DEMAND RESPONSE TESTS AT A TYPICAL OFFICE SPACE IN A FEDERAL BUILDING

DR 09.09 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 DR 09.09. 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.

ABBREVIATIONS AND ACRONYMS

ALCS	Advanced Lighting Controls Systems
FBI	Federal Bureau of Investigation
fc	Footcandle
GSA	General Services Administration
kW	Kilowatt
LPD	Lighting Power Density
M&V	Measurement and Verification
OTF	Office of the Future
RCP	Reflected Ceiling Plan
SCE	Southern California Edison
sf	Square Feet
TI	Tenant Improvement
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 Federal Building in Los Angeles, CA. The DR study is managed by Southern California Edison's (SCE) Design and Engineering Group and is part of the Office of the Future (OTF) initiative. The OTF is a new energy efficiency approach supported by a consortium of some of the nation's largest and most progressive energy utilities.
The primary goals of this project are the following:

1. Determine whether the advanced lighting controls system allows for reliable control of facility lighting loads from SCE, or business management as part of a Demand Response Program,
2. Examine demand reductions that are achievable with a well-designed lighting system, and
3. Provide measured and technical data in support of the OTF initiative.

The project site consists of one-half of the 12th floor of the Los Angeles Federal Building. The site has 8,000 square feet (sf) in area space occupied by a division of the Federal Bureau of Investigation (FBI). This building was previously delamped and retrofitted with T8 lamps and electronic ballasts, and fitted with a relay-based lighting control system. The east half of the floor was relighted using state-of-the-art technology, while the west half was left in its original condition. The new lighting is capable of demand reduction, tuning, and other energy-savings strategies.

The project was highly representative of the challenges and complications facing retrofit projects in everyday office buildings. In this case, the design was limited by two characteristics common to older office buildings: encapsulated asbestos fireproofing, and lack of seismic upgrading. To resolve these issues, the general lighting system was attached to the furniture, and over 12,000 pounds (lbs) of old light fixtures were removed from the ceiling to lessen seismic loads. A new ceiling using 90% reflective ceiling tiles was installed to increase lighting system efficiency. Finally, the connection to the emergency lighting system was simplified and improved.

Lighting circuits in the building were monitored to document the demand reduction of the new lighting and control systems. Power meter recorders were installed next to the lighting panels beginning in 2009, and modified to provide enhanced data in one-minute intervals in July 2011.

Installation of the lighting system and control hardware was completed in June 2011. The testing of the Advanced Lighting Control System's (ALCS) ability to respond to a remotely generated demand response command was completed in July 2011. Commissioning reduced the ballast dimming settings to 80% of the lighting's rated electrical input. This new commissioned level is also designated as the baseline for the DR testing performed at the Federal Building.

Successful testing occurred during the same business hours over three separate days in July of 2011: Tuesday, July 12; Thursday, July 14; and Monday, July 18. Part of the testing involved changing the DR level to five different settings; 10%, 15%, 20%, 25%, and 30% reductions with respect to the commissioned level. Each setting lasted for one hour after which it returned to the baseline DR level of 0%. ES-Table 1 shows the planned schedule of the DR lighting tests.

ES-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.

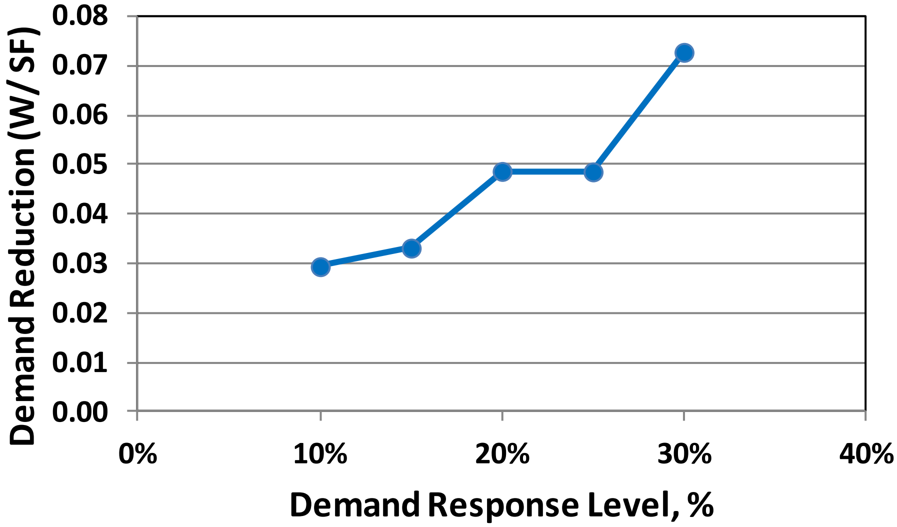
ES-Table 2 presents DR lighting demand reduction in kilowatt (kW) and Watts per square foot (W/sf). The measured lighting density during the baseline period was (0.43 W/sf), and lighting density during the DR testing at the 30% level was (0.36 W/sf). The total demand response savings across the new commissioned ALCS is 0.58 kW at the 30% DR level.

ES-TABLE 2. LIGHTING DEMAND REDUCTIONS

MEASUREMENT DESCRIPTION	DR LIGHTING VALUE	UNITS
Office Area	8,000	sf
Demand Response Savings at 30% DR	0.58	kW
Baseline Lighting Power Density (0% DR Level)	0.43	W/sf
Lighting Power Density at 30% DR Level	0.36	W/sf
Demand Reduction at 30% DR	0.07	W/sf

The demand reduction at DR level 30% is .073 W/sf. An average power savings of 17% was achieved for the lighting systems being controlled during the DR test with control level at 30%.

ES-Figure 1 shows 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 0.07 W/sf at the 30% DR level. A smooth transition between all tested settings was not observed. This is evident as the 20% and 25% level settings indicate no savings increase between those levels.



ES-FIGURE 1. LIGHTING DEMAND REDUCTION PER SQUARE FEET AT VARIOUS LEVEL SETTINGS DURING DEMAND RESPONSE TESTING

The DR strategies tested in this study showed significant demand reduction with ALCS, and it is recommended that there are future studies to address:

- Evaluation of DR strategies and their interaction with other controls such as occupancy sensors and real time dimming.
- Evaluation of DR reductions from plug loads.
- Investigation into the role of office occupant behavior changes with feedback from actual energy usage.

INTRODUCTION

This study evaluates the Demand Response (DR) capability of Advanced Lighting Control Systems (ALCS) developed by Encellium Systems. This ALCS was installed on half of the 12th floor of the Los Angeles Federal Building. 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 is part of the Office of the Future (OTF) consortium, which is a group of utilities in cooperation to increase efficiency in leased office buildings. Southern California Edison (SCE) is working with the Office of the Future (OTF) Consortium to assemble technical renovation guidelines that specify performance requirements for various tenant improvements (TI).

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.

Peak electricity load has been controlled by various programs types, including very large customer participation in:

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

Peak demand has also been controlled by residential customers participating in air conditioning cycling programs.

SCE is investigating the potential for DR technologies 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 demand reduction systems. The larger the load that can be controlled, the more useful it will be. 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 PROJECTS

SCE is testing the implementation of ALCS on half of the 12th floor of the Los Angeles Federal Building, representing 8,000 square feet. The ALCS controls the level of dimming via dimmable ballasts installed as part of this project.

The primary goals of this project are the following:

1) Determine whether the advanced lighting controls system allows for reliable remote control of facility lighting 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 OTF initiative.

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 in 100 MW that could be shed.

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 FEDERAL BUILDING DEMONSTRATION PROJECT DESCRIPTION

The ALCS was installed on half of the 12th floor of the Federal Building in addition to the lighting packages developed for the 25% energy efficiency solution. The light fixtures have the capability to interface with an ALCS and dim the lights resulting in demand reduction. Lighting demand use was monitored to quantify the demand reductions. We conducted a series of tests on the system to show the feasibility of this type of installed DR system.

SITE DESCRIPTION

The Federal Building was previously delamped and retrofitted with T8 lamps and electronic ballasts, and fitted with a relay-based lighting control system. For this project, the east half of the floor was relighted using state-of-the-art-technology, while the west half was left in its original condition. The new lighting system is capable of demand reduction, tuning, and other energy savings strategies.

The project was highly representative of the challenges and complications facing retrofit projects in everyday office buildings. In this case, the design was limited by two characteristics common to older office buildings: encapsulated asbestos fireproofing and lack of seismic upgrading. To resolve these issues, the general lighting system was attached to the furniture, and over 12,000 pounds (lbs) of old light fixtures were removed from the ceiling to lessen seismic loads. A new ceiling using 90% reflective ceiling tiles was installed to increase lighting system efficiency. Finally, the connection to the emergency lighting system was simplified and improved.

Data loggers were installed in the electric meter room to collect detailed baseline electric load profile data. Loggers also measured demand reductions attributable to the ALCS.

TECHNICAL REQUIREMENTS

LIGHTING AND LIGHTING CONTROLS

Reduction of demand through a combination of lighting technologies, lighting layout, and controls is possible. The lighting packages developed for the 25% solution feature energy efficiency and offer advanced control features to adjust to personal preferences, daylight availability, workspace vacancy, and DR needs.

PILOT EXISTING CONDITIONS

LIGHTING

The existing lighting systems consisted of 1x4 fluorescent troffers overhead. The 1x4 luminaires were original 1970-era troffers, retrofitted with T8 lamps and specular reflectors.

Sample light level measurements were taken at workers' desks. The result was a range of values with light levels of 30-60 footcandles (fc). Moreover, average light-level representations were determined to be inaccurate due to lighting obstructions from overhead file cabinets at each desk, and large piles of paperwork throughout the office. When asked, employees indicated that lighting was generally acceptable or too intense. The existing conditions are summarized:

- Employees indicated a balance between paperwork and computer work, with paperwork research requiring large volumes of materials. Employees range in age from 20-60 years, with the majority being 35-50 years of age.
- Employees were asked about specific lighting locations. From their responses, light levels of 30-40 fc were generally considered appropriate for paperwork.
- General light level throughout the open office area was overall slightly more than necessary, with typical levels in the middle of the room (open floor) being 50-60 fc.
- Employee fieldwork resulted in the lighting of a large number of unoccupied desks and in the storage area.

Controls were centralized to a single on/off switch serving as the master for all overhead lighting. The system was programmed for operation between 5:30AM and 6:00PM daily, and could be manually overridden in 2-hour periods. Controls for the private offices were wall box motion sensor switches.

EVALUATION OF EXISTING LIGHTING CONDITIONS

The overhead lighting system is arranged in an unusual 2′ x 5′ main-grid ceiling. Relatively standard 1′ x 4′ lights are located in 1′ bands (similar to today's "tech-zone" ceilings) on 5′ centers, separated by nonstandard 60″ x 24″ tiles. Nominal 12″ x 12″ openings between fixture ends have either small tiles or HVAC grill openings. Some time ago the original 1x4 lens fixtures were delamped to a single F32T8 lamp and retrofitted with a specular reflector and electronic ballast. The result is a general lighting system generating over 60 fc (empty room) at 1.2 W/sf. There was no zone switching, although quite a few lights were on emergency or night light systems.

LIGHTING SOLUTION

OVERARCHING CONSIDERATIONS

The primary consideration is that this project provides an excellent opportunity to demonstrate state-of-the-art DR practices in a normal, functional, everyday open office space equipped with older furniture, ceilings and partitioned offices. In many ways, this space is representative of large office buildings that are typically used by government agencies and private businesses.

The second consideration is that the project demonstrates the need for careful and creative solutions to the challenges and limitations presented by older buildings. The Federal Building was once state-of-the-art, with high light levels, an aesthetically appealing custom ceiling, and sprayed-on asbestos fireproofing. Almost 50 years later, new standards have caused many of these features to be seen as liabilities. In this case, working around the three principal issues of asbestos, seismic concerns, and nonstandard building systems made the project particularly challenging and severely constrained the project design options.

The third consideration is that the lighting could be used to help renew the appearance of the office space. Conventional lensed lighting systems typically have a subtle negative connotation. However, this project was seen as an opportunity to introduce an aesthetic solution while preserving cost effectiveness, demand response, and functionality.

LIMITATIONS

Four conditions were seen as limitations to the lighting design:

a) The original building design had sprayed-on asbestos fireproofing. In buildings with plenum return HVAC systems; this fireproofing does not meet current standards. Thus, the building must be modified by either changing the HVAC to ducted return, or by totally removing the asbestos (abatement). In the former case, the ongoing presence of asbestos requires encapsulation; otherwise, each tile removed for building maintenance would require spot abatement and asbestos cleanup. This building has encapsulation that allows ceiling access; however, contact with the structure is to be avoided.

b) The original structure was built before modern seismic codes. A seismic upgrade is expensive and interrupts building use for months, or years. This building has not yet been upgraded, which would make it challenging to carry out seismic improvements without requiring other extensive building improvements.

c) The original building's ceiling grid is not standard – the building tile is 5′ x 2′, whereas the standard grid is 4′ x 2′. In addition to the impact to lighting systems, the nonstandard tile limited options for manufacturers and purchasing, especially with respect to the high performance ceiling needed for more efficient interior spaces.

d) The interior office partitions and workstations are older, discontinued products from an outdated federal specification. Lack of furniture standardization made attachments more complicated.

A further project challenge related to a worldwide electronics parts shortage that made dimmable electronic ballast temporarily difficult to obtain. Aided by the lighting consultant and SCE, fixture manufacturers were able to obtain enough ballast for the project.

DESIGN PROCESS AND DECISIONS

The project focused on two separate solutions:

- A new lighting system for the open office area
- A new lighting system for the partitioned private offices and conference rooms

In the open office area, ceiling height and orderly furniture arrangements pointed to a number of task and ambient lighting system approaches. In the enclosed spaces, furniture and wall uses suggested the installation of recessed lighting systems.

OPEN OFFICE AREA

GENERAL LIGHTING REPLACEMENT SCHEME

Although the existing lighting system was found to be well beyond its useful life, the project design decision was primarily driven by seismic considerations. The original troffer lighting system employed 1960's era heavy-gauge housings; their removal would reduce ceiling load by about 1.5 to 2 lbs/sf. Even if a few luminaires remained, the result would be a much safer ceiling system. Replacement of mineral tile (1 lb/sf) with fiberglass tile (1/2 lb/ sf) was also investigated, but cost and availability of 60" x 24" tiles resulted in the use of mineral tiles.

For office areas with adequately high ceilings, at least 9', the typical choice for general lighting is a generic indirect system. However, this system would require structural attachment to be safe, and it was not chosen due to the spot asbestos abatement required by a significant number of structural attachments. Instead, a similar system was chosen that would be attached to the furniture. This system allows for a matching wall uplight addressing perimeter locations.

The resulting general indirect lighting system is further augmented by 33 new recessed luminaires that specifically illuminate only the normal path of egress. This permits both a clear definition of the egress path (emergency powered luminaires) and prevents the general lighting system from being activated unless someone is working in the area.

The connected lighting power of these systems in the open office area is about 0.51 W/sf. This is slightly below average but within the typical range for lighting systems now being promoted for general office lighting. Because view windows are available on both the north and south sides, the space is well lit during the day even when lights are dimmed for reasons of available daylight or low percentage of occupancy.

A total of nine art accent lights ("monopoints") were added to the space. These are 20W ceramic metal halide (CMH) luminaires designed for aesthetic purposes, intended to enliven the space by lighting art or accents. Their power density is only about 0.03 W/sf, but they are strategically located for maximum effectiveness.

ENCLOSED SPACES

Lighting for the enclosed spaces was chosen to replace the existing 1x4 lens fixture with a state-of-the-art, energy efficient T5 rounded lens fixture and dimming ballast. Task lights were retrofitted with new lamps and electronic ballasts, and connected to a motion sensor switch as with open office task lights. In these spaces, the typical connected load density is about 0.8 W/sf. Private offices also have daylighting and vacancy sensor controls. Occupants also have the ability to adjust the lighting levels according to their preferences.

Table 3 summarizes the lighting fixtures used in the relighting project that have DR capability along with the total installed Watts from each fixture type.

TABLE 3. LIGHTING FIXTURE SCHEDULE AND INSTALLED WATTS

TAG	LUMINAIRE DESCRIPTION	WATTS	NUMBER	FIXTURE WATTAGE
F1	Panel-Mounted Uplight	31	41	1,271
F2	Wall-Mounted Uplight	31	34	1,054
F3.1	Task Light	31	20	620
L1	Task Light	16	106	1,696
F4	Recessed Troffer	31	33	1,023
F5	1x4 Troffer	31	22	682
H1	Accent Light	22	9	198
	Total of Installation		265	6,544

Figure 2 shows the reflective ceiling plan.

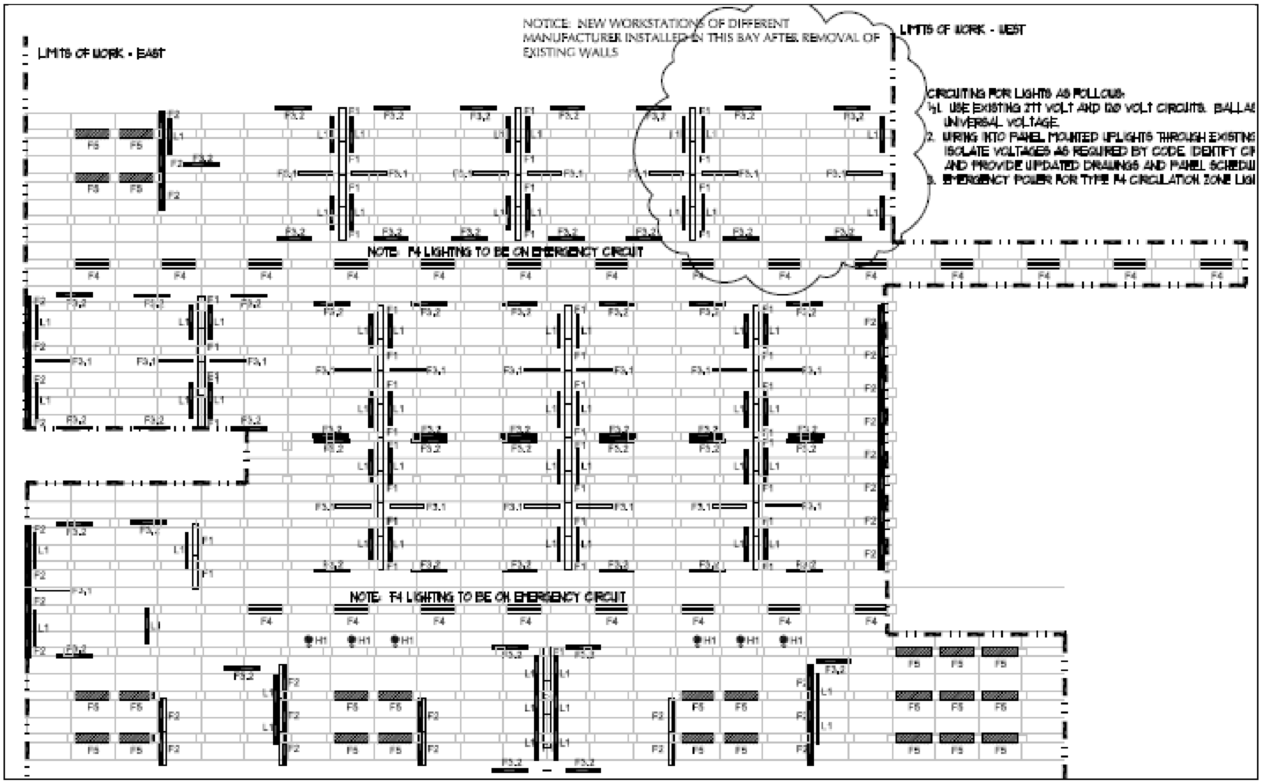


FIGURE 2. REFLECTIVE CEILING PLAN OF THE FBI OFFICE RELIGHTING PROJECT

LIGHTING CONTROLS

A new lighting control system was installed. It is comprised of a central programming and processing server and a number of distributed control modules throughout the space, and is able to control on/off settings and dimming functions of lights. The system used for this project is based on generic 0-10 volt (V) dimming ballasts and is wired using conventional Ethernet cables (although it is not connected to the data system).

The system provides the following functions and strategies:

- Tuning to reduce overall lighting use by 20%. Commissioning reduced the ballast dimming settings to 80% of the lighting's rated electrical input. This new commissioned level is also designated as the baseline for the DR testing performed at the Federal Building. 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 majority of the installed lighting is capable of DR and can respond to a DR or real-time pricing signal. The lighting that is capable of DR can be dimmed to any level that is agreed upon by the owner and SCE. However, note that as

the lighting is already dimmed down 20%, this becomes the new 100% baseline level for all succeeding DR events.

- DR was measured for 265 lighting fixtures. A signal from SCE, or building management, can reduce the power setting of the fixtures by 10% or more.
- Large Zone non-predictable scheduling. Circulation and general workstation ambient lighting are activated by any motion in the space, but the indirect ambient lighting activates at a low ambient setting (about 33% of normal).
- Small Zone non-predictable scheduling. Dual-technology ceiling motion sensors are used to activate lights in small zones and groups. The overhead ambient lighting increases to 100% and common task lights turn on when a worker is present at any of the four workstation desks in each "pod".
- Daylighting with separate north and south zones of general lighting.

The control system used for this project was selected for its exceptional interface. The building owner/operator can easily program control features and receive useful system data such as operating time and actual power set levels.

LIGHTING PRODUCTS

The lighting products used in the Federal Building installation are summarized in Table 4.

TABLE 4. LIGHTING EQUIPMENT AND MANUFACTURER

EQUIPMENT	MANUFACTURER	MANUFACTURER LOCATION
Wall uplights	Orgatech	California
Accent lights	Erco Lighting	New Jersey
1x4 troffers	Cooper Lighting	Georgia
6" x 4' circulation lights	Prudential Lighting	California
Lighting controls	Encellium Systems	Pennsylvania

TECHNICAL APPROACH/TEST METHODOLOGY

In order to characterize the demand reductions resulting from OTF pilot projects, New Buildings Institute (NBI) devised a Measurement and Verification (M&V) protocol that evaluates savings. The protocol was augmented by additional measurements provided by ADM Associates.

Initially, lighting and controls are installed in the office space, including a 100-hour 'burn-in' period for the lighting. This period allows new lamps to stabilize (mercury distribution, settling of phosphor/impurities, etc.) and begin operating at optimal levels. This is especially important when using dimming. The burn-in period also allows monitoring of the total connected load of the newly installed lighting.

Metering installed at the whole-building and office-space levels is used to establish the 'As-Is' baseline, representing existing demand prior to any DR testing. The duration of each baseline is based on the lighting DR test schedule in ES-Table 1 found in the Executive Summary.

METERING EQUIPMENT AND DATA ACQUISITION

The east side of the office is served by a separate electrical service, with a single 277/480 lighting panel. The meter was connected to the data acquisition system (DAS) located on the west side using wireless communications. All metered data were uploaded via a GSM cellular connection to a remote database for analysis by NBI personnel. The data was redundantly sent to an energy dashboard provided by a third-party vendor.

Data were gathered at 15-minute intervals except during DR testing when data were gathered at 1-minute intervals.

Table 5. summarizes the metering equipment.

TABLE 5. SUMMARY TABLE OF METERING EQUIPMENT

Meter #	Load	Panel	Location	CT Size	Meter
NBI 1	Lighting	L12C	12th Floor East side	100 Amps	WattNode WNB-3Y-480-P TrueRMS
ADM 10386	Lighting	L12C	12th Floor East side	20 Amps	Enernet K-20 True rms Meter Recorder

Power measurements were average true power during the interval (kW).

DATA ACQUISITION

NBI data were brought to a central unit via Obvius ModHopper Wireless-Mesh Data communication units. The central data acquisition system was an Obvius AcquiSuite Server A8812-GSM with GSM cellular internet modem. ADM's monitoring equipment was installed only a short period and manually downloaded data to a laptop at the end of the testing period. The power data from the K-20 were used to provide enhanced resolution to the data collected from the WattNodes.

MEASUREMENT AND VERIFICATION SUMMARY

M&V meter readings were verified with handheld instruments to ensure accurate current readings.

TEST PROCEDURES

During DR testing, personnel from SCE initiated the test commands from an offsite office. All computers, equipment and loggers were synchronized to NIST clocks on Pacific Time. The clocks were synchronized using the following web link: http://nist.time.gov/timezone.cgi?Pacific/d/-8/java.

DR testing was successfully conducted on the same business hours over three separate days in July of 2011: Tuesday, July 12; Thursday, July 14; and Monday, July 18. During the test periods recording intervals were reduced to 1-minute intervals. 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 6 shows the planned schedule of the lighting tests.

TABLE 6. 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, July 13 was also recorded by the data loggers as a comparison to demand during the three 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.

DR TEST DAYS

DR testing was successfully conducted on the same business hours over three separate days in July of 2011. The results of the representative test scenarios for the ALCS are shown below. Two types of meters were used to collect data: the original monitoring devices and the enhanced resolution devices. During DR testing in each building area, data were logged every 1 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 July days mentioned above. Figure 3 illustrates power usage during a non-test day, which is representative of typical power use of the office space without ALCS power level reductions. The electrical use data series illustrates the minute-to-minute electrical usage from electrical breaker Panel L12C. The shaded vertical portions of the graph show the periods where power would have been reduced if the tests were implemented. The load fluctuations during the day are from occupancy sensors, daylight dimming, and dimming controls used by occupants.

Figure 4 through Figure 6 illustrate the three days of DR testing. The figures show drops in demand when power level settings were reduced as per the DR testing schedule. However, the consistency of power reductions with the level settings for each of the three days of testing is not as evident in this case, due to power fluctuations.

DATA ANALYSIS

The DR power reductions were determined by using all available data for the testing periods over the three days. Therefore, each power level setting was activated three times and for each activation, there was a similar deactivation back to the baseline DR level of 0%. This provided six load transition points to include in the analysis of each level setting. Several 1-minute power measurement intervals on either side of the event time were averaged and the difference before and after the event time was used to calculate the event load change.

Analysis was based on the six averaged power differences and outliers were removed. Outliers were most likely caused by coincidence of load changes from other controls, producing an interactive effect.

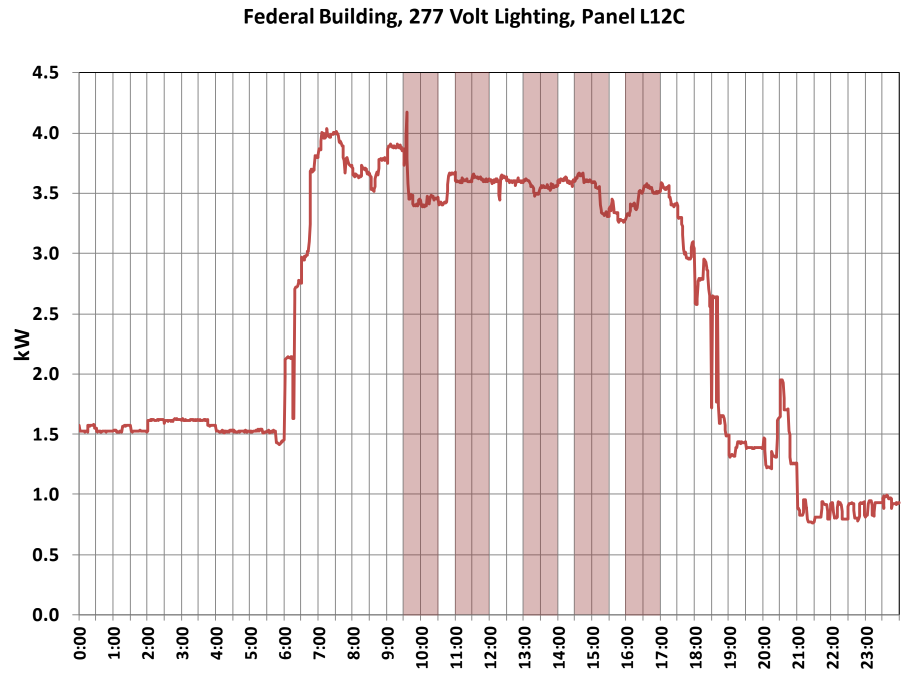


FIGURE 3. LIGHTING LOAD DURING A NON-TEST DAY WEDNESDAY JULY 13

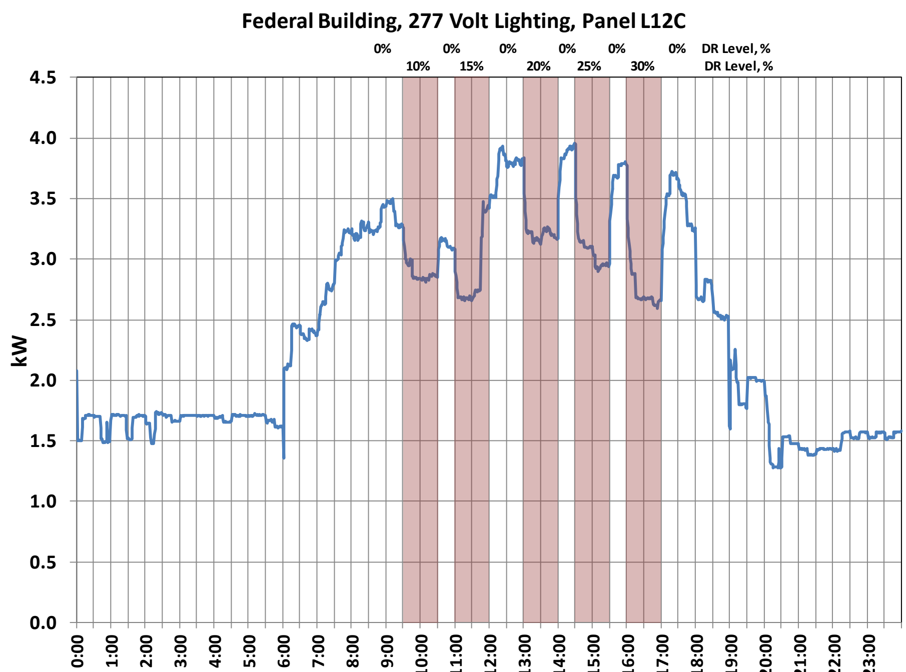


FIGURE 4. LIGHTING LOAD DURING DEMAND RESPONSE TESTING, TUESDAY JULY 12

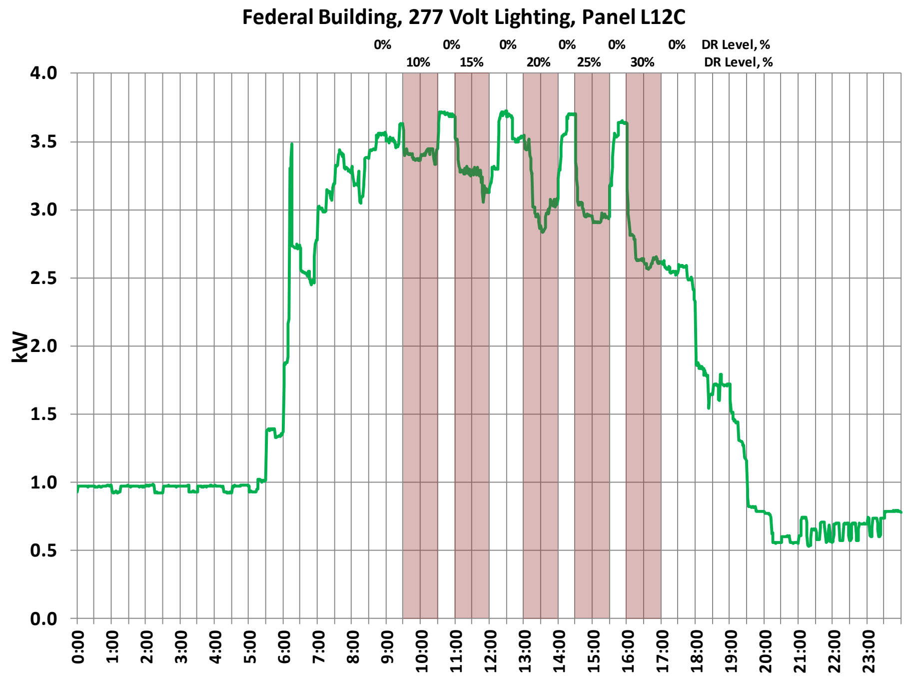


FIGURE 5. LIGHTING LOAD DURING DEMAND RESPONSE TESTING, THURSDAY JULY 14

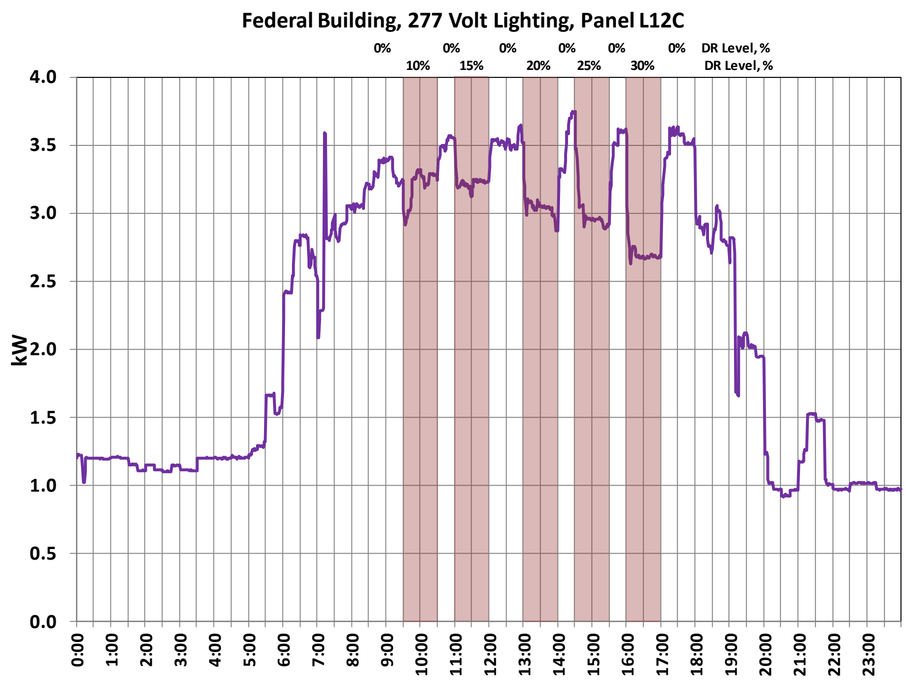


FIGURE 6. LIGHTING LOAD DURING DEMAND RESPONSE TESTING, MONDAY JULY 18

DEMAND RESPONSE RESULTS

Table 7 shows the average reduction (excluding outlier values) in total demand reductions and lighting power density demand reductions for each level setting derived from data shown in Figure 4 through Figure 6. The maximum DR reduction was 0.58 kW, or approximately 11.2% of the commissioned wattage from the fixtures at the 30% DR level setting. The percentage reductions assumes an electrical baseline of 5.2 kW of lighting, 80% commissioned setting of the 6.5 kW available from fixtures presented in Table 3. However, the reduction percentage presented is conservative as it is not typical for all of the lights to be on and available during the entire DR test.

In an alternative approach, the baseline was derived from an average (excluding outliers) of all measured loads observed in the 277V panel minutes before the DR tests. This resulted in a baseline of 3.4 kW (instead of 5.2 kW), indicating a 17% demand reduction at the 30% DR level setting. This perspective in percentage savings is also conservative as any non-DR loads would result in a lower baseline measure, leading to higher percentage savings.

A third approach is to present the reductions in terms of lighting density. The reduction is 0.073 W/sf at the 30% DR level setting for the 8,000 square feet of office involved with the DR testing. The reduction is distributed over the 265 fixtures with DR capability. As the wattage rating of fixtures varies, an average Watt per fixture cannot be accurately calculated.

TABLE 7. DEMAND REDUCTION LEVEL SETTING VERSUS MEASURED AVERAGE DEMAND REDUCTION

DR LEVEL, %	AVERAGE DEMAND REDUCTION (W)	AVERAGE DEMAND REDUCTION (W/SF)	CONTROL SYSTEM TIMING
10%	236	.029	9:30 a.m. – 10:30 a.m.
0%	0.0	0.0	10:30 a.m. – 11:00 a.m.
15%	266	.033	11:00 a.m. - 12:00 p.m.
0%	0.0	0.0	12:00 p.m. - 1:00 p.m.
20%	390	.049	1:00 p.m. - 2:00 p.m.
0%	0.0	0.0	2:00 p.m. – 2:30 p.m.
25%	390	.049	2:30 p.m. - 3:30 p.m.
0%	0.0	0.0	3:30 p.m. - 4:00 p.m.
30%	584	.073	4:00 p.m. - 5:00 p.m.

Figure 7 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 measured lighting power saving. A smooth transition between all tested settings was not observed. This is evident as the 20% and 25% DR level settings indicated no increase in demand reduction. This occurrence suggests that the system may be operating under step controls where a relatively small change in the power setting (5% change from 20% to 25% DR level setting) is not reflected in the actual ALCS operation. This instance may also be due to an uncertainty in the data introduced by load fluctuations.

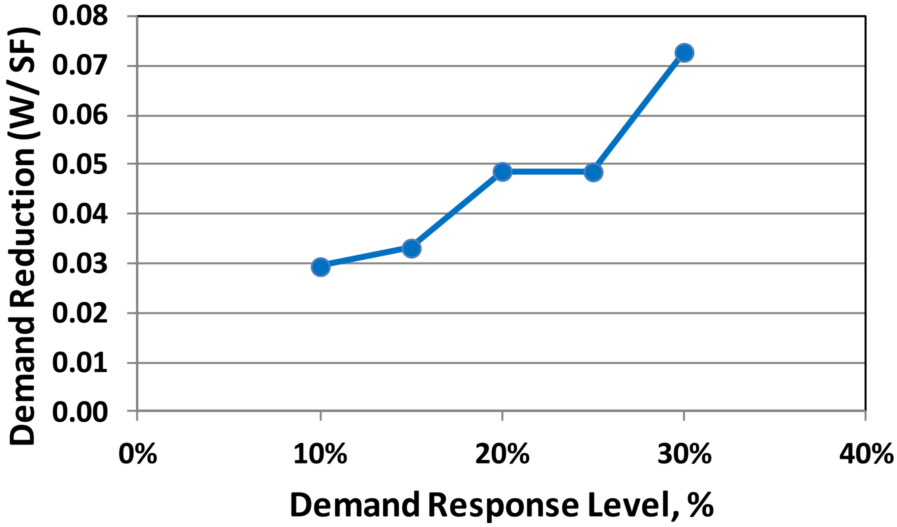


FIGURE 7. LIGHTING DEMAND REDUCTION PER SQUARE FEET AT VARIOUS LEVEL SETTINGS DURING DEMAND RESPONSE TESTING

DISCUSSIONS

This project implemented new technology to provide demand reductions. Evaluation of the lighting system should be designed to be cost effective and provide accurate results. Two types of measures were used to collect data; the original monitors as well as the enhanced resolution devices. In order to facilitate monitoring and analysis of demand, it may be useful to select candidate sites that have well-defined spaces where it is possible to isolate the end use that is being evaluated. The results from monitoring such spaces will be more effectively analyzed and presented.

CONCLUSION

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

1. Examine the advanced lighting controls system that allows for reliable control of the facilities lighting loads from business management as part of a Demand Response Program: DR testing for the ALCS confirmed that lighting loads may be reliably managed by business management as part of a DR Program. The demand reduction was not proportionate to the reduction in all setting levels. If a desired reduction is needed, it should be tested to determine actual DR reduction rather than relying on the system setting.
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 was 0.58 kW, or 0.073 W/sf at the 30% DR level. The percentage reduction is approximately 17% assuming a baseline of 3.4 kW.

This was a case study of the impacts ALCS can have on DR. The results provided may not be effectively extrapolated to other sites or the general population.

Power readings measured throughout the DR test illustrated unstable lighting loads. To remedy this problem, sites with stable base lighting loads should be chosen to establish a more definitive set of readings and results.

This report can provide measured and technical data back to the OTF Consortium to inform the process. The results of this study illustrate the power reductions under this ALCS.

RECOMMENDATIONS

The results of this pilot and other OTF projects show evidence of demand reduction. The highly controlled lighting solutions demonstrated in the pilot could be incentivized, and the broader OTF TI-directed initiative 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.

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 better understand seasonal variations in various locations.
- Comparisons of existing space lighting quality to advanced lighting design with controls.

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.
- The site may be representative of older office buildings with asbestos requiring expensive hazardous waste removal for conventional recessed lighting fixture replacement. It is suggested that investigation of surface mounted lighting fixtures that could be installed without disturbing the asbestos may alleviate upgrade implementation obstacles.
- 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

Raw and processed data collected for the evaluation of this project are located in the embedded Excel file. Additionally, information on equipment calibration is also provided in one of the worksheets in the same file.

Fed Bldg DR Test
Data July 2011 Apper