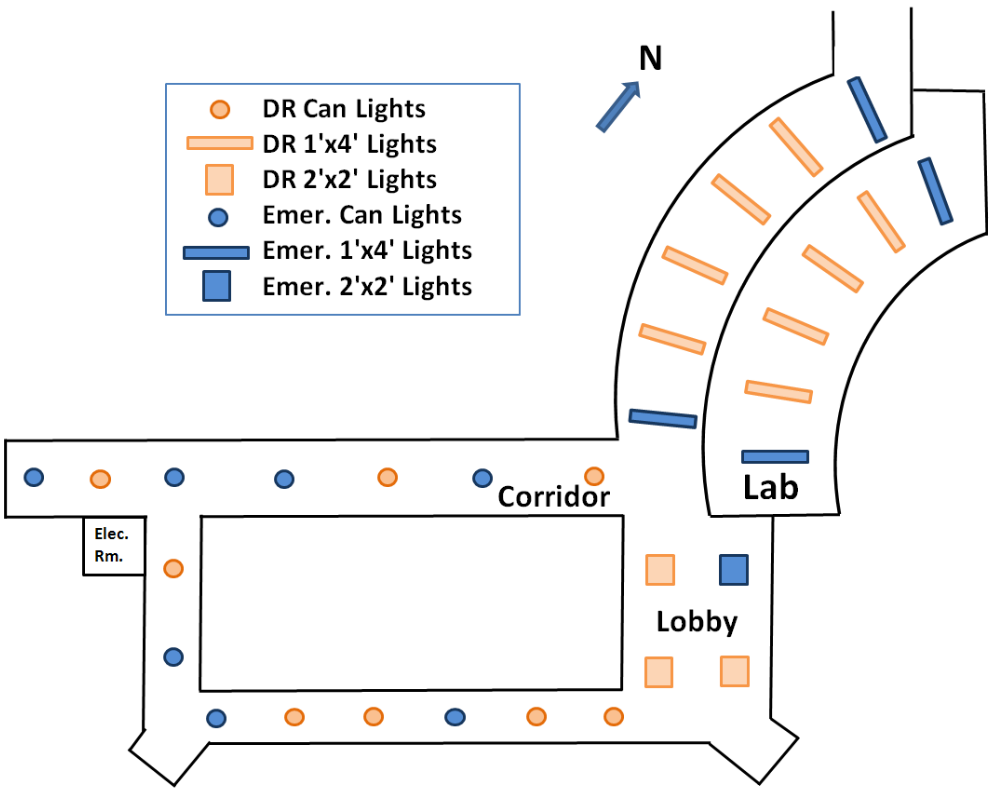

FIGURE 2. GROUND FLOOR TEST AREA CORRIDOR LIGHTING LAYOUT

The new lighting system is capable of demand reduction and tuning. The project was highly representative of retrofit projects in typical Class A office buildings. Data loggers were installed to collect electric load profile data during DR testing and to measure demand reductions attributable to the ALCS.

LIGHTING CONTROL SOLUTION

LIGHTING FIXTURES

There are three types of fixtures installed as part of this DR demonstration. They will be discussed in the following order by the location in which they are installed: straight corridors, lobby, curved corridors, and lab.

The existing straight corridor fixtures were replaced with recessed can lights. Eight Lightolier Calculite LED downlights with DR control were installed (see Figure 3). Each DR-capable downlight has an occupancy sensor mounted flush in the ceiling tile near each fixture. The programmed timeout is 6 seconds so that the lights do not stay on any longer than is needed. There are seven emergency security lights that are not part of the DR test that are intermingled with the DR test lights. The security lights are on continuously, so the corridor is never without some light.

Three LED fixtures with DR control were installed in the lobby. The small lobby is actually an extra wide corridor at a junction of spaces. A fourth fixture that looks identical is security lighting and is not controlled. These fixtures are shown in the right-hand photo of Figure 3. Each DR-capable fixture has an occupancy sensor mounted flush in the ceiling tile near each fixture. The fixtures are 2' x 2' Lunera 2230 series. They consist of grid lay-in ultra-thin LED plates that easily replace ceiling tiles. The DR-controlled fixtures are rated at 50 Watts (W) while the direct-wired security light model is rated at 59W.

FIGURE 3. STRAIGHT CORRIDOR LED CAN LIGHTS (LEFT) AND 2X2 LED LOBBY LIGHTS (RIGHT)

Four LED fixtures with DR control were installed in the curved corridor. A curved glass wall separates the curved corridor and the teaching lab. There are six fixtures in this corridor; both end fixtures are security lighting and are not controlled. The fixtures are shown in the right side of Figure 4. Each DR-capable fixture has an occupancy sensor mounted in a gray can on the end of the fixture. The programmed timeout is 6 seconds so that the lights do not stay on any longer than is needed. The fixtures are Lunera 6430 series ultra-thin LED light bars, which are suspended from the ceiling and measure 1' x 4'. The DR-controlled fixtures are rated at 31W with the direct-wired security light model rated at 44W.

The teaching lab has the same configuration of lighting layout and fixture types as the curved corridor. There are two security lights, one at each end of the room. The only difference from the teaching lab is that the four DR-controlled fixtures in the curved corridor are synchronized to turn on and off together and have a 10-minute timeout. A summary of the lighting fixtures is provided in Table 3 provides a summary of the lighting fixtures.

FIGURE 4. CURVED CORRIDOR AND TEACHING LAB LIGHTING

TABLE 3. SUMMARY OF DR LIGHTING FIXTURES AND LOCATIONS

LOCATION	NUMBER OF FIXTURES	RATED WATTAGE (W / FIXTURE)	FIXTURE TYPE
Straight Corridors	8	20	Lightolier Calculite LED
Lobby	3	50	2' x 2' Lunera 2230, LED
Curved Corridor	4	31	1' x 4' Lunera 6430, LED
Teaching Lab	4	31	1' x 4' Lunera 6430, LED
Total	19		

LIGHTING CONTROLS

This project installed a new lighting control system. A Redwood Systems RE64 (Redwood Engine) conducts reliable operation of the LED fixtures. It provides full dimming for LED fixtures that use 60W or fewer, and uses Redwood occupancy sensors. Full dimming allows for optimization of light levels to accommodate the user's comfort while maintaining maximum energy savings.

Redwood technical staff commissioned the system. The system's "Follow Me" mode achieves the greatest savings by offering a mode that "follows" the user through the corridor and initiates high mode for fixtures directly in front of and behind the user, while leaving the remaining fixtures off. This creates a ripple of high-mode light levels for users as they walk through the corridor. The corridor LED lights were programmed to ramp up in 0.25 seconds upon occupancy sensor trigger and 3-second fade after a 6-second timeout.

The system uses the Redwood Engine that converts alternating current (AC) power to direct current (DC) power, powering up to a 1,580W load per engine. Class 2 wiring running from engine to LED fixture delivers the power. The wire that delivers power also acts as a communication line between the engine and the fixture.

The 19 LED fixtures connected to the Redwood Engine used 33 of the 64 available channels, as seen in Figure 5. Some fixture types require more than one channel. The Redwood Engine is mounted on a wall in the space above the ceiling in the straight corridor near the electric room. The LED lights were commissioned to 85% light level output. The system percentage-level settings are based on light output rather than power input.

FIGURE 5. REDWOOD SYSTEMS ENGINE FOR CONTROLLING LED LIGHTS

The primary consideration is that this project is an excellent opportunity to demonstrate state-of-the-art DR practices in a normal, functional, campus building.

The system provides the following functions and strategies:

- Tuning to reduce lighting use by 15%. Commissioning reduced the light output settings to 85% of the lighting's rated output. This new commissioned level is also designated as the baseline for the DR testing. This capability compensates for the normal overdesign of lighting. Overdesign is caused by the standard practice of rounding up to integer numbers of luminaires and adding luminaires to make for aesthetically appealing installations.
- The installed lighting is capable of DR and can respond to a DR or real-time pricing signal, although these were not implemented. The owner and SCE can dim the lighting that is capable of DR to any level that is agreed upon. However, it should be noted that as the lighting is already dimmed down by 15%, this becomes the new 100% baseline level for all succeeding DR events.

Redwood technical staff commissioned the system during technical site visits involving upgrades, additions, or troubleshooting of the system.

TECHNICAL APPROACH/TEST METHODOLOGY

In order to characterize the demand reductions resulting from this pilot project, ADM Associates, Inc. devised a Measurement and Verification (M&V) protocol adapted to this facility.

Power to all DR-controlled lighting fixtures passes through the Redwood Engine controller. Metering was installed in the electrical room to monitor the circuit powering the Redwood Engine. Measurement of the engine accounts for power of the lights and the controller.

METERING EQUIPMENT AND DATA ACQUISITION

ADM installed an Enernet K-20 meter recorder to monitor the power use of the Redwood Engine. A 5 Amp current transformer was clamped around the circuit connected to the Redwood Engine. Data were recorded at 1-minute intervals to provide high resolution. The K-20 was programmed to record kW, kVA, Volts, and Amps. One-time power measurements were made using an AEMC 3910 true RMS power meter to provide field calibration of the installation. Although not required, additional redundant monitoring was installed. This included a Hobo external channel logger with a 5 Amp current transformer. The Hobo was set to record data in 1-second intervals, which limited the recording duration to half a day due to memory constraints.

Power data were recorded in one-minute intervals from November 1 to November 16. Data were manually downloaded to a laptop on three separate occasions during the monitoring period.

TEST PROCEDURES

The Redwood Engine controller did not have remote access for this demonstration project. An individual was required to connect a laptop to the system in order to program and run tests. Personnel from SCE programmed the controller prior to the tests to step through a series of conditions. The program schedule was then automated and did not require on-site initiation of the events. All computers, equipment and loggers were synchronized to National Institute of Standards and Technology clocks on Pacific Time, as obtained from the following web link: http://nist.time.gov/timezone.cgi?Pacific/d/-8/java.

DR testing was conducted for the same business hours over three separate days in November of 2011: Wednesday, November 2; Thursday, November 3; and Tuesday, November 8. During the test periods recording intervals were 1-minute. The testing procedure included changing the lighting level to five different settings: 10%, 15%, 20%, 25%, and 30% below the commissioned level. Each setting lasted for one hour, after which it returned to the baseline DR level of 0%. Table 4 shows the planned schedule of the lighting tests.

After the first two test days it was determined the tests should include periods with all the lights on. The occupancy timeout was increased from 6 seconds to 10 minutes. This control could only be made manually and the system was left in this mode for several days. The third day of the test (Nov. 8) was not representative of typical operation because monitoring staff continually walked through the hall to turn on the lights. A fourth day (Nov. 16) was added to the test where the lights were programmed to stay on and run through an identical set of DR levels at a faster pace. The DR level periods lasted 10 minutes and the reset to baseline lasted 5 minutes. In addition, there were 10-minute periods where only one location of lights was on at a time and one period where all lights were turned off. It should be noted that besides the DR lights, there are security lights throughout the space in order to maintain a safe level of lighting, which remain on at all times.

TABLE 4. LIGHTING DEMAND RESPONSE TEST SCHEDULE

DR LEVEL, %	CONTROL SYSTEM TIMING
10%	9:30 a.m. – 10:30 a.m.
0%	10:30 a.m. – 11:00 a.m.
15%	11:00 a.m. - 12:00 p.m.
0%	12:00 p.m. - 1:00 p.m.
20%	1:00 p.m. - 2:00 p.m.
0%	2:00 p.m. – 2:30 p.m.
25%	2:30 p.m. - 3:30 p.m.
0%	3:30 p.m. - 4:00 p.m.
30%	4:00 p.m. - 5:00 p.m.

A non-test day, November 1, was also recorded by the data loggers as a comparison to demand during the test days.

DATA ANALYSIS AND RESULTS

This section presents and discusses the data collected from monitoring of the controlled lighting. Analysis of the data included five DR tests on three different days. Charts and tables displaying the data are presented in this chapter.

DEMAND RESPONSE TEST DAYS

DR testing was successfully conducted for the same business hours over three separate days in November of 2011: Wednesday November 2, Thursday November 3, and Tuesday November 8. The results of the representative test scenarios for the ALCS are shown below. During DR testing in the corridor and lab spaces, data were logged every minute. The DR levels were 10%, 15%, 20% 25%, and 30% below the commissioned level. Each setting lasted for one hour after which the lighting level returned to the baseline DR level of 0% before the next interval setting.

The test for the DR system was conducted on the three November days mentioned above plus one additional day where all the lights were on and the time schedule was abbreviated. Figure 6 illustrates power usage during a non-test day, which is representative of typical power use of the spaces without ALCS DR reductions. The electrical use data series illustrates the minute-to-minute electrical usage from all 19 lighting fixtures and from the controller. The shaded vertical portions of the graph show the periods where power would have been reduced if the tests had been implemented. The load fluctuations are from occupancy sensors turning lights on and off.

Figure 7 and Figure 8 illustrate two typical days of Demand Response testing. Note that when the demand is near 0.14 kW, it indicates that the teaching lab lights are turned on. The figures show drops in demand when power level settings were reduced as per the DR testing schedule. Evidence of power reductions with the level settings for each of the two days of testing is evident. Some anomalies are the results of occupancy controls turning the teaching lab lights off. A third day of the same testing is not presented because it did not represent typical operation.

A separate test was conducted on November 16 with all the lights turned on and is shown in Figure 9. The DR levels were implemented in the same order as the first two test days. Immediately following normal stepped testing the DR level was set to 0%, and only one group of lights were operated at a time. Starting at 3:50 p.m., and for each of the following 10-minute periods, the respective order of lights on was lab, curved corridor, lobby, straight hall, and all off. The all off mode measures the power of the controller.

DATA ANALYSIS

Average power was calculated from the recorded measurements to represent each DR level. The DR power reductions were determined by analyzing all representative available data for the testing periods over the two days. Averages include output from various fixtures based on local occupancy control during each of the DR levels.

Analysis was based on averaged power levels. A second analysis was based on reductions if no on/off control from occupancy sensors had occurred.

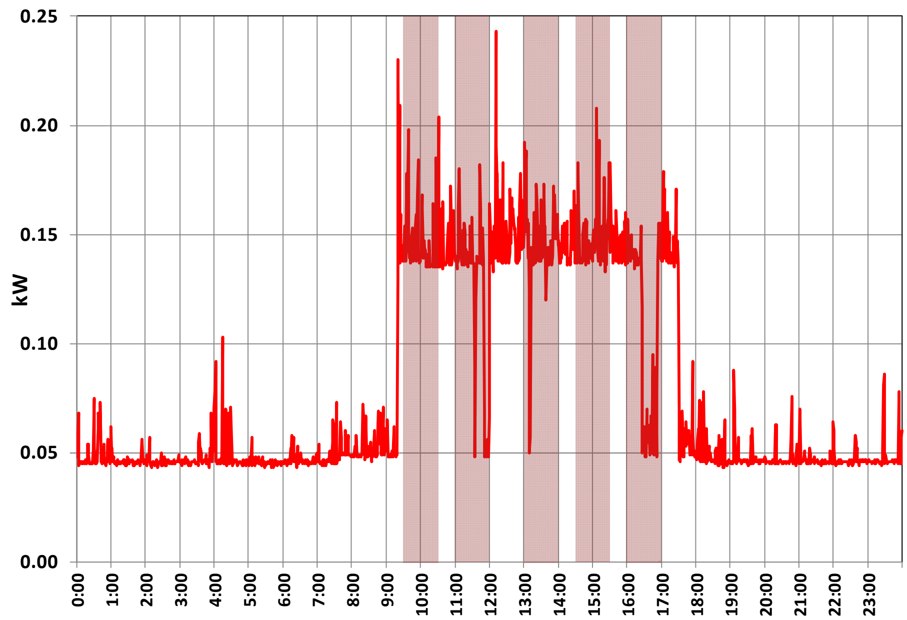

FIGURE 6. LIGHTING LOAD DURING A NON-TEST DAY TUESDAY NOVEMBER 1

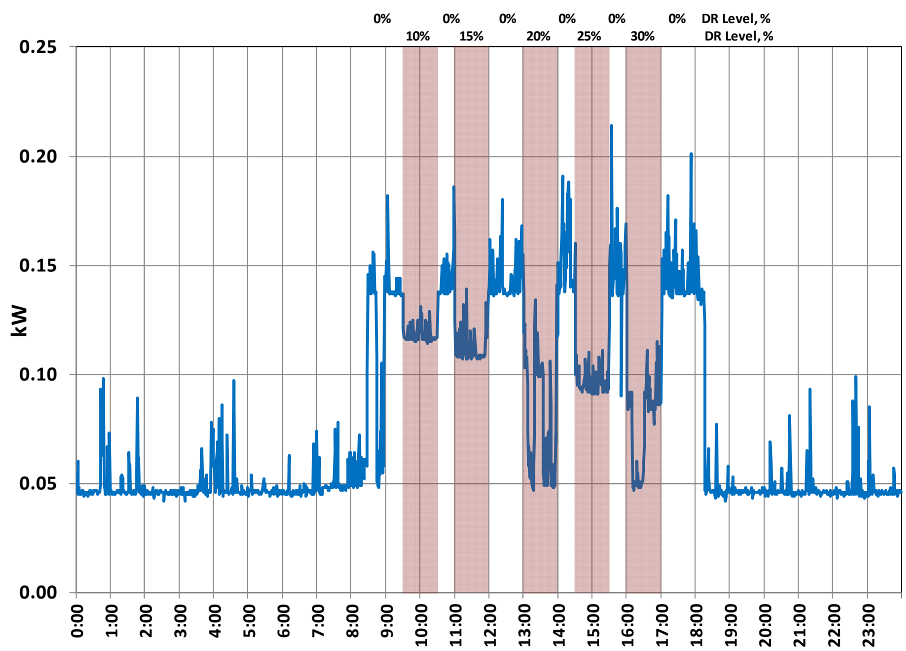

FIGURE 7. LIGHTING LOAD DURING DEMAND RESPONSE TESTING, WEDNESDAY NOVEMBER 2

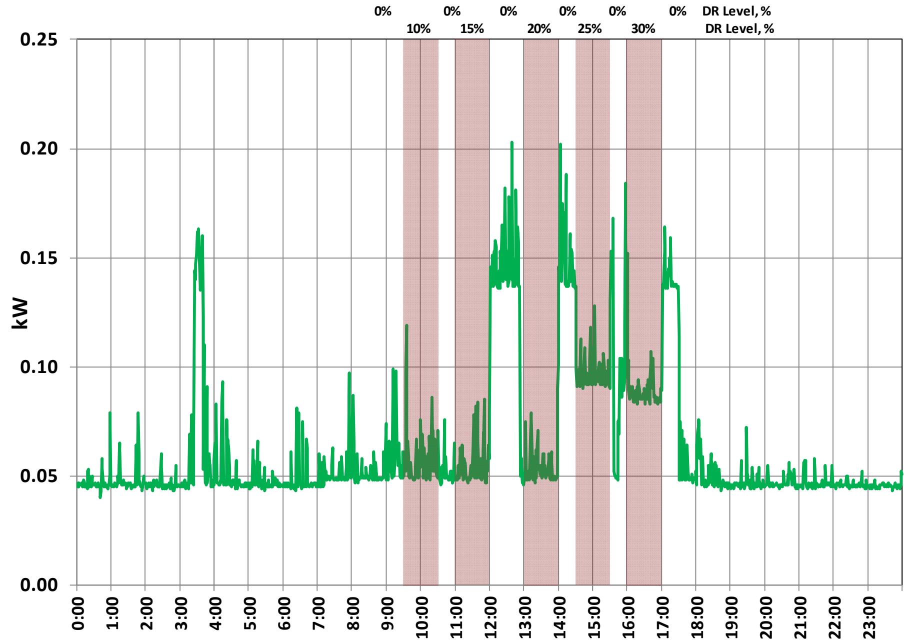

FIGURE 8. LIGHTING LOAD DURING DEMAND RESPONSE TESTING, THURSDAY NOVEMBER 3

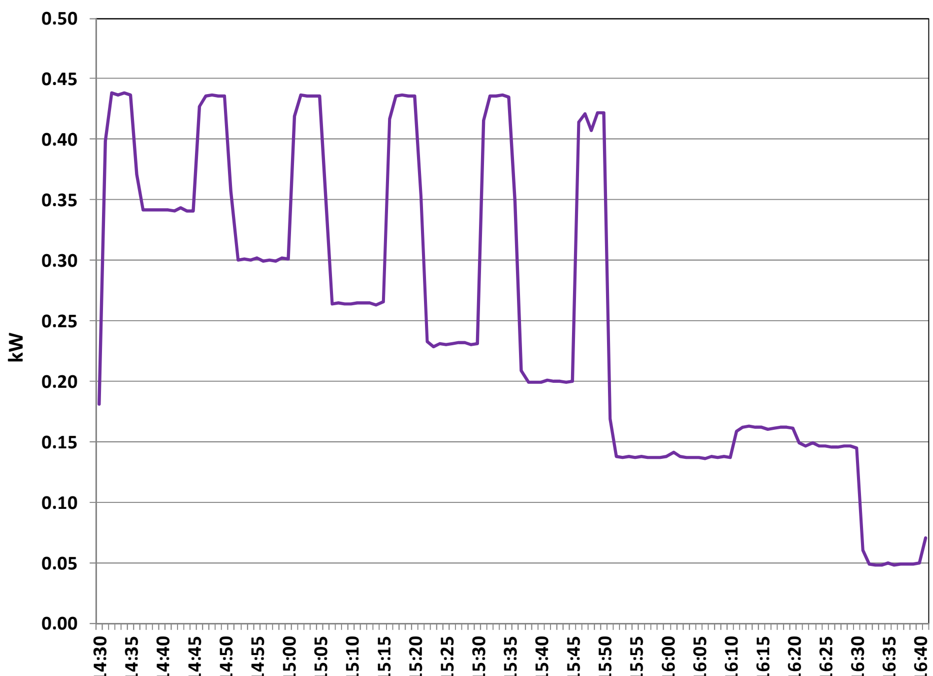

FIGURE 9. LIGHTING LOAD DURING DEMAND RESPONSE TESTING, WEDNESDAY NOVEMBER 16

DEMAND RESPONSE RESULTS

Table 5 shows the average demand reductions across all fixtures, as well as lighting power density demand reductions for each level setting derived from data shown in Figure 7 and Figure 8. Averages include output from various fixtures based on local occupancy control during each of the DR levels. The maximum DR reduction was 62W (0.031 W/sf) at the 30% DR level setting. This is approximately a 43% reduction of the average wattage based on the lights that were on at the time of the test.

TABLE 5. DEMAND REDUCTION LEVEL SETTING VERSUS MEASURED AVERAGE DEMAND REDUCTION

DR Level, %	Average Demand (W)	Average Demand Reduction (W)	Average Demand Reduction (W/sf)	Control System Timing
0%	144	0	0	9:00 a.m. – 9:30 a.m.
10%	121	23	0.011	9:30 a.m. – 10:30 a.m.
15%	114	30	0.015	11:00 a.m. - 12:00 p.m.
20%	108	36	0.018	1:00 p.m. - 2:00 p.m.
25%	89	55	0.028	2:30 p.m. - 3:30 p.m.
30%	82	62	0.031	4:00 p.m. - 5:00 p.m.

In an alternative analysis, the impact of turning off the lights from the occupancy sensors was ignored; the results from this analysis are shown in Table 6. The maximum DR reduction in this case was 236W per fixture (0.118 W/sf), or 54% of the commissioned wattage from the fixtures at the 30% DR level setting. The reduction is based on all 19 fixtures turned on.

TABLE 6. DEMAND REDUCTION LEVEL SETTING VERSUS MEASURED AVERAGE DEMAND REDUCTION WITH NO OCCUPANCY CONTROL

DR Level, %	Average Demand Reduction (W)	Average Demand Reduction (W/sf)
0%	0	0.000
10%	95	0.047
15%	136	0.068
20%	172	0.086
25%	205	0.103
30%	236	0.118

Figure 10 displays the relationship between control system level settings and DR demand reduction of the ALCS. The figure shows a general upward trend between DR level setting and average measured lighting demand reduction with the greatest savings being 0.031 W/sf at the 30% DR level. This is for the typical occupancy observed in the corridor area and the lab, occupied. A second dotted line represents the demand reduction that would be achievable if the system did not have occupancy sensor dimming.

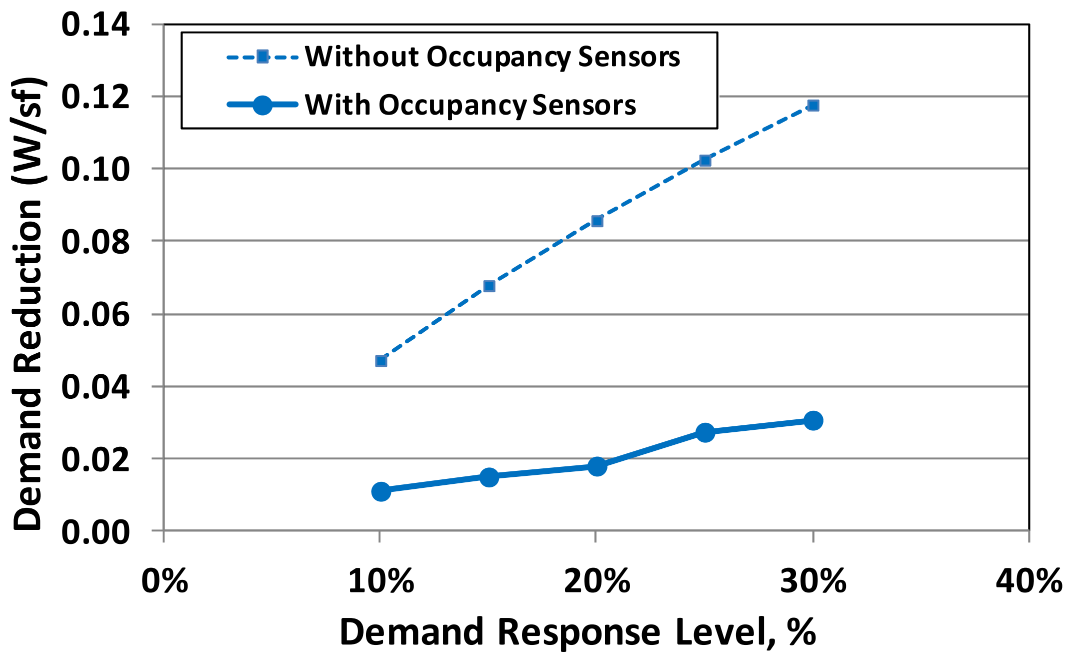

FIGURE 10. LIGHTING DEMAND REDUCTION PER SQUARE FEET AT VARIOUS DR LEVELS DURING TESTING

DISCUSSIONS

This project implemented new technology to provide demand reductions. Demand reduction is maximized when DR controls are the only method used to dim or turn off lighting. When control of operating mode is available through other controls such as occupancy sensors, the DR impact diminishes.

The occupancy sensor controls have a timeout of 6 seconds for individual corridor lights. The result is they are off most of the time, and no DR reduction is available if the lights are off. The teaching lab lights have a 10-minute timeout that controls all four of the fixtures in the lab. The majority of DR reduction is obtained from the lab lights rather than the corridor lights.

The Redwood Engine was configured for local programming. Remote control for DR events was not tested with the equipment installed for this test pilot.

Security lighting fixtures were distributed throughout the spaces and operate 24/7 at full brightness. There was no monitoring of the security lights, nor were they equated into test results because they remained on.

CONCLUSION

The main objectives of the project were to determine the following:

1. *Examine the ALCS that allows for reliable control of corridor lighting loads from business management as part of a DR Program:* DR testing for the ALCS confirmed that lighting loads can be reliably managed by business management as part of a DR Program, but requires local connection to the controller.
2. *Examine demand reductions that can be achieved with a well-designed, smart lighting control system:* There was a reduction in overhead lighting load demand after the installation of ALCS and new lighting fixtures. The DR reduction for lighting averaged 62W, or 0.031 W/sf at the 30% DR level. The percentage reduction is approximately 43%.

The project originally was intended for corridor lighting, but was expanded to include a teaching lab. Almost all of the DR reduction is attributable to the lights in the teaching lab because these lights are on for most of the day. The teaching lab uses approximately 88% of the energy use of the DR-controlled lights. The teaching lab lights use more energy because the occupancy timeout is 10 minutes in the lab verses six seconds in the corridors.

This was a case study monitoring the impacts of ALCS on DR.

This report can provide measured and technical data to the Smart Corridor concept process. The results of this study illustrate the power reductions associated with implementing ALCS.

RECOMMENDATIONS

The results of this pilot and other DR projects show evidence of demand reduction. The highly controlled lighting solutions demonstrated in this pilot could be incentivized. Moreover, the broader Smart Corridor concept that addresses demand feedback to occupants and overall building demand would experience further demand reduction under these methods.

The technical best practices and case studies resulting from this and other demonstration projects should also be clearly defined and promulgated for future purposes.

As new pilot programs are implemented, sites with the greatest potential for clear results and low measurement error should be chosen. As this site demonstrated, the savings is very dependent on space type.

Further study of highly controlled lighting solutions may further clarify the results, which include the following:

- Measurement of power usage throughout the course of the year to understand seasonal variations in various locations.
- Measurement of hourly profiles to study demand reduction impact potential for various time windows that are most likely to have a call for DR.

Additional recommended steps may support and expand upon the results of this pilot:

- This pilot only explored incremental DR settings up to 30%. Future studies that examine greater power reductions (for example, incremental DR settings up to 50%) could further the understanding of the power saving potential of this ALCS.
- Further study of the market impact of mass implementation of this ALCS would improve our understanding of factors related to easing the stress to the electric grid.

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APPENDIX A – DATA AND EQUIPMENT INFORMATION

Raw and processed data collected for the evaluation of this project can be found in the embedded Excel file. In addition, information on equipment calibration is provided in one of the worksheets in the same file.

UCI DR Data Appendix.xlsx