Office of the Future Federal Building Demonstration

ET09SCE1210 Report

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Disclaimer

ABBREVIATIONS AND ACRONYMS

DEER	Database for Energy Efficient Resources
DOE	Department of Energy
FBI	Federal Bureau of Investigation
FC	Footcandle
GSA	General Services Administration
GWH	Gigawatt Hour
K	Kelvin
kw	Kilowatt
kWh	Kilowatt Hour
LED	Light-Emitting Diode
LPD	Lighting Power Density
M&V	Measurement and Verification
NBI	New Buildings Institute
OTF	Office of the Future
PAF	Power Adjustment Factor
PNNL	Pacific Northwest National Laboratory
RCP	Reflected Ceiling Plan
RFP	Reflected Floor Plan
SCE	Southern California Edison
SF	Square Feet
TI	Tenant Improvement
VTC	Video Tele-Conference
w	Watts
w/sf	Watts per Square Foot

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EXECUTIVE SUMMARY

The Office of the Future (OTF) program is a new energy efficiency approach supported by a consortium of some of the nation's largest and most progressive energy utilities. OTF targets existing multi-tenant commercial office buildings with packages of advanced energy efficiency and demand response strategies. These strategies can be applied at the tenant level for building owners. This sector has been problematic for utility incentive programs to capture.

This pilot project has three primary goals:

1) Examine the performance characteristics of highly controlled lighting systems in a real-office environment compared to existing lighting and applicable codes,

2) Monitor plug-load energy use, and

3) Provide measured and technical data back to the OTF consortium to inform them of the process.

This project consists of one half of the 12th floor of the Los Angeles Federal Building (8,024 square feet (ft^2)d) occupied by a division of the Federal Bureau of Investigation (FBI). This building was previously delamped, 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. Energy use metering before and after the relighting project allows for direct comparison of potential savings in a real workspace. Additionally, 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 faced in retrofit projects in everyday office buildings. In this case, the design was limited by two problems 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.

The measured results of this project reveal that a high-performance lighting design with controls delivers savings considerably beyond

code-calculated estimates. Results further show that during daytime occupied hours the site uses, on average, 47% less power than code calculations. The new system reduced the connected load by 56%.

In addition, the results reveal the complexity of isolating and measuring loads. The lighting circuit was monitored separately from the plug-load circuit, but workstation task lights were included in the plug circuit measurements.

The research also contributed to OTF program objectives and will serve as a reference for Southern California Edison (SCE) and other Consortium members. The technical findings are grouped into three areas: lighting, metering, and plug loads.

Overall recommendations include a more detailed review of the test results, as follows:

- Provide metering-based feedback to designers, contractors, and building operators
- Give greater attention to plug-load power density to include research into the EE of the equipment
- Study the highly controlled lighting solutions and plug loads to include:
    - Measure power and energy performance throughout the year to understand seasonal variations in various locations.
    - More detailed measurement of plug-load use and savings from plug-load control measures in office spaces.
    - Investigation into the role of office occupant behavior changes possible with feedback from measured results.

Comparison to Existing		Existing, or Baseline	Federal Building – 12th –East	Savings over Existing	Percent
Lights					
Annualized Energy	kWh/Yr	42,435	18,681	23,755	56%
Annualized Energy per SF	kWh/SF/Yr	5.29	2.33	3	56%

INTRODUCTION

The Office of the Future (OTF) Consortium is a group of utilities working together to make a greater efficiency impact in leased office buildings. Southern California Edison (SCE) is working with the OTF Consortium to assemble technical renovation guidelines. These guidelines specify performance requirements for different attributes of tenant improvement (i.e., lighting, plug loads, etc.), and whole building that result in at least a 25% savings over the Title 24 2008 code. This relighting project was conducted by SCE as part of the OTF pilot projects to demonstrate that additional efficiency is possible by introducing advanced design and highly controllable lighting equipment into office spaces.

GOAL OF THE PILOT PROJECTS

This projects goal is to collect measured energy use from on-the-ground installations. Measured outcomes can be compared to the existing baseline and the various code baselines, as defined in California by 2008 Title 24.[1]

TECHNICAL REQUIREMENTS

LIGHTING AND LIGHTING CONTROLS

Energy and demand can be reduced through a combination of lighting technologies, luminaire selection, lighting layout, and controls. 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 demand control. Recommended designs enhance lighting quality and provide options for personal control.

PLUG-LOAD MEASURES

The term ‘plug loads’ refers to devices plugged into electrical outlets. Although these devices account for a substantial share of a building’s energy use, they are not yet addressed in current energy codes. Primary types include computers and peripheral equipment (speakers, monitors, etc.), office equipment (copiers), kitchen equipment,

[1] California Title 24 available at http://www.energy.ca.gov/title24/

vending machines, and a wide variety of other devices from cell phone chargers to personal space heaters.

Plug-load efficiency measures can:

- Reduce the energy consumption of active equipment
- Switch off inactive equipment
- Eliminate extraneous equipment

HVAC Review

The 25% solution includes a service to review the efficiency of lighting, Heating, Ventilation, and Air Conditioning (HVAC) systems, and tune performance, if needed, to assure systems are functioning properly. In addition to saving energy, this can reduce complaints about lack of comfort.

A performance review of existing systems will identify energy inefficiencies that can be cost-effectively corrected and used to restore or improve the system's original level of energy-efficient operation. This process covers what are commonly referred to as 'low-cost, no-cost' measures addressing the following areas.

- Controls
- Heat exchange equipment
- Core heating and cooling equipment
- Staff training

Advanced Metering

Verification of performance and the ability to sustain persistent savings are valuable and can be enhanced by metering strategies. An interval data meter with remote data capabilities, a system that meters energy data at intervals of one hour or less and relays it to a remote database, will result in a more successful and cost-effective program.

The OTF Consortium recommends installation of a nonrevenue sub-meter ('check meter') and energy display device in the TI package when wiring configurations permit isolation of tenant loads. At a minimum, the device will display power at the electrical distribution panel serving the space.

THE FEDERAL BUILDING DEMONSTRATION PROJECT DESCRIPTION

This project consists of one half of the 12th floor of the Los Angeles Federal Building (8,024 square foot (ft^2)) occupied by a division of the FBI. This building was previously delamped, 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. Energy use metering of each half allows for direct comparison of potential savings in a real workspace. Additionally, 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 problems 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 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.

PILOT EXISTING CONDITIONS

LIGHTING

The existing lighting systems consisted of 1x4 fluorescent troffers overhead, with 24" and 30" undercabinet lights at every desk. The 1x4 luminaires were original 1970-era troffers, retrofitted with T8 lamps and specular reflectors. The task lighting system employed T12 lamps and magnetic ballasts. Due to security procedures and the setting of the relay control system, the general lighting system operated approximately 64 hours per week.

Sample light-level measurements were taken at workers desks. There was a range of values with light levels of 30-60 footcandles. Moreover, average light-level representations were determined to be meaningless due to the overhead file cabinets at each desk and large piles of stored files and paperwork throughout the office. 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's to 60's, with the majority between 35 and 50 years old.
- Employees were questioned 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 a bit more than needed, with typical levels in the middle of the room (open floor) to be 50-60 footcandles (fc).
- Employee fieldwork resulted in the lighting of a large number of unoccupied desks and storage areas.

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

The existing lighting systems are shown in Table 1.

TABLE 1. EXISTING LIGHTING SYSTEMS

SOURCE	APPLICATION	WATTS	W/SF
1x4 troffer	General lighting	8,990	1.12
Task lighting	All desks	3,180	0.42
Total		**12, 170**	**1.54**

EVALUATION OF EXISTING CONDITIONS LIGHTING

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. Previously, the original 1′ x 4′ 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 Watts per square foot (W/ft^2). There was no zone switching, although quite a few lights were on emergency/night light systems.

While improving the general lighting system was the principal focus of this project, the task lighting systems could not be ignored. Each workstation is equipped with two undercabinet lights that appear to be part of the furniture system package. Both 24″ (F20T12) and 30″ (F30T12/CW) fixtures using magnetic ballasts were found.

PLUG-LOAD EXISTING CONDITIONS

An inventory of installed plug-load devices, summarized in Table 2, reveal the non-regulated loads. This inventory represents the plug-load equipment on the entire floor, not solely the eastern portion where the relighting project took place. The lighting circuit was monitored separately from the plug-load circuit.

TABLE 2. EXISTING PLUG LOAD EQUIPMENT AND NUMBERS

EQUIPMENT TYPE	NUMBER
Task lights	66
Desktop Computer	68
Laptop Computer	17
Thin Client Computer	1
LCD Computer Monitor	68
CRT Computer Monitor	2
Printer	13
Desktop Speakers	56
Scanner	5
Fax	3
Plotter	1
Fan	1
Television (6 LCD, 2 CRT)	8
Mini Refrigerator	1
Microwave	1

LIGHTING SOLUTION

OVERARCHING CONSIDERATIONS

Consideration 1: This project is an excellent opportunity to demonstrate state-of-the-art energy efficiency practices in a normal, functional, everyday open office space. One equipped with older furniture, ceilings, and a few partitioned offices. In many ways, it represents the potential in the large building stock belonging to the Federal government as well as other government agencies and most corporations and companies large and small.

Consideration 2: 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, a handsome custom ceiling and sprayed-on asbestos fireproofing. Almost 50 years later, new standards have turned many of these features into liabilities. In this case, working around the three principal problems of asbestos, seismic concerns and nonstandard building systems made the project particularly challenging and severely constrained the design choices.

Consideration 3: The lighting could be used to help renew the appearance of the office space. Conventional lensed lighting systems have a subtle negative connotation. This project was seen as an opportunity to introduce an aesthetic solution as long as cost effectiveness, energy efficiency, and functionality were preserved.

LIMITATIONS

Four conditions were seen as limiting the lighting design:

a) The original building design called for sprayed-on asbestos fireproofing. In buildings with plenum return HVAC systems, this is now unacceptable. Moreover, the building must be modified either by 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, every removal of a ceiling tile for building maintenance would require spot abatement and asbestos cleanup. This building has encapsulation that allows ceiling access, but for which 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 been upgraded yet. This raises the question of how any work can be carried out to improve the building's seismic qualities without requiring extensive work anywhere else.

c) The original building's ceiling grid is not standard. The building standard tile is 5' x 2', not 4' x 2'. In addition to the impact to lighting systems, the nonstandard tile affected the purchasing options. The odd size of the tile and the high performance needed for the more efficient interior spaces increased the cost and reduced the number of vendors that could supply the correct tiles.

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

The project was further challenged by a worldwide electronics parts shortage that made dimmable electronic ballast temporarily hard to get. Aided by the lighting consultant and SCE, fixture manufacturers were able to obtain the required quantity of such ballasts 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 suggest a number of task and ambient lighting system approaches. In the enclosed spaces, furniture and wall uses suggested recessed lighting systems.

OPEN OFFICE AREA

GENERAL LIGHTING REPLACEMENT SCHEME

The existing lighting system was found to be well beyond its useful life, but what really drove the design decision were seismic factors. The original troffer lighting system employed 1960's-era heavy-gauge housings. Their removal would reduce ceiling load by about 1.5 to 2 pounds (lbs.)/ft^2. Even if a few luminaires remained, the result would be a much safer ceiling system. A further seismic consideration, replacement of mineral tile (1 lb/ft^2) with fiberglass tile (1/2 pound per sf) was also investigated, but cost and availability of 60”x24” tiles resulted in mineral tiles being used.

For offices with adequately high ceilings, at least 9’, the obvious choice for general lighting is usually a generic indirect system. However, this would require structural attachment to be safe, and it was set aside to avoid the spot asbestos abatement required by a significant number of structural attachments. Instead, a similar system attached to the furniture was chosen. 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 ensures the general lighting system is only activated when 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 normal but within the range of lighting systems now promoted for general office lighting.

Nine art accent lights (“monopoints”) were added to the space. These are 20Wceramic metal halide (CMH) luminaires designed for accent and punch, 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 impact.

Task Lighting Scheme

The initial site investigation showed that most of the overhead lighting was illuminating the floor. Tasks were not well lighted as a rule.

The chosen design has three task lighting systems:

- A panel-mounted task light for the desk without an overhead bookcase. There is one luminaire with an integral manual dimmer per workstation, with a total load of about 0.20 W/sf.
- Modernized original undercabinet lighting. Each luminaire was equipped with low-power ballast having reduced light and power levels. In addition, each still provided 40-50 fc on the desk surface under the overhead shelf or cabinet. The total load of these task lights is about 0.21 W/sf.

- A cable-mounted task light for common tables between workstations. This luminaire can be dimmed through the lighting control system. The total load is about 0.08 W/sf.
- After the relighting project, SCE noticed that some occupants installed personal task lights as well. This was likely due to the stacks of paper and boxes that partially blocked the furniture-mounted task lights. During the week of July 5, 2011, all 66 occupants were given a Finelite 9W task light.

The panel-mounted task light, undercabinet lighting, and Finelite task light are included in the metered plug-load circuit. The cable-mounted task light was included in the lighting circuit in the measured results.

ENCLOSED SPACES

Lighting for the enclosed spaces replaced the existing 1’ x 4’ lens fixture with a state-of-the-art, super-efficient T5 rounded lens fixture and dimming ballast. Task lights were retrofitted with new lamps and electronic ballasts, 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.

Table 3 shows a summary of the lighting fixtures used in the relighting project 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	1’ x 4’ Toffer	3	22	682
H1	Accent Light	22	9	198
	Finelight task light	9	66	594
	Total Wattage of Installation			7,138

Figure 1 shows the reflective ceiling plan.

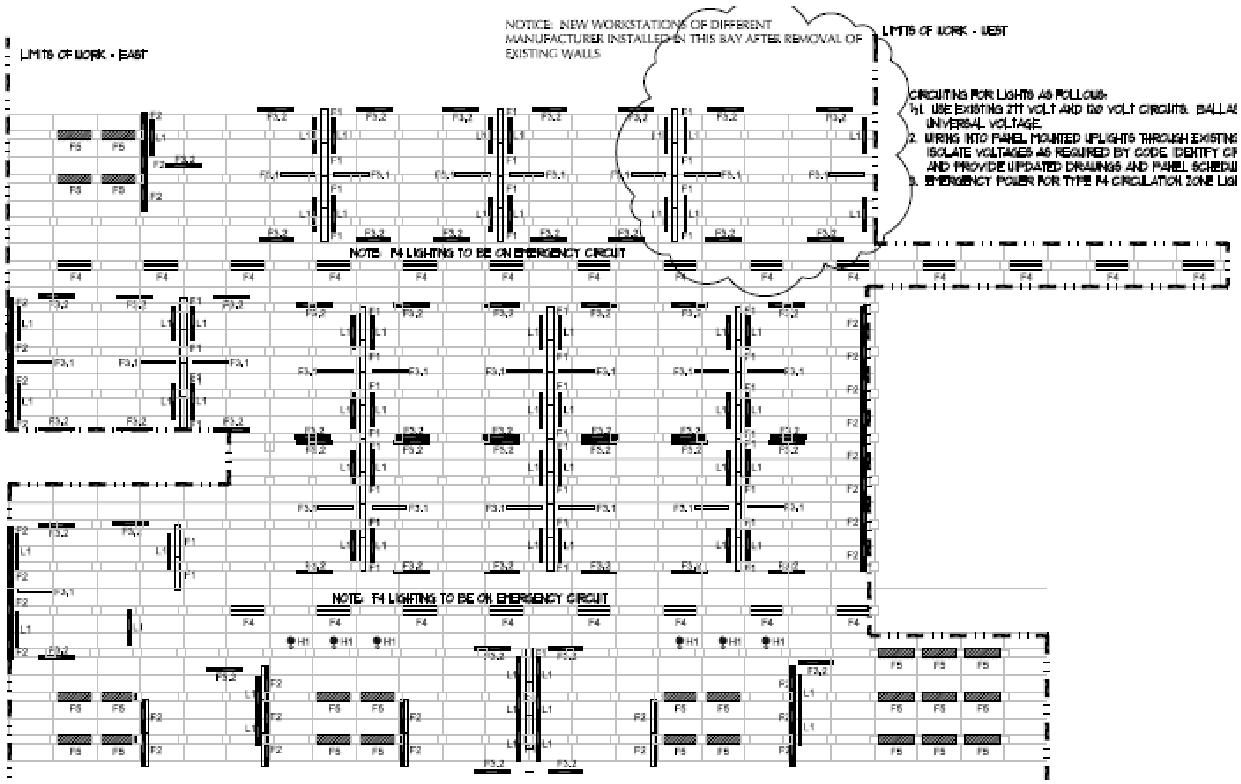

FIGURE 1. REFLECTIVE CEILING PLAN OF THE FEDERAL BUILDING DEMONSTRATION PROJECT

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 can control on/off and dimming functions of lights. The system 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). In addition, a separate workstation motion sensor and plug strip was provided for task-light switching and switching of other loads not needed when the workstation was unoccupied.

The system provides the following functions and strategies.

- Tuning to reduce overall lighting use by 20%. 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 attractive installations.

- Most of the lighting is capable of demand response (DR) and can respond to a DR or real-time pricing signal. The lighting capable of DR can dim to any level that the owner desires or agrees to with SCE. However, it is important to note that since the lighting is already dimmed down 20% this becomes the new '100%' lighting level from which all DR events begin.
- Large Zone non-predictable scheduling. Any motion in the space activates circulation and general workstation ambient. However, the indirect ambient when activated operates at a low lighting 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% when a worker is present at any of the four workstation desks in each 'pod,' with the common task lights turned on as well.
- Daylighting with separate north and south zones of general lighting.

The control system 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 this installation are. summarized in Table 4

TABLE 4. LIGHTING EQUIPMENT AND MANUFACTURER

EQUIPMENT	MANUFACTURER	MANUFACTURER LOCATION
Workstation-mounted uplights and wall uplights	Orgatech	Los Angeles
Pendant Task Lights and Workstation Task Lights	Smedmarks	Wisconsin
Accent lights	Erco Lighting	New Jersey
1' x 4' troffers	Cooper Lighting	Peachtree City, GA
6" x 4' circulation lights	Prudential Lighting	Los Angeles, CA
Lighting controls (for enabling DR, or all kinds)	Encellium Systems	Pennsylvania
Workstation plug strips	Wattstopper	San Jose, CA

TEST METHODOLOGY

To characterize the savings resulting from OTF pilot projects, New Buildings Institute (NBI) devised a Measurement and Verification (M&V) protocol. The protocol evaluates savings resulting from each type of measure implemented, e.g., lights or plug-load measures, as well as the entire package. Figure 2 depicts the creation of baselines and implementation of different measure types in order to assess the impact of each, as well as the entire package. This diagram represents the idealized approach when all OTF measure types are implemented.

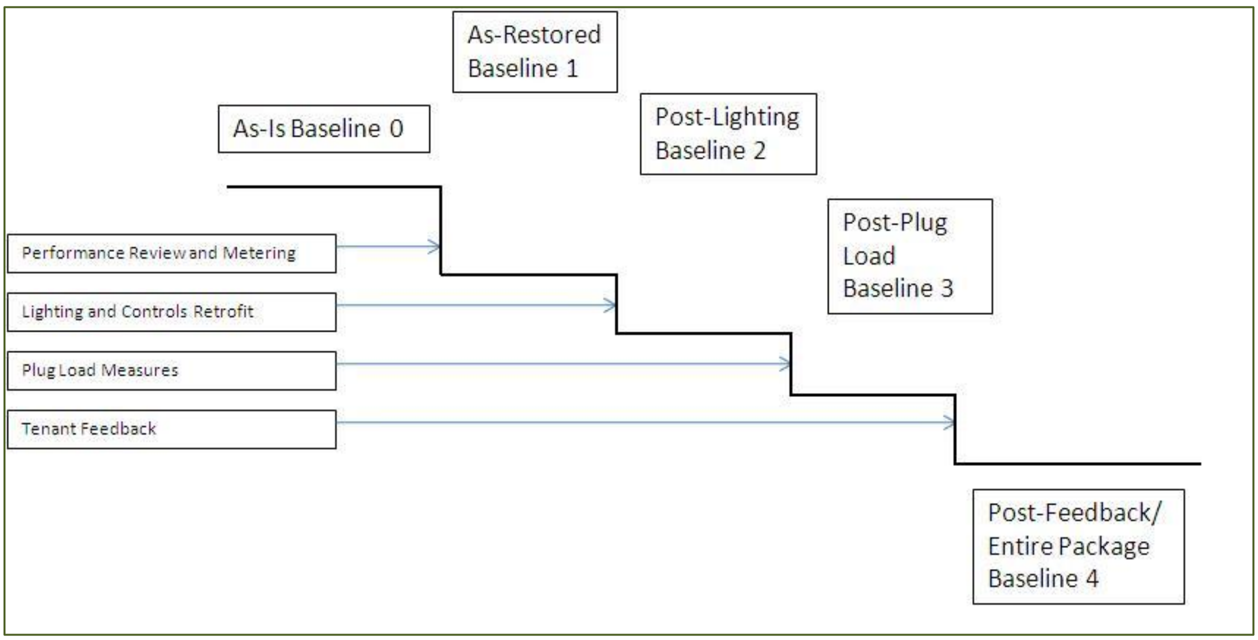

FIGURE 2. A GRAPHIC SHOWING THE M&V BASELINE METHOD FOR EVALUATING OTF PILOT INSTALLATIONS

NBI recommended a formal protocol for assessing performance and encouraged consistency among the various pilot projects conducted by OTF Consortium members. The protocol suggested the construction schedule be tiered to allow distinct monitoring periods after installation of a measure type to establish a baseline from which to determine the savings impact of the subsequent measure type. The duration of each baseline is a minimum of four weeks.

Metering installed at the whole-building and office-space levels establishes the 'As-Is' baseline. This represents existing energy use before any conservation measures are installed. The performance review and feedback of whole-building meter data established an 'As-Restored' condition intended to reflect how a code-level building will operate when existing equipment and schedules are corrected to an optimal operating condition.

Next, lighting and controls are installed in the office space, including a 100-hour 'burn-in' period for the lighting. To operate optimally, new lamps must stabilize (mercury distribution, phosphor/impurities settle, etc.). This is especially important when using the dimming feature. The burn-in period also allows monitoring of the total connected load of the newly installed lighting. After the lighting is burned in and fully commissioned, the 'post-lighting' baseline is established. Subsequently, the plug-load measures are installed and monitored. This establishes the 'post-plug-load-measures' baseline. Lastly, the tenant feedback screen is enabled to assess any savings impact attributable to the performance feedback provided to office occupants. In addition, it compares the entire package against the 'As-Is' and 'As-Restored' baselines.

NBI conducted the M&V of the Federal Building Demonstration project in accordance with the general procedure developed for OTF pilot projects. However, they simplified the approach to reflect the realities of this project. For example, the east and west portions of the 12th floor were monitored separately for comparison. Additionally, the lighting and controls system were installed simultaneously along with plug-load occupancy controls. This study does not include a HVAC review.

METERING EQUIPMENT AND DATA ACQUISITION

Separate electrical services served east and west sides of the office, each with a single 277/480 lighting panel and two 120/208 plug-load panels. Three meters were installed on each side to monitor each panel. The meters on the east side were connected to the data acquisition system (DAS) located on the west side using wireless communications. The meters on the west side were connected directly to the DAS. All meter data was uploaded via a GSM cellular connection to a remote database where it was analyzed by NBI personnel. The data was redundantly sent to an energy dashboard provided by a third-party vendor.

Data was gathered at 15-minute intervals except during demand response testing when data was gathered at 1-minute intervals.

Table 5 provides a summary of metering equipment.

TABLE 5. SUMMARY TABLE OF METERING EQUIPMENT

Meter #	Load	Panel	12th Floor Location	CT Size	Meter
1	Lighting	L12C	East side	100 amps	WattNode WNB-3Y-480-P TrueRMS
2	Outlets	P12C	East side	100 amps	WattNode WNB-3Y-208-P TrueRMS
3	Outlets	12CC	East side	100 amps	WattNode WNB-3Y-208-P TrueRMS
4	Lighting	L12A	West side	100 amps	WattNode WNB-3Y-480-P TrueRMS
5	Outlets	P12A	West side	100 amps	WattNode WNB-3Y-208-P TrueRMS
6	Outlets	12AA	West side	100 amps	WattNode WNB-3Y-208-P TrueRMS

Energy Measurements East:

- Energy use meter reading (kilowatt hour (kWh))
- Average True Power in the Interval (kilowatt (kW))

Energy Measurements West:

- Energy use meter reading (kWh)
- Average True Power in the Interval (kW)
- Instantaneous True Power in the Interval (kW)
- Minimum Instantaneous True Power in the Interval (kW)
- Maximum Instantaneous True Power in the Interval (kW)

Data Acquisition:

Data was 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.

Measurement and Verification Summary:

Handheld instruments verified the M&V meter readings to ensure accurate current readings.

Lighting and plug loads were monitored for a baseline period and a performance period. The lighting measurements were used to compare existing performance versus the Federal Building Demonstration new lighting system that was installed. According to the on-site administrator contact, the occupancy and use of the space between the two periods were unchanged.

The plug loads are reported for academic purposes. However, the plug load circuit was impacted by multiple changes that made analysis and comparison difficult. Specifically, furniture-mounted task lights were replaced, Finelight task lights and Wattstopper Isole plug-load control devices were provided to workstation occupants, and several pieces of server equipment were added to the space during the performance period.

Both the existing system and the Federal Building Demonstration new system included in-furniture task lighting. This task lighting was supplied by the plug-load service on each side that supplied the workstation and its plug loads. In this configuration, the energy use of the task lighting was nearly impossible to separate from the workspace plug load. Additional monitoring, not complete at the time of this report, would be necessary to separate out the task lighting load from the plug loads. In the Federal Building Demonstration case the task-lighting usage was projected using the plug-load service profile as a proxy for task-lighting usage. This is discussed in the Results section.

In addition to the existing lighting system, both the new lighting system and the plug-load usage were compared to the west side of the office that was still using the original lighting system controlled by BAS sweeps.

Figure 3 demonstrates, from left to right, a typical installation where AcquiSuite acquires data from the office-space and whole-building meters, brings it to a remote database via a cellular modem and shows how the data is used by the whole-building operator, office-space feedback screen, and for M&V analysis.

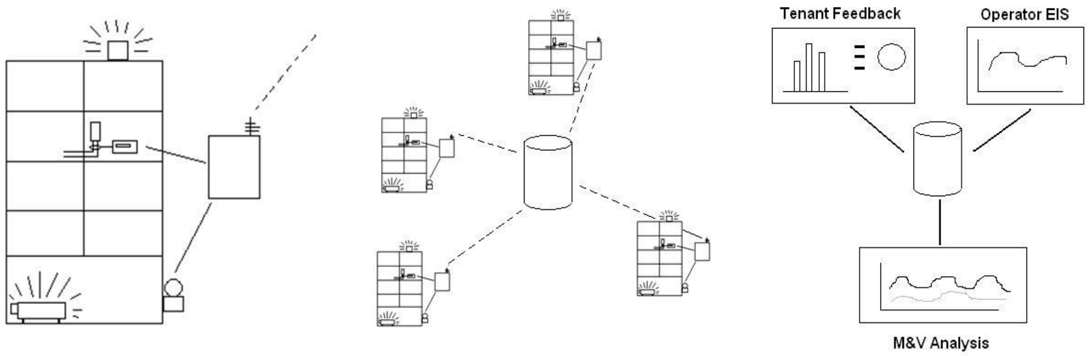

FIGURE 3. GRAPHIC DEPICTING THE DATA ACQUISITION PLAN FOR THE OTF PILOT PROJECTS

DATA ANALYSIS AND RESULTS

Both meter data and calculated code metrics were analyzed to determine the level of savings over code and generally report system energy and power performance.

The monitoring period was January 22, 2011 through July 13, 2011. The existing baseline period was January 22 through March 22, 2011, and the relighting performance period was May 10 through July 6, 2011. The demand-response test took place on July 12 and 13, 2011. Installation and burn-in were conducted between the baseline and performance periods.

The analysis below examines the energy use over a 24-hour period, defined as the 'daily' metric. Weekdays are defined as Monday through Friday and exclude a typical office schedule of 10 workday holidays per year. Weekdays are distinguished from Saturdays. Sundays and holidays are separately considered and referred to as 'Sunday/holiday'. See Appendix A for raw data.

In addition to the 24-hour metrics, the analysis separately examines energy use between the hours of 6 a.m. and 6 p.m. This time period is referred to herein as the 'occupied hours' since it is the time the office space is most likely to be in use.

TITLE 24 CODE CALCULATIONS

In California, Title 24 establishes a maximum lighting connected load level. When using the space-by-space method, a lighting practitioner makes a schedule of space types represented and the square footage of each space type. The practitioner then multiplies these by the watts per square foot as allowed by Title 24 code. According to the code, wattage contributed by 'decorative' fixtures is considered 'Additional Wattage Allowances' and permissible to add to the total allowed watts.

The sum of these space types plus additional wattage allowances creates the maximum connected lighting energy demand for that particular space.

In the Federal Building Demonstration project, the Title 24 Code Calculations are as follows. Table 6 shows the Title 24 Area Category Calculations for the east portion of the 12th floor office occupied by the FBI.

TABLE 6. FEDERAL BUILDING DEMONSTRATION PROJECT AREA CATEGORY METHOD CALCULATIONS

Area Category	Watts / Square Foot	Area in Square Feet	Allowed Watts
Private Offices	1.1	1,168	1,284
Open Offices	0.9	6,658	5,592
Corridor	0.6	198	119
Totals		8,024	6,995

TITLE 24 POWER ADJUSTMENT FACTORS

Power Adjustment Factors (PAFs) provide an approved methodology to adjust the code calculations. There are two types of PAFs allowed when sophisticated controls are employed: (1) non-daylight controls and (2) daylight controls. This project only used the daylight power adjustment factors as indicated in Table 7. Some designers use these PAFs to increase the lighting demand allowed by Title 24, while others use them to downwardly adjust the installed lighting power.

TABLE 7. DAYLIGHT POWER ADJUSTMENT FACTORS FOR CONTROLS

Room Area	Location	Daylight Area (ft^2)	General Lighting Power Density	Watts of Controlled Lighting (ft^2)	PAFs	Control Credit Watts
South Open	Sidelight	1,126	.22	372	.20	74
North Open	Sidelight	784	.21	403	.20	80
North Private	Sidelight	538	.28	279	.20	112
North Private	Sidelight	305	.27	279	.15	42
All	Demand Response	8,061		7,926	.05	396
South Private	Sidelight	330	.20	186	.20	37
Total	Daylight					741

In the Federal Building Demonstration project, the PAFs and resulting control credit watts (741W) were used to downwardly adjust the installed lighting power (7,138 Watts) as outlined in Equation 1.

EQUATION 1. ADJUSTED INSTALLED LIGHTING POWER FOR FEDERAL BUILDING DEMONSTRATION PROJECT

Installed Lighting Watts – Lighting Control Credit = Adjusted Installed Lighting Power

7,138W – 741W = 6,397W

CONNECTED LOAD COMPARISON

Table 8 shows the connected and calculated lighting power density (LPD) of the existing and retrofitted lighting systems, including 2008 Title 24 code requirements calculated with and without PAFs. As previously noted, some practitioners use PAFs to increase the allowable lighting connected load. However, in this case the controls credits adjusted the allowed lighting connected load downward.

TABLE 8. CONNECTED AND CALCULATED LIGHTING POWER DENSITIES

	Existing Lighting	T-24 2008	Relighting as Installed	Relighting Adjusted for Controls Allowances
Connected Load	12,170W	6,995W	7,138W	6,397W
Calculated LPD (W/sf)	1.51 W/sf	0.87 W/sf	0.88 W/sf	0.79 W/sf
Compared to Existing Lighting System	-	-	- 41 %	- 47 %
Compared to Title 24	+ 73%	-	- 2 %	- 9 %

Note: A positive percent (+) indicates system exceeds existing condition or code, while a negative (-) indicates a reduction.

- The connected load of the previous system exceeded the Title 24 2008 allowance by +73%. This demonstrates the large potential of retrofitting existing office spaces to bring buildings to and beyond code levels.

- The new system reduced the connected load (with PAFs) by -47% compared to the previous system. This is an important metric for owners and contractors when discussing the pre- and post-design and potential energy savings.
- The connected load of the new system is -2% less than Title 24 before controls allowances; the final design is -9% better than the Title 24 allowance with controls. This demonstrates the assumed value embedded in codes regarding the ability of codes to reduce energy. It also shows the flexibility the Title 24 controls allowance provides contractors by permitting a higher connected load *if* it is controlled. Designers and contractors then have more options for system selection and the focus becomes the control of the lighting rather than the nominal wattage.
- This estimate of the savings from controls that is inherent in the PAFs used in design calculations does not reflect the measured performance of the high-performance lighting system with controls as measured in the field.

AVERAGE AND PEAK POWER COMPARED TO EXISTING BASELINE

Assessment of the measured average and peak power before and after the Federal Building Demonstration project allows for a comparison of the real change to the space energy use. Table 9 shows the average and peak lighting power compared to the existing system. However, the task lights are not included in the lighting circuit measured results outlined in Table 8.

In the relighting project, these L1 task lights represent 1,696W of connected load and the Finelight task lights represent 594W for a total of 2,290W of task lighting that was measured as part of the plug load circuit. This represents 0.28 W/sf of lighting load that is not included in the lighting circuit.

TABLE 9. AVERAGE AND PEAK LIGHTING POWER COMPARED TO THE EXISTING SYSTEM

		24-HR WEEKDAY AVERAGE POWER (W/SF)	24- HR WEEKDAY PEAK POWER (W/SF)	12-HR WEEKDAY 6AM-6PM POWER (W/SF)	12-HR WEEKDAY NIGHT AVERAGE POWER (W/SF)	24-HR WEEKEND AVERAGE POWER (W/SF)
Existing System	Measured	0.56	0.81	0.78	0.35	0.31
Federal Building Demonstration	Measured	0.23	0.46	0.33	0.13	0.11
Existing System Compared to Relighting		- 59%	- 43%	- 58%	- 63%	- 65%

Note: A negative percent (-) indicates that the relighting system uses less than the existing conditions.

- The task light contribution to the plug-load circuit (instead of the lighting circuit) creates challenges for the analysis. The contribution of the L1 and Finelite task lights are not included in Table 9 but are addressed in the section below.
- When compared with the existing system, the new system consistently reduced power by at least 43% - 65%, with the range varying by occupied and unoccupied periods and weekday versus weekend days.

ESTIMATING THE CONTRIBUTION OF TASK LIGHTS

The task lights present challenges for data analysis. Common area relighting is measured as part of the lighting circuit. However, workstation task lights, both before and after the relighting project, were measured as part of the plug-load circuit measurements.

While the occupancy of the east space did not change from the existing period to the performance period, the measurements on the plug-load circuit were impacted by significant changes. First, the furniture-mounted task lights were retrofitted. Secondly, Finelite 9W LED task lights were added to all 66 workstations. Finally, several servers believed to be on the east plug-load circuit were changed. This made it difficult to use the meter data to determine the magnitude of the task lighting change.

Estimates must therefore be made of the impact of task lights on the lighting measured results. The installed capacity of desk-mounted task lighting in the existing case was 0.42 W/sf, while the installed capacity of desk-mounted task lighting in the Federal Building Demonstration case was 0.29 W/sf (represented by L1 for 1,696W and Finelite task lights for 594W for a total of 2,290W of connected load).

Task lighting was characterized by estimation separate from the overhead lighting metrics. This was done because they were measured on the plug-load circuit that was metered separately from the lighting circuit. The typical plug-load weekday profile was used to assume what percentage of task lights were "on" during the day. This is a conservative estimate because the occupancy sensors should control much more strictly than the manual controls of the existing system. The assumption is that they were the same and the task lighting would be used at the maximum installed capacity at its peak. This provided an hourly profile ranging from 0 to 0.29 W/sf determined by the plug load conditions as shown in Figure 4.

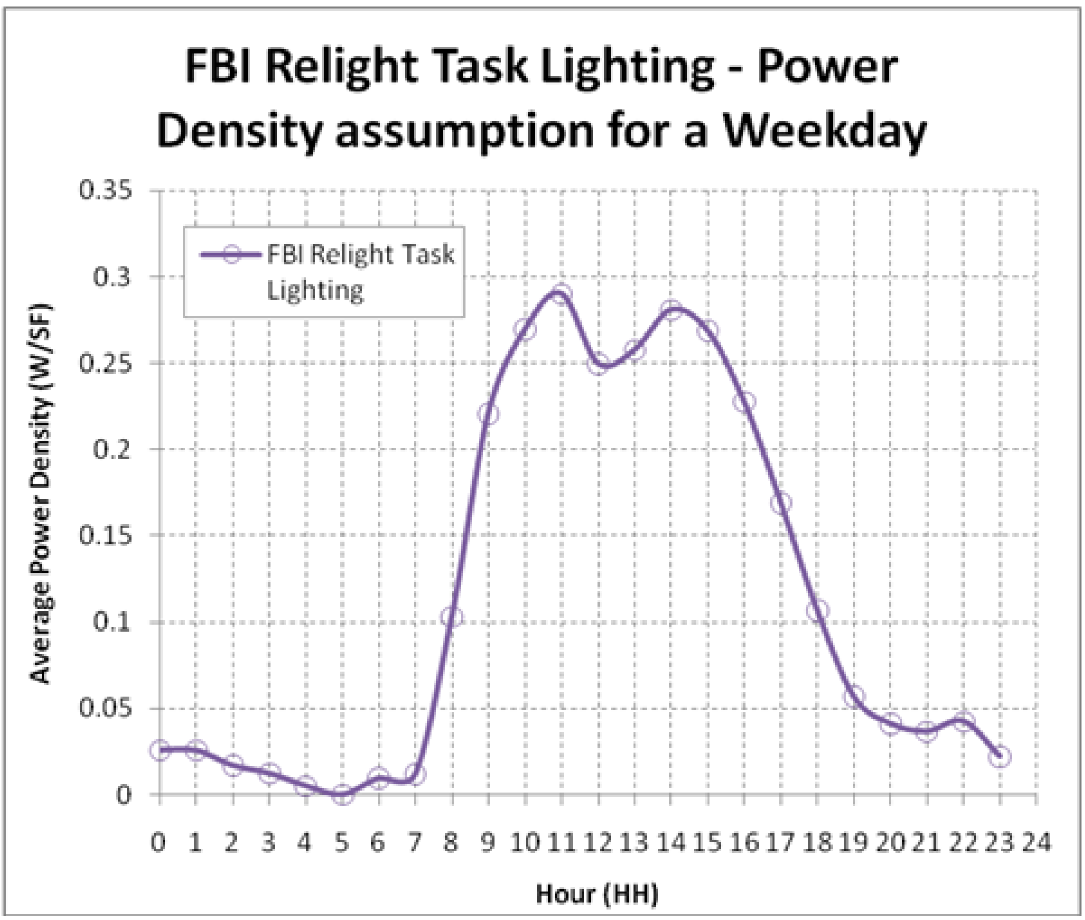

FIGURE 4. ASSUMED CAPACITY OF TASK LIGHTING FOR WEEKDAYS IN PERFORMANCE PERIOD

Table 10 presents the numerical estimates of the contribution of task lighting, both before and after the relighting

TABLE 10. ESTIMATED TASK LIGHTING CONTRIBUTION INCLUDED IN PLUG LOADS

		24-HR WEEKDAY AVERAGE POWER (W/SF)	24-HR WEEKDAY PEAK POWER (W/SF)	12-HR WEEKDAY 6AM-6PM POWER (W/SF)	12-HR WEEKDAY NIGHT AVERAGE POWER (W/SF)	24-HR WEEKEND AVERAGE POWER (W/SF)
Task Light Contribution Before Relighting	Estimated	0.17	0.42	0.24	0.17	0.10
Task Light Contribution After Relighting	Estimated	0.11	0.29	0.16	0.07	0.07
Percent Difference		- 35%	- 31%	- 33%	- 59%	- 30%

It was assumed that the peak power seen in Table 8 was coincident with the peak power of the overhead lighting as seen in Table 9. The sum of the numbers provides an estimate of the total system lighting performance, as shown in Table 11.

TABLE 11. LIGHTING SYSTEM ENERGY USE FROM MEASURED RESULTS PLUS TASK LOAD ESTIMATES

		24-HR WEEKDAY AVERAGE POWER (W/SF)	24-HR WEEKDAY PEAK POWER (W/SF)	12-HR WEEKDAY 6AM-6PM POWER (W/SF)	12-HR WEEKDAY NIGHT AVERAGE POWER (W/SF)	24-HR WEEKEND AVERAGE POWER (W/SF)
Before Project	Measured plus Task Estimate	0.73	1.23*	1.02	0.52	0.41
After Project	Measured plus Task Estimate	0.34	0.75*	0.49	0.20	0.18
Percent Difference		- 53%	- 39%	- 52%	- 62%	- 56%

* These peak demand numbers assume coincidence between the overhead and task lighting demand peaks. This is likely not the case but represents a theoretical maximum given the 0.29 W/sf of task lighting.

MEASURED LIGHTING PERFORMANCE COMPARED TO CODE LIGHTING POWER DENSITY CALCULATIONS

Comparing measured results to code-installed capacity provides insight as to how effective Title 24 PAFs are in estimating the contribution of savings from controls. explains the difference between code calculations and conservative measured results. The analysis includes the estimated contribution of task lighting to allow for an apples-to-apples comparison.

TABLE 12. 2008 TITLE 24 CODE CALCULATIONS VERSUS MEASURED POWER

		24-HR WEEKDAY AVERAGE POWER (W/SF)	12- HR WEEKDAY 6AM-6PM POWER (W/SF)	MAXIMUM 15-MINUTE POWER DENSITY MEASURED (W/SF)
2008 TITLE 24 LPD	Calculated	0.87	0.87	0.87
FEDERAL BUILDING DEMONSTRATION FEDERAL BUILDING DEMONSTRATION	Measured plus Task Estimate	0.34	0.49	0.75
Percent Change		- 60 %	- 43 %	- 11 %

- Lighting system energy use consists of both overhead systems and task lights. Often tasks lights are included in a plug load circuit, which makes it difficult to compare the measured results of the entire lighting system.
- The peak lighting demand of 0.75 W/sf is at least 11% better than the 2008 Title 24 level LPD of 0.87 W/sf. The average occupied power density measured in the field performed at least 43% better than code calculations.
- This suggests that code calculations with PAFs do not accurately reflect the measured results achieved with advanced lighting controls.
- The code baseline exists to promote a minimal best practice to contractors and owners when changing fixtures or systems. Since it is legally required, it becomes the baseline to determine if the new system outperformed a code-minimum system. It also serves as the basis of utility incentives when code is triggered by a project. Due to increased code stringency, it is more difficult to achieve dramatic savings beyond the new higher baseline. However, there are many systems, aided significantly by control strategies that can and do exceed code.

MEASURED LIGHTING PERFORMANCE COMPARED TO CODE PREDICTED ENERGY PERFORMANCE

In current practice, the installed connected load of a particular lighting system is compared to the code-allowed connected load to assess the extent to which it meets or exceeds 'code-level' requirements. This comparison only considers the power demand (in watts) of the lighting installed, not measured energy consumption. Lighting controls are accounted for by allowing PAFs to reduce the effective connected load to a level called the 'Adjusted Installed Capacity'.

Code requirements in watts per square foot (W/sf) do not provide an easy means of comparison to 15-minute interval meter data. To make definitive assessments of energy savings versus code, we must assume a code-level use profile. A good choice for an assumed use-profile will reflect a baseline for lighting usage that will be used in a whole-building model to project overall building performance.

For this energy analysis NBI relied on the use-profiles outlined in the DEER, the accepted methodology used to create a database of deemed energy savings for efficiency measures in California climate zones. The DEER use-profiles reflect the expected energy performance for different office area types, e.g., open office, private office, and for different lighting types, i.e., CFL, T8 fluorescent, over the course of typical days, with distinctions between weekdays, Saturdays and Sunday/holidays.

The code-level connected load in each space type and the respective use-profiles are used to establish daily energy use amounts that are then used to make an annual projection of energy use and peak demand in W/sf. This provides a means to compare code-predicted energy performance to metered energy performance extrapolated over the course of a typical year.

Figure 5 visually demonstrates the comparison between the metered and code-level performance using a weekday use-profile. Figure 5 shows a plot of the average metered W/sf at each hour across all weekdays in the performance period and average code-level weekday hourly W/sf used in the code-level projection. It then co-plots these with the relevant connected load levels, shown as straight horizontal lines as they are fixed numbers in W/sf. The conservative task lighting energy use estimates are included in this visual representation of the data.

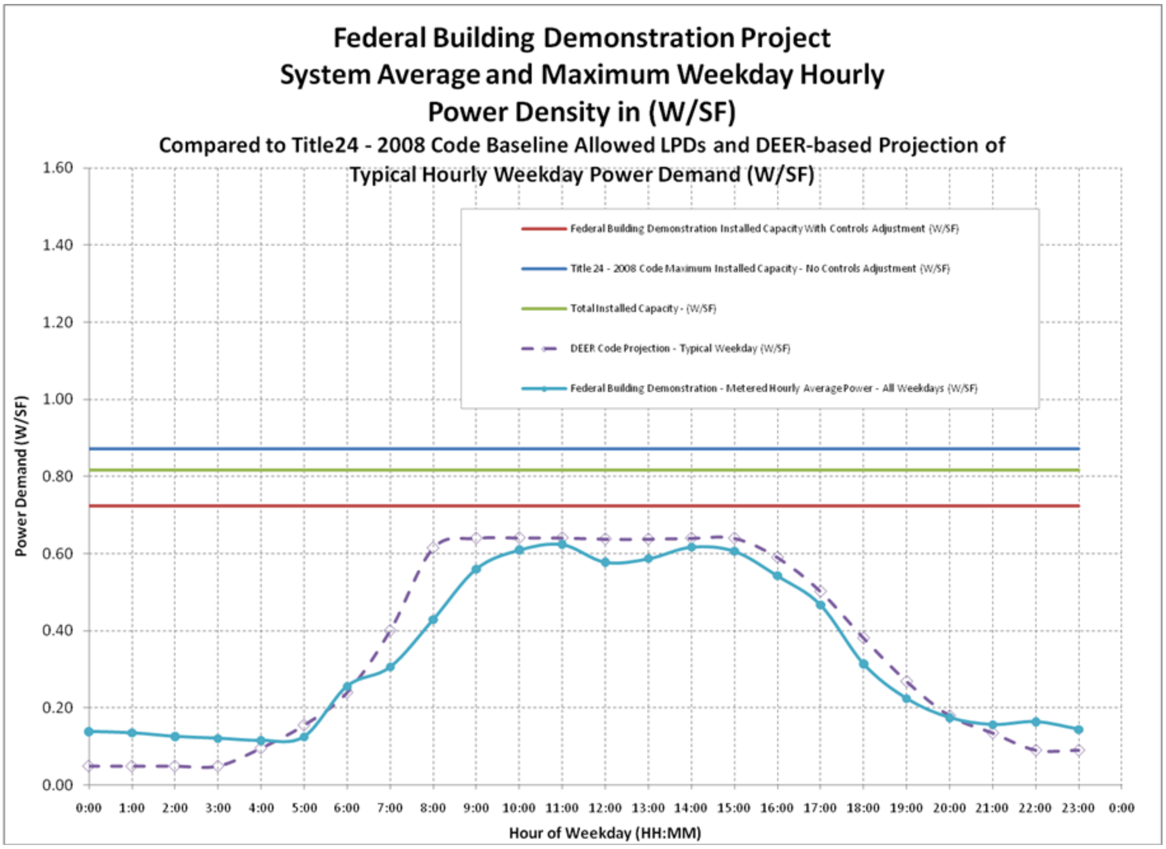

FIGURE 5. A CHART OF WEEKDAY FEDERAL BUILDING DEMONSTRATION PROJECT AVERAGE POWER DENSITIES WITH VARIOUS CODE BASELINE COMPARISONS

PLUG-LOAD DATA

Plug-load energy use was monitored before and after installation of the lighting retrofit. While the occupancy of the east space did not change from the existing period to the performance period, the measurements on the plug-load circuit were impacted by two significant changes. First, the task lights were retrofitted. Secondly, several servers believed to be on the east plug-load circuit were changed. However, the results are reported for academic reference.

Table 11 shows daily metrics for the performance of the Federal Building Demonstration project plug loads. In addition, Table 11 shows the measured performance of plug loads both before and after the relighting project. Various metrics, including a 24-hour metric, an 'occupied period' weekday metric, an 'unoccupied period' weekday metric, a weekend metric, and peak measurements are reported.

TABLE 11. AVERAGE AND PEAK PLUG LOAD POWER COMPARED TO THE EXISTING SYSTEM

		24-HR WEEKDAY AVERAGE POWER (W/SF)	24- HR WEEKDAY PEAK POWER (W/SF)	12-HR WEEKDAY 6AM-6PM POWER (W/SF)	12-HR WEEKDAY NIGHT AVERAGE POWER (W/SF)	24-HR WEEKEND AVERAGE POWER (W/SF)
Existing System	Measured	1.33	2.02	1.36	1.30	1.37
Federal Building Demonstration	Measured	1.48	2.10	1.51	1.46	1.56
Existing System Compared to Relighting		12%	4%	11%	12%	14%

DISCUSSION

RELIGHTING COMPARISON TO CODE

In California, Title 24 establishes a maximum lighting connected load level. PAFs are used to adjust the code calculations to reflect the contribution of lighting savings associated with particular types of lighting controls. These calculations sometimes establish the baseline for utility incentive programs.

The Federal Building Demonstration project provided measured levels of power density per square foot much lower than code calculations. In this pilot, the calculated new lighting retrofit LPD is just 9% better than the 2008 Title 24 calculated design guidelines when using control allowances applied to the nominal LPD requirements on a space-by-space basis.

Despite the estimates of savings in the space-by-space calculations, the measured peak energy demand at any time during the performance period was at least 11% less than code calculations. In addition, average power was 43% better than code calculations.

RELIGHTING COMPARISON TO EXISTING CONDITIONS

The new system consistently reduced power compared with the existing system. Decreases ranged between 39% and 62%, depending on how the analysis was conducted; for example, during occupied and unoccupied periods, weekday versus weekend days, etc. These reductions of lighting power, which could be calculated into energy use, are significant for the lighting system. The California Energy Use

Survey[2] suggests that lighting represents 27% of commercial office energy use in California.

RELIGHTING COMPARISON TO PREDICTED CODE ENERGY PERFORMANCE

Code calculations in watts per square foot do not provide an easy means to compare to 15-minute interval meter data nor to make definitive assessments of energy savings without the presumption of a typical use profile. The DEER[3] database provides well-documented estimates of energy and peak demand savings and has been designated by the CPUC as its source for deemed and impact costs for program planning. It uses a methodology for predicting energy performance given various space types, which were used to estimate a code-predicted energy use of the Federal Building office over time.

MEASURED PERFORMANCE

Comparing lighting system energy use to measured results was difficult due to the rather large contribution of task lights because they were included in the plug-load circuit.

PLUG LOADS

Plug loads are an opportunity for savings. The plug-load results revealed that overall energy use and power density attributable to plug loads was quite high compared to the lighting use in the Federal Building Demonstration office. Moreover, it appears that despite plug load control devices, opportunities still exist to turn additional equipment off at night or on the weekends when the office is unoccupied.

The plug-load data provides a glimpse into the problem of managing energy use in office spaces and the need for a combination of control measures and office energy use feedback to address plug-load energy. Moreover, it shows the difficulty associated with measuring plug loads when changes to servers or other equipment are made.

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[2] 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.

[3] http://www.energy.ca.gov/deer/

POTENTIAL MARKET IMPACT

According to the California Commercial Energy Use Survey (CEUS), offices are the single largest commercial energy use in California, with 16,430 gigawatt hours (GWh) used annually. Offices represent 21% of the total commercial square footage and 25% of all the commercial energy use in California. In SCE service territory, offices represent 18% of commercial square footage (385,110,000 SF) and 21% of total commercial energy use (6,162 GWh). [4]

CEUS data in SCE service territory suggests interior lighting energy use is 1,681 GWh annually. Office equipment is reported as 1,024 GWh annually.

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

[4] 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.

CONCLUSIONS

The measured results of this project are evidence that a high-performance lighting design, with controls, delivers considerable savings. In fact, the savings are beyond code-calculated estimates even when using conservative estimates for the use of task lights.

The report also reveals the complexity associated with comparing code calculations in power density to measured energy performance, since predicting energy performance requires assumptions about occupancy and hours. NBI used a DEER profile to estimate a code energy performance to compare measured results.

The research contributed to the OTF program objectives and will serve as a reference for SCE and other Consortium members.

The following is a summary of the specific technical and indoor environment conclusions based on the research performed during this project.

NEW LIGHTING AND CONTROL SYSTEM

Lighting controls for all spaces with motion sensors, manual override, tuning, and computer-programmable control was the technology most responsible for reduced energy savings. This demonstrates the importance of a 'system' as opposed to isolated technologies. Other findings include:

COMPARED TO CODE POWER CALCULATIONS

- The Federal Building Demonstration retrofit control system demonstrated that controls optimize energy savings potential and provide much better performance than is estimated by code calculations.
- The project confirmed that connected load is a weak indicator of measured energy performance. Rather it is a cap against worst-case energy use. In this project, the relighting design calculated savings over the 2008 Title 24 baseline was just 9%.
- The code estimate of savings from controls does not reflect the measured performance of the high-performance lighting system with controls as measured in the field. This is critical because code calculated contributions from controls set the baseline for utility incentive programs. However, measured savings seem to indicate that performance is much better than code calculations would suggest.

- The measured power use of the new system performed significantly better than the code design power maximum (.87 W/sf).
    - Average power was at least 60% less (.34 W/sf) for a 24-hour period than the code-level average.
    - Power between the hours of 6 a.m. and 6 p.m. was at least 43% less (.49 W/sf) for a 12-hour period than the code-level power.
    - Peak power was at least 11% less (.75 W/sf) than the code-level power.

COMPARED TO EXISTING SYSTEM

The existing building market for energy retrofits does not think in terms of code or LPD. Their interest is in pre/post savings and other improvements that benefit their space, tenant and asset. Thus, the findings of the new system compared to the previous system are valuable program and market information.

- The previous system's connected load exceeded Title 24 2008 allowance by +73%. This demonstrates the large potential for retrofits of existing office spaces to bring buildings to and beyond code levels.
- The new system reduced the connected load (with PAFs) by -47% compared to the previous system. This is an important metric for owners and contractors when discussing pre- and post-design and potential energy savings.
- Compared with the existing system, the new system consistently reduced power by between -39% and -62%, with the range varying by occupied and unoccupied periods and weekday versus weekend days. This has strong implications for the real demand targets of utilities and the price signals to owners that can be leveraged to motivate upgrades.

Compared to Code Energy

- Extrapolating to predict energy performance against code power expectations is challenging. The method here compared the average energy used to the code requirement adjusted to energy by applying a DEER profile.

Metering

- In advanced lighting systems with controls, some initial period of metered data review and feedback is essential to ensuring the lighting system's energy savings are optimized.

Plug Loads

- Plug-load energy use presents opportunities for reductions, especially at night and on weekends.

RECOMMENDATIONS

SCE's Energy Efficiency Group will examine the results of this pilot and other OTF savings evidence and consider routes to incentivize highly controlled lighting solutions and the broader OTF Tenant Improvement (TI) directed program that also addresses office plug loads, energy feedback to occupants, and overall building energy.

SCE will consider the potential benefits of creating and promulgating technical best practices and case studies resulting from this and other demonstration projects. This could entail some type of metering-based feedback and/or acceptance testing to ensure lighting controls are working as intended.

Metering-based feedback to designers, contractors, and building operators is critical to achieving optimal energy savings. Even if the monitoring and feedback period is temporary, this initial feedback ensures that lighting controls are operating as designed and turning off lighting when the office is unoccupied. The controls allowance for 2008 Title 24 did not accurately assess the benefit of highly controlled performance in this case. It is recommended that code officials revisit the structure of the allowance to facilitate comparisons between the metered lighting energy and power data.

Measures to address plug-load power density should be given greater attention within the context of office spaces and TIs. These investigations should include research into the energy efficiency of the equipment currently being used as well as determining what noncritical products can be controlled by occupancy sensors.

Greater study of highly controlled lighting solutions and plug loads is suggested. Studies might include:

- Measurement of power and energy performance throughout the year, to help understand seasonal variations in various locations.
- Detailed measurement of plug-load use and savings from plug-load control measures in office spaces.
- Investigation into the role of office occupant behavior changes, possibly with feedback from measured results.

APPENDIX A – AVERAGE WEEKDAY POWER DENSITY

	NAME	FEDERAL BLDG. 12TH – EAST
	SQUARE FT.	8,024
	FROM	######
	TO	7/5/11

Time	DEER Code Projection - Typical Weekday (W/SF)	Post Retrofit Metered Hourly Average Power - All Weekdays (W/SF)	Post task lights	Pre Retrofit Metered Hourly Average Power - All Weekdays (W/SF)	Pre Task Lights
0	0.05	0.14	0.03	0.30	0.04
1	0.05	0.14	0.03	0.27	0.04
2	0.05	0.13	0.02	0.24	0.02
3	0.05	0.12	0.01	0.24	0.02
4	0.09	0.12	0.01	0.23	0.01
5	0.15	0.13	0.00	0.24	0.00
6	0.24	0.26	0.01	0.72	0.01
7	0.39	0.31	0.01	0.74	0.02
8	0.60	0.43	0.10	0.87	0.15
9	0.62	0.57	0.22	1.05	0.32
10	0.62	0.62	0.27	1.13	0.39
11	0.62	0.63	0.29	1.16	0.42
12	0.62	0.58	0.25	1.10	0.36
13	0.62	0.59	0.26	1.11	0.37
14	0.62	0.62	0.28	1.13	0.41
15	0.62	0.61	0.27	1.13	0.39
16	0.57	0.55	0.23	1.07	0.33
17	0.49	0.47	0.17	0.99	0.24
18	0.37	0.32	0.11	0.78	0.15
19	0.26	0.23	0.06	0.66	0.08
20	0.17	0.18	0.04	0.46	0.06
21	0.13	0.16	0.04	0.42	0.05
22	0.09	0.16	0.04	0.36	0.06
23	0.09	0.14	0.02	0.33	0.03

REFERENCES

[CEUS] 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.

[DEER] Database for Energy Efficient Resources, 2004-2005 version 2.01, California Utilities Commission at http://www.deeresources.com/

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