Office of the Future Executive Suite Demonstration

ET 09SCE1200 Report

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June 21, 2011

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Acknowledgements

Southern California Edison's Design & Engineering Services (DES) group is responsible for this project. It was developed as part of Southern California Edison's Emerging Technologies program under internal project number ET09SCE1200 - check. Doug Avery from DES conducted this technology evaluation with overall guidance and management from Paul Delaney, SCE Emerging Technologies Assessment Manager. For more information on this project, contact doug.avery@sce.com.

This report was prepared by New Buildings Institute (NBI) on behalf of Southern California Edison (SCE) and the Office of the Future Consortium.

The Office of the Future Consortium:
Southern California Edison, NEEA, NYSERDA, National Grid, BC Hydro, NSTAR, Sempra Utilities and Sacramento Public Utility District

ABBREVIATIONS AND ACRONYMS

DEER	Database for Energy Efficient Resources
DOE	Department of Energy
fc	footcandle
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 strategies that can be applied at the tenant level for building owners.

This sector has been problematic for utility incentive programs to capture. The approach varies by building type and class, but executive offices and spaces of similar quality used by law firms, brokerage houses and other high-end Class A occupancies are a critical market. This report represents the findings from an initial OTF pilot of this Class A existing office type.

The Executive Suites are located in GO4, a commercial office building owned and managed by Southern California Edison (SCE) in Rosemead, California. The SCE executive offices on the fourth floor provided an opportunity to measure energy use and to undertake a relighting project that meets the architectural, aesthetic and functional demands of the space while employing current energy efficient products and design techniques.

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 OTF consortium members to inform the OTF process.

The executive office space is 14,635 square feet and has 20 occupants. The primary spaces are 10 private offices, an open office area and a video conference room. GO4 was built in 1984; the lighting was last updated in 1999. The principal components of the project were:

1. Removal of low-efficiency, generic recessed 2x2 fluorescent lighting and replacement with high-efficiency lighting systems, incorporating: a) pendant linear lighting in private and open offices, b) pendant round luminaires in the main conference room and circulations areas, and c) MR 16 incandescent spots and floods providing general lighting in the open office and corridor area.
2. Replacement of low-efficiency accent lighting with high-efficiency accent lighting.
3. Addition of an advanced lighting control system including smart dimmable fluorescent ballasts tuned to 80% power maximum with the potential for greater reductions depending on user-chosen light levels.
4. Installation of Measurement and Verification (M & V) metering on the lighting system and office equipment plug-load devices and appliances.
5. The results of this executive suite project reveal that a high-performance lighting design with controls delivers savings considerably beyond code-calculated estimates. Measured results show that during daytime occupied hours the site uses, on average, at least 54% less energy than code calculations. The new system reduced the connected load by 53%.

   The lighting system redesign improved the work environment through changes in illumination levels, contrasts and aesthetics. Some examples are increased light at the

work plane for executive assistants, more uniform lighting in the executive suites, better individual dimming controls on fixtures, reduced contrasts and erratic lighting patterns in the conference area, improved lighting for video events and an updated, and more professional visual environment befitting Class A executive office space.

Recommendations from the results of this pilot and other OTF savings evidence should include; providing results to the Energy Efficiency Program staff members representing the various sponsors of the OTF collaborative, , consider a collaboration of the OTF consortium partners as well as industry actors to create and promulgate technical best practices and case studies resulting from this and other demonstration projects, metering-based feedback to designers, contractors and building operators is critical to achieving optimal energy savings.

In addition, 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 expand TI. 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.

A more detailed study of highly controlled lighting solutions and plug loads is necessary. Suggested studies include:

- Measurement of power and energy performance throughout the year to better understand if there are significant seasonal variations in various locations.
- 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.

EXECUTIVE SUMMARY – PROJECT SAVINGS TABLE

	AVERAGE ENERGY	PEAK DEMAND	ANNUAL ENERGY USE
Old System	274.5 kWh	19.4 kW	91,944 kWh
New System	153.3 kWh	9.7 kW	52, 839 kWh
Savings	44%	50%	43%

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 that specify performance requirements for different attributes of tenant improvement (TI) (lighting, plug loads, etc.) and whole building that result in at least a 25% and 50% savings over code, respectively. Despite the unique physical characteristics of the GO4 executive suites, the relighting – change relighting to lighting redesign project was conducted by SCE as part of the OTF pilot projects in order to demonstrate the efficiency of introducing advanced design and highly controllable lighting equipment into office spaces.

GOAL OF THE PILOT PROJECTS

The purpose of the OTF pilot projects 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 incorporate energy efficiency features and offer advanced controls 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 that are plugged into electrical outlets. Primary types include computers and peripheral equipment (speakers, monitors, etc.), office equipment (copiers), kitchen equipment, vending machines and a wide variety of other devices from cell phone chargers to personal space heaters.
Plug-load efficiency measures can:

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

Heating, Ventilating, and Air Conditioning (HVAC) Review

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

A performance review of existing systems is in the process of identifying 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 very 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.

GO4 PILOT PROJECT DESCRIPTION

The GO4 executive suite, located at 8631 Rush Street in Rosemead, CA, is a commercial office building owned and managed by SCE. Built in 1984, it is a 5-story steel-frame building with a glass curtain wall. The pilot project involved the lighting redesign of 14,635 SF of space occupied by the senior executives of this major corporation. The pilot installation provided an opportunity to demonstrate energy savings from a lighting redesign project that meets the architectural, aesthetic and functional demands of the space.

This is a rather unique office with 20 occupants. There are 10 private offices, 10 open office workstations, 11 restrooms, 1 conference room (with video conference capabilities), corridors (including lighting to highlight art displayed) and 1 kitchen area.

PILOT EXISTING CONDITIONS

LIGHTING

The existing lighting systems are the result of a 1999-2000 renovation. The principal lighting system (about 56% of the existing lighting) is an overhead 2x2 system using T8 U-lamps. The remaining 44% is an assortment of art accent lights and incandescent down-lights.

Sample light-level measurements were taken at night along the desk tops of executive assistants, along the work area niches where executive assistants work on printers, faxes and filing, and in executive offices at the main desk pad, the keyboard and screen return and the back credenza with under-cabinet light. In general, the following conditions are summarized:

- Light levels at the desks of executive assistants were marginal for ordinary paperwork and inadequate for fine and detailed paperwork. 25-30 footcandles (fc) were measured in these spaces. Light levels of 40-60 fc should be reached when needed (IES Category E task).
- Printer niche lighting, measured at 50-100 fc, exceeded necessary levels, which would be 20-30 fc.
- Executive offices have a lot of daylight, minimizing the impact of electric lighting. Credenza light levels were too high, keyboard areas were generally too low, main desk areas were generally too low and meeting table areas were about right. The offices of the CEO and president were better lit than other offices (portable task lights were noted in two instances).
- The general light level throughout the executive assistant open office area was about right.
- Light levels in the conference room were about right, with a minimum of 50 fc average.

Each private office has a motion sensor connected to separate daylit and non-daylit zones, and each zone has a switch/dimmer. Controls for the open office area were programmable on/off with an override switch. Controls for the CEO office and conference room were Lutron Grafik Eye®, a software application that allows you to control both light and daylight. It is fully customizable and adjusts lights and shades for any task or activity at the touch of a button. The existing lighting systems are shown in Table 1.

TABLE 1. EXISTING LIGHTING SYSTEMS

SOURCE	APPLICATION	Watts	W/sf
2x2 paracube T8U	General lighting	15,304	1.05
MR16 art accents	Artwork and conference room	3,038	0.26
Dual 26W CFL Down-lights	CEO and conference room, other locations	3,534	0.24
26W CFL Sconces	Main open area and toilets	1,914	0.13
Other 2x2 parabolic and special T8U and FT55	General lighting and VTC Lighting in conference room	1,260	0.09
Cove lighting T8	CEO and conference room	1,020	0.07
Undercabinet lighting T8	Throughout	300	0.02
Total		**26,370**	**1.86**

EVALUATION OF EXISTING LIGHTING CONDITIONS

The overhead 2x2 lighting system provided most of the task and ambient light in the executive suites. Comprised of small-cell louver fixtures, it generated an average of approximately 30-40 fc at 1.05 W/sf - quite poor by today's standards. The lighting power was less dense in the open office area and denser in the private offices due to the number of fixtures in each area.

While improving the general lighting system was the primary focus of this project, the secondary lighting systems could not be ignored if the project was to meet current code. The existing compact fluorescent downlights and MR16 accent lights combined to add 0.50 W/sf to the existing project. Both could be better designed and use less energy and should be a major part of any new lighting scheme.

The lighting systems in the conference room were extremely busy and unattractive, doing no justice to the room's appearance. The room has high camera positions that allow indirect lighting for video terminal conferencing. The existing cove lighting could be improved but was otherwise an asset to the space to be reused.

Other existing lighting includes:

- MR16 art accent lights, both recessed and monopoint, to illuminate the suite's art collection
- Compact fluorescent down-lights in circulation areas, toilet rooms and CEO offices
- Incandescent wall sconces at toilet-room vanities
- Compact fluorescent wall sconces with faux alabaster plastic shades in common circulation area

PLUG LOAD EXISTING CONDITIONS

An inventory of installed plug-load devices revealed the non-regulated loads and are summarized in Table 2. The electrical service serving the space was metered in a way that both the lighting and plug load, or outlet load, could be monitored separately.

TABLE 2. EXISTING PLUG LOAD EQUIPMENT AND NUMBERS

EQUIPMENT TYPE	NUMBER
Desktop Computer	11
Laptop Computer	10
LCD Computer Monitor	18
Printer	18
Desktop Speakers	11
Copier	2
Fax	11
Multi-function Device	3
Portable Heater	2
Television (3 LCD, 2 plasma, 7 CRT)	12
Coffee Maker	1
Refrigerator/Freezer	1
Toaster Oven	1
Microwave	1
Task light	10
Floor lamp	1
Label Printer	8
Hole Puncher	5
Typewriter	2
Electric Stapler	10
Ear piece charger	4
Calculator	2
Pencil sharpener	3
Shredder	6
Stereo	1
DVD player	2
Decorative fountain	1
Clock radio	6
Speaker Phone	9

OFFICE OF THE FUTURE EFFICIENT SOLUTION

LIGHTING DESIGN AND CONTROLS APPROACH

The overarching design consideration is that the space selected for the pilot is the executive suite of a major corporation. The original lighting design demonstrated this through its use of art accent lights, sconces, cove lighting and other high-quality lighting details. The result of this project is to achieve aesthetics suited for the space.

The second major consideration is to demonstrate energy efficiency in the corporate setting. Lower-power, more efficient lighting and better lighting controls can maximize energy savings. This includes tuning, daylight sensing, motion sensing and other techniques. Whatever design is created, the effects of controls are significant and must be factored into the selection. The use of cutting-edge technologies such as LED should be emphasized, where possible.

DESIGN PROCESS AND DECISIONS

Finelite, a manufacturer of efficient lighting systems based in Northern California, submitted two designs for consideration. Both designs focused on the general lighting and did not address any of the other lighting systems. A computer model of the open area including two of the executive assistant workstations was created. The study area was approximately 1,100 sf, small enough to permit quick analysis but large enough to allow numerical comparison of competing schemes. In order to compare cost and energy efficiency, Title 24 spreadsheets were created in which decorative and accent lighting were included to provide a better overall comparison of competing schemes.

GENERAL LIGHTING DIRECT REPLACEMENT SCHEME

The general lighting replacement scheme is a 1:1 replacement of existing 2x2 fixtures with Finelite's new high-performance recessed (HPR) 2x2. As shown in Figure 1, using the 2-lamp T8 version of the fixture the design achieves an average light level of 23 fc throughout the space. Task light levels on the work surfaces are between 25 and 35 fc. General light levels never fall below 10 fc.

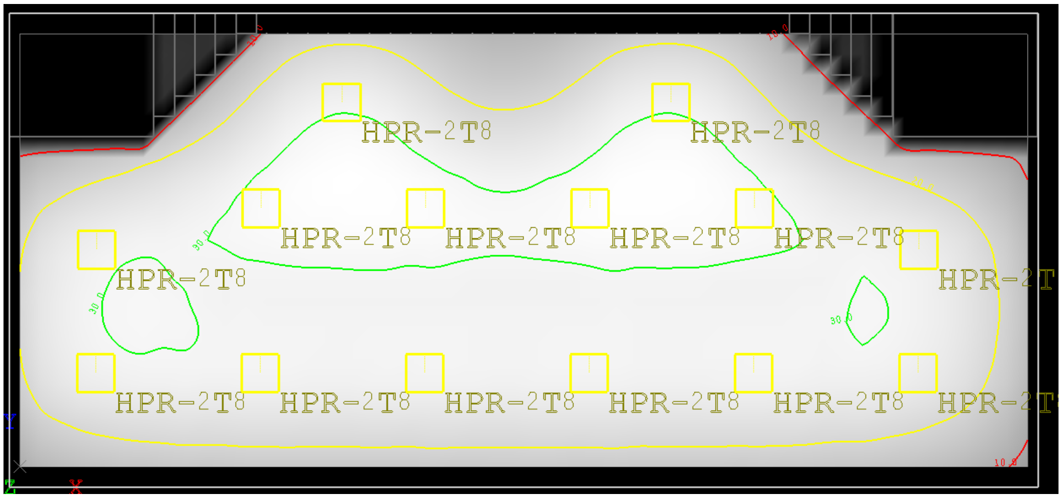

FIGURE 1. DIRECT REPLACEMENT: 23 FC AVG. TASKS <35 FC, 0.45 W/SF

While extremely efficient, this design failed to provide the added light levels needed for the workstations. The illumination is too diffused and not focused on the work area. Such overhead lighting forces the use of task lighting attached to the workstation, but the workstation configuration does not readily allow this.

GENERAL LIGHTING COMBINATION SCHEME RECESSED AND SUSPENDED

This is a variation resulting from a field meeting with Finelite. It is a combination of the Finelite 2x2 and pendant lights series 16 and 12. Several studies of increasing light and power levels were carried out from data provided by Finelite.

The first design (V2.1) shown in Figure 2 is the most aggressive, with a small number of single-lamp 2x2 luminaires and single-lamp pendant lights over each workstation. The average light level is less than 10 fc, and task light levels are between 20 and 40 fc.

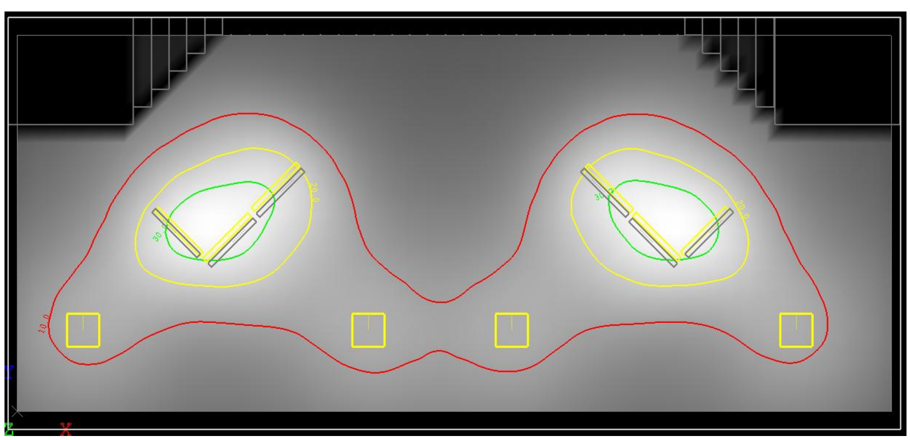

FIGURE 2. SCHEME V2.1: 12 FC AVG., TASKS <40 FC, 0.21 W/SF

This design is inadequate for both task and ambient lighting. Another design (V2.2), represented in Figure 3, having a larger number of single-lamp 2x2's surrounding pendant downlights for the desks produces an average light level of 18 fc, and the single downlight lamp pendants raise task light levels to 30-40 fc, slightly lower than existing average light levels, but a significant energy improvement.

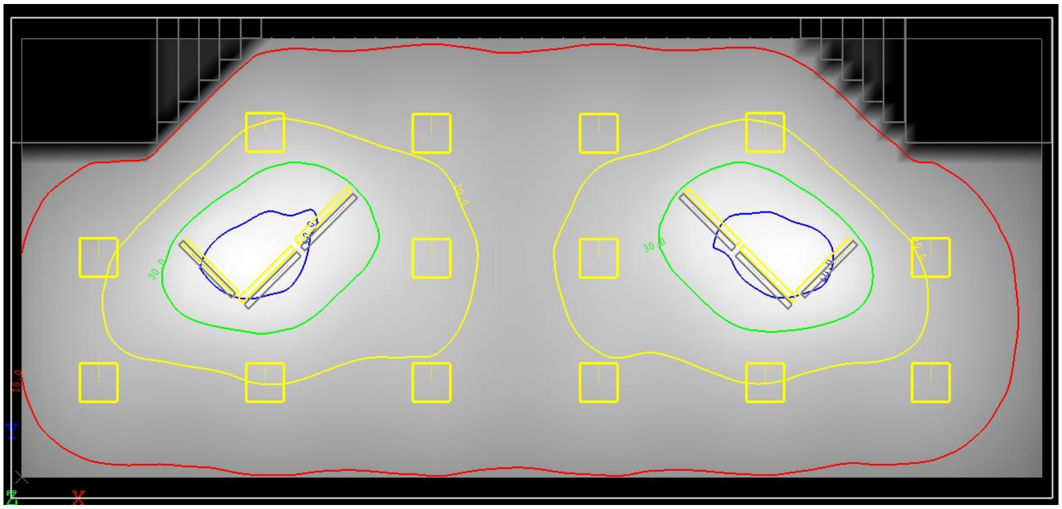

FIGURE 3. SCHEME V2.2: 18 FC AVG., TASKS 30-45 FC, 0.32 W/SF

Figure offers another design, V2.3 that adds two-lamp indirect lighting in the pendant and reduces the number of 2x2's. This design assumes the uplight and downlight are separately switched. Two analyses were made: V2.3a, with the uplights at 50% power/light, and V2.3b, with the uplights at full light, as shown in Figure . Both produce light levels needed to meet project criteria, with the added benefit that they could be different dimmed scenes of the same lighting system.

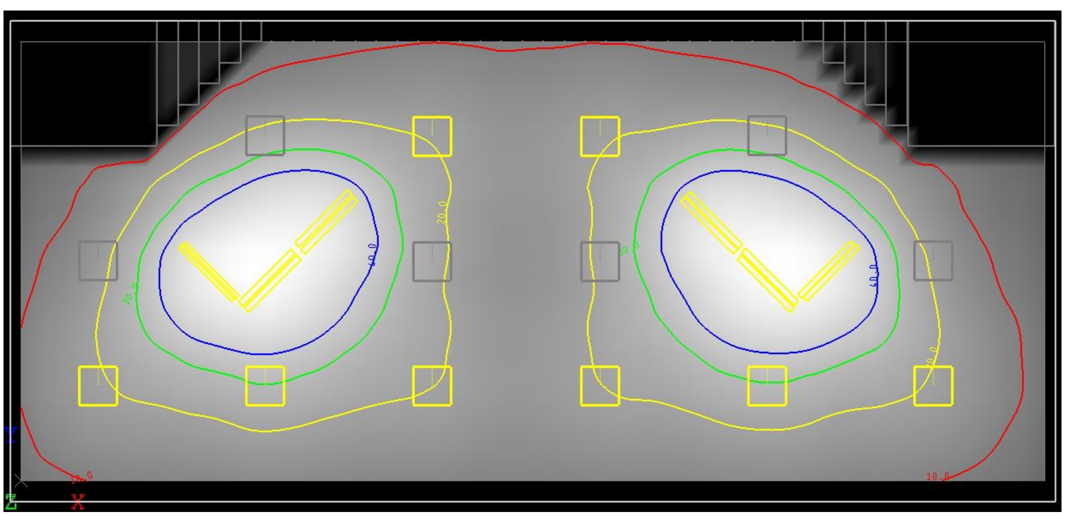

FIGURE 4. SCHEME V2.3A (UPLIGHT DIMMED): 23 FC AVG., TASKS >40 FC, 0.45 W/SF

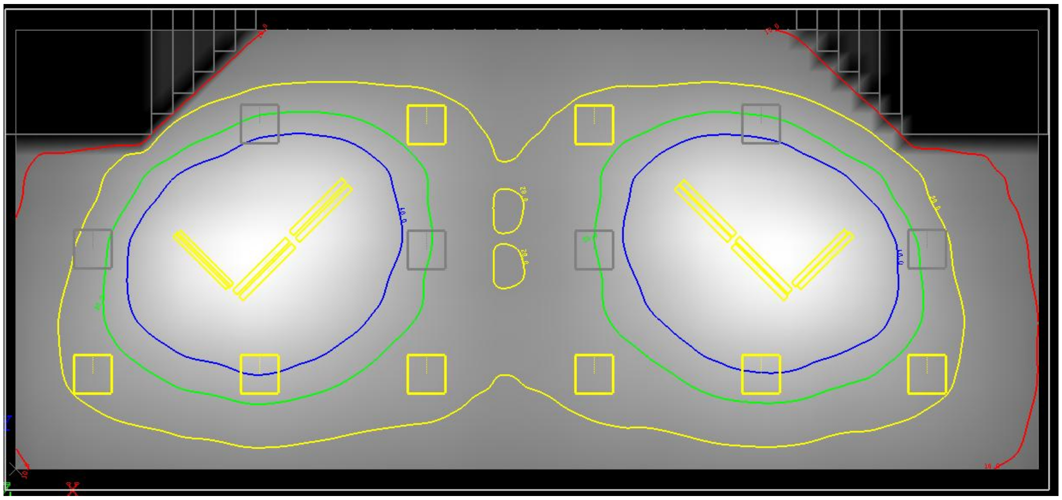

FIGURE 5. SCHEME V2.DB: 31 FC AVG., TASKS >40 FC, 0.60 W/SF

GENERAL LIGHTING FINAL DESIGN

About the time these conventional designs were being evaluated, a breakthrough (better and more reliable performance of the LED lamps and improvements in the heat-sink in the fixture design) in LED luminaire design permitted round downlights to produce adequate lumens for general lighting. The final design, similar to Scheme V2.3 and shown in Figure and Figure , employs downlights in place of the 2x2 fluorescent luminaires and a direct/indirect pendant light over the workstation. Although not quite as efficient as the Finelite 2x2, the LED downlight creates a 'quiet ceiling' of superior appearance and dressiness not possible with the 2x2 fixtures. Like the Finelite V2.3 design, analysis was done with designs using 50% uplight tuning and 100% light output.

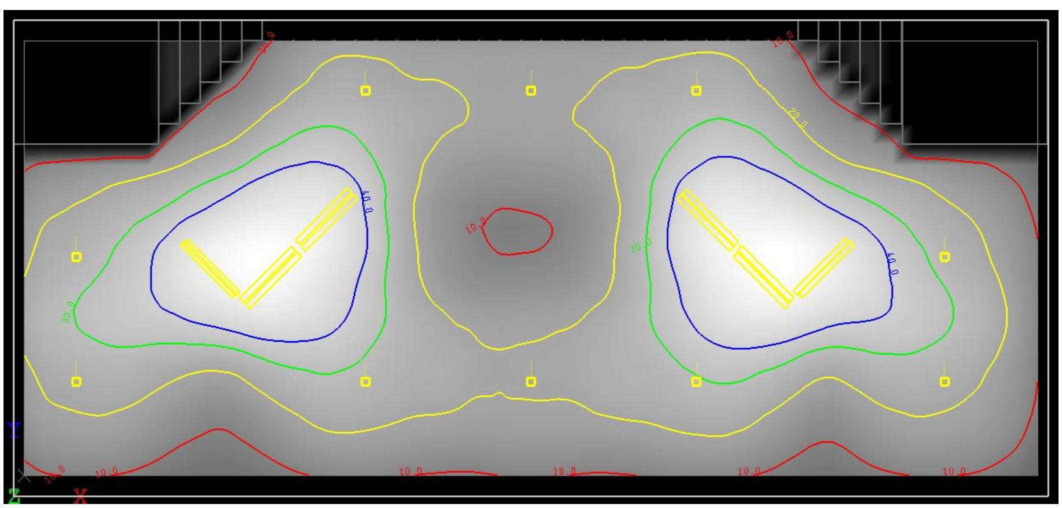

FIGURE 6. FINAL DESIGN (UPLIGHT DIMMED): 24 FC AVG., TASKS >40 FC, 0.50 W/SF

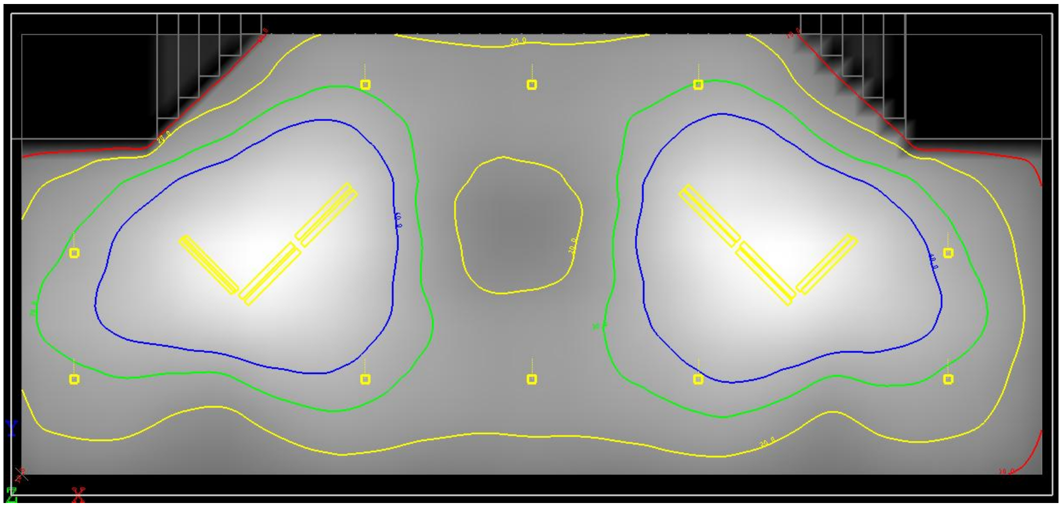

FIGURE 7. FINAL DESIGN: 34 FC AVG., TASKS >40 FC, 0.62 W/SF

MAIN CONFERENCE ROOM LIGHTING

The central conference room is also referred to as the 'video conferencing room.' It is equipped as a high-performance board and meeting room with multiple camera video conferencing capabilities.

The original lighting is a mixture of project-standard 2x2 luminaires and special VTC-style 2x2 luminaires in the ceiling over the conference table, which is in a raised coffer and uplighted around its perimeter with a fluorescent cove light. Under the perimeter soffit, compact fluorescent downlights created a scallop pattern on the walls. The busy ceiling and inconsistent light on the walls were considered aesthetically inferior and deserving of improvement. A minimum of additional ceiling work (new ceiling tiles and under-soffit work) was authorized. Among the room's performance requirements was the need for good camera recognition of faces without shadowing, high task-light levels on the conference table for detailed paperwork, and dimmable scenes for a variety of meeting types including social events and high-impact video programs.

The most obvious change replacement was recessed 2x2 ceiling luminaires with suspended direct-indirect fluorescent pendant lights (type F4). When combined with the existing cove lights (F5), the general and diffuse light provides superior diffuse light with shadowless face lighting when cameras are in use. When lower light levels are needed, these systems can be dimmed or extinguished, with recessed task accent lights (A1) and circulation lights (L1) serving the highlighting and wayfinding needs for darker scenes and social moods. The result is an orderly and attractive ceiling. The existing Lutron dimming, scene-selecting Grafik Eye system was preserved and connected to the new lighting, as shown in Figure .

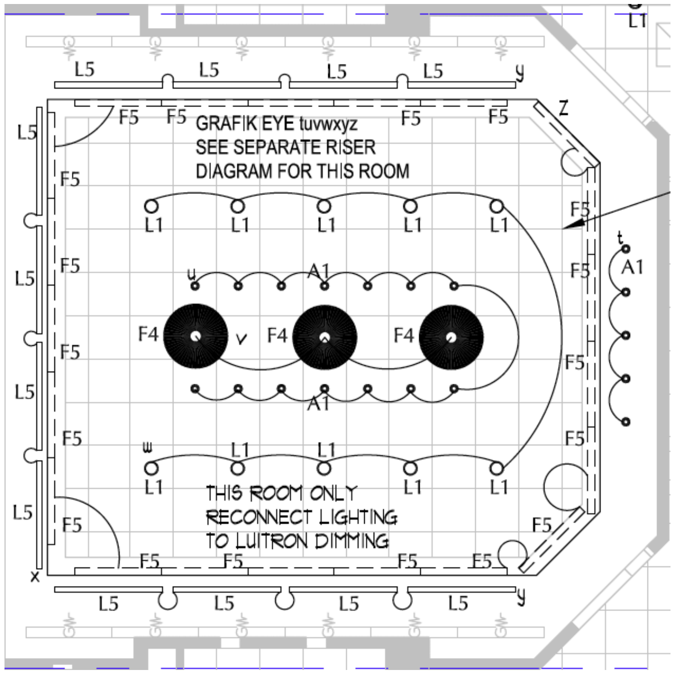

FIGURE 8. RELIGHTING PLAN, VIDEO CONFERENCE (BOARD) ROOM

The following figures show photographs of the executive offices. Figure shows photographs of the conference room before and after the lighting redesign project.

FIGURE 9. (LEFT) ORIGINAL MAIN VTC CONFERENCE ROOM (RIGHT) ENERGY EFFICIENT RELIGHTING

The most unusual lighting system added to the project is type “L5”, a linear LED wall washer that produces extremely even vertical illumination on the side and end walls, as shown in Figure 1.

FIGURE 1. LED LINEAR WALLWASH

FIGURE 2. RELIGHTED MAIN VIDEO CONFERENCE ROOM (LOOKING TOWARDS BACK WALL)

In Figure 2, note the two art accent lights 'monopoints' on either side of the window. These are 20-Watt (W) LED luminaires designed for retail and museum display use. The larger downlights are also LED.

SECURE ELEVATOR ENTRANCE

There are several elevators devoted to assuring executives and VIP's secure transfer from parking to the executive suite. This special reception area was redesigned and visually upgraded using compact fluorescent pendant lights, as shown in the before and after photographs in Figure 3.

FIGURE 3. (LEFT) ORIGINAL SECURE ELEVATOR LOBBY (RIGHT) REDESIGNED ELEVATOR LOBBY

OTHER LIGHTING SYSTEMS

Under existing conditions, the 'other' lighting systems in the space included:

- MR16 art accent lights, both recessed and monopoint, to illuminate the suite's art collection
- Compact fluorescent down-lights in circulation areas, toilet rooms and CEO offices
- Incandescent wall sconces at restroom vanities
- Compact fluorescent wall sconces with faux alabaster plastic shades in common circulation area

These lighting systems were also improved with more efficient and attractive luminaires.

Table 3 shows the lighting fixture schedule and installed Watts.

TABLE 3. LIGHTING FIXTURE SCHEDULE AND INSTALLED WATTS

TAG	LUMINAIRE DESCRIPTION	WATTS	NUMBER	FIXTURE WATTAGE
F1	NOM 8'x 4' system pendant L shape	256	6	1536
F1A	NOM 8'x 4' system pendant C shape	342	4	1368
F2	NOM 4'x 4' system pendant L shape	228	6	1368
F2A	NOM 8'x 4' system pendant L shape	256	2	512
F3	NOM 8' long system pendant	228	9	2,052
F4	NOM 36" Diameter indirect chandelier	232	3	696
F5	Cove Light 4' units	30	34	1,020
F6	NOM 24" diameter uplight pendant	56	10	560
L1	LED recessed downlight	20	111	2,220
A1	Low voltage halogen	22	19	418
H1	Ceramic Metal Halide accent light	22	26	572
H2	Ceramic Metal Halide accent light	22	36	792
L4	LED accent light	20	49	980
L5	LED linear wallwash	60	12	720
L6	LED undercabinet (per foot)	6	71	426
M	Sconce Main Area	35	8	280
B	2' x 2' Troffer	20	8	160
N	Sconce Vanity	20	22	440
	Total Wattage of Installation			16,180

LIGHTING CONTROLS

All spaces are equipped with digital lighting controls for all lighting with motion sensors, manual override, tuning and computer programmable control. The following summarizes the luminaire controls strategy:

- The entire lighting system is universally tuned down by 20%.
- All open office workstations were tuned to meet the preferences and needs of the occupant. Each workstation is equipped with an occupancy sensor that turns on lights to the occupant's preferred light level when someone arrives at the desk and reduces lighting levels to 15% power when the space is unoccupied.
- All private offices have motion sensors set to occupancy mode, which operates the lights with an auto-on when occupied and auto-off when vacant. Manual dimming is provided at a wall-mounted control unit.

- The conference room reused an existing Lutron scene-selecting GRAFIK Eye system. This relies on the user to select the setting appropriate to the activity - videoconference, meeting, etc.
- All public areas are on a time-clock schedule that turns off all art and decorative lighting after work hours and on weekends.

TECHNICAL APPROACH/TEST METHODOLOGY

In order to characterize the savings resulting from Office of the Future pilot projects, NBI devised a Measurement and Verification (M&V) protocol that evaluates savings resulting from each type of measure implemented (e.g., lights or plug-load measures) as well as the entire package. Figure 4 depicts the creation of baselines and implementation of different measure types in order to assess the impact of each type of measure, as well as the entire package. This diagram represents the idealized approach when all measure types of the OTF are implemented.

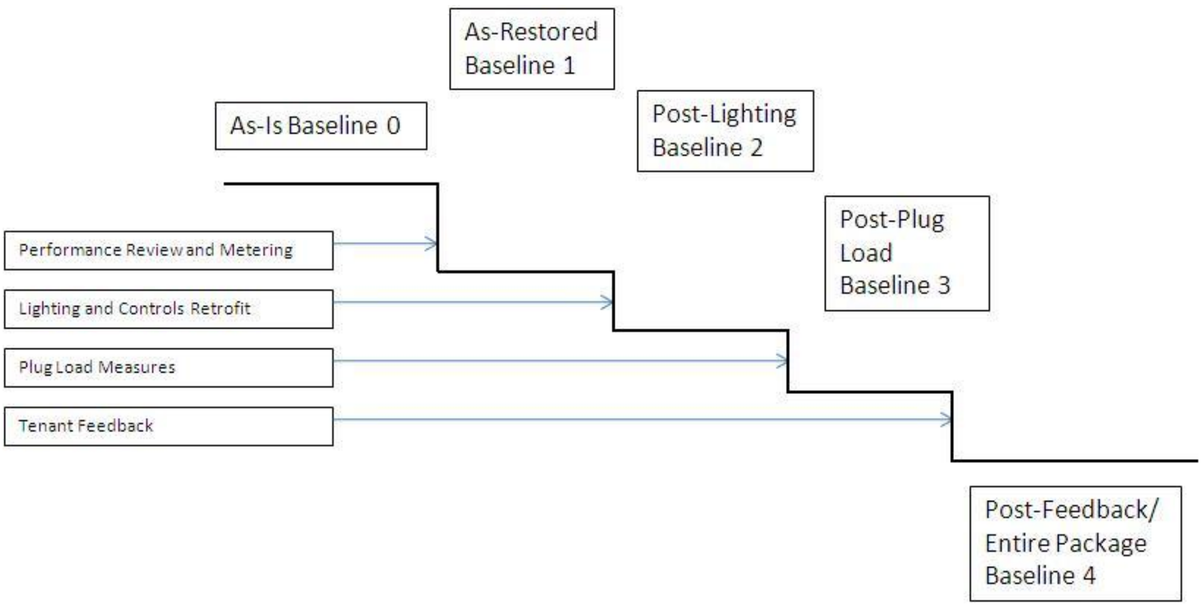

FIGURE 4. A GRAPHIC SHOWING THE M&V BASELINE METHOD FOR EVALUATING OTF PILOT INSTALLATIONS

We recommended a formal protocol for assessing performance in the pilot projects 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 in order 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, except in the case of the plug loads where two weeks was deemed sufficient. The reason for the two weeks is that plug load does not typically change. It is more a constant load and the two week timeframe is a standard industry-accepted length of time when establishing plug load baseline usage.

Metering installed at the whole-building and office-space levels established the 'As-Is' baseline and 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 dimming is used. 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 to establish 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 and also to compare the entire package against the 'As-Is' and 'As-Restored' baselines.

NBI conducted the M&V of the GO4 executive suite pilot project in accordance with the general procedure developed for OTF pilot projects but simplified the approach to reflect the realities of this project. At the executive suite pilot installation, the lighting and controls system were installed simultaneously. No HVAC review was conducted and no plug-load measures were introduced as part of this pilot study.

METERING EQUIPMENT AND DATA ACQUISITION

Metering equipment was installed in order to separate lighting from outlet loads. The following equipment was installed on the fourth floor at GO4:

- Obvius AcquiSuite Server A8812-GSM with GSM cellular internet modem
- Veris meter H8163-CB with Modbus output on the office plug-load 120/208 VAC service panels 4LNA and 4LNB
- Veris meter H8163-CB with Modbus output on the office plug-load 120/208 VAC service panel 4LNC
- Veris meter H8163-CB with Modbus output on the office lighting-load 277/480 VAC service panel 4HN
- Obvius ModHopper Wireless-Mesh Data Acquisition units that relay Modbus communications back to the AcquiSuite Server

The metering provided the following data points for lighting and outlet loads at 15-minute intervals:

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

In an effort to eliminate delays and errors associated with transferring data files, data from all OTF pilot projects was gathered and entered into a single remote database. The data was used not only for M&V but also to provide feedback to the lighting designer and installer about system performance shortly after the installation.

The measured results also revealed the complexity of isolating and measuring loads. High power demand observed between 6:00 p.m. and 6:00 a.m. and on the weekends seemed to indicate the lights were not turning off at night. After due diligence that included a follow-up investigation of the panel and discussions with the lighting installers, it was determined there must be an unknown, persistent load on the panel being metered.

This persistent load was present initially and during the performance lighting period. After detailed investigation it was found that several non-lighting circuits had been added to the panel without proper notation. While the persistent load was identified, the investigation was not conclusive enough to estimate its magnitude.

Because it could not be quantified, the persistent load was not accounted for in the analysis. The measured results are included in the analysis that follows and are therefore conservative – meaning that actual savings from the lighting redesign project are expected to be even greater than the measured results suggest.

Figure 5 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.

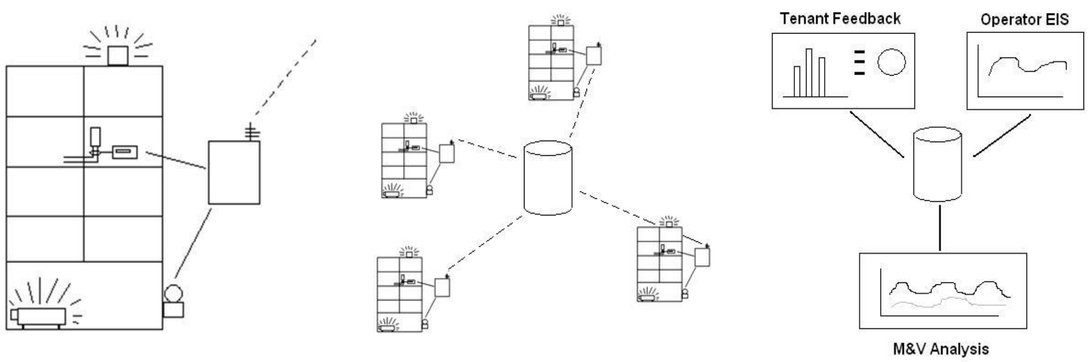

FIGURE 5. GRAPHIC DEPICTING THE DATA ACQUISITION PLAN FOR THE OTF PILOT PROJECTS

DATA ANALYSIS AND RESULTS

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

The monitoring period was March 15, 2010 through April 1, 2011. The existing baseline period was March 15, 2010 through October 8, 2010, and the lighting redesign performance period was January 3, 2011 through April 1, 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 6:00 a.m. and 6:00 p.m. In this report, this time period is referred to as the 'occupied hours', since it is the most likely time the office space is in use.

TITLE 24 CODE CALCULATIONS

In California, Title 24 Building Energy Code 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 and 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 executive suite relighting project, the Title 24 Code Calculations are as follows. Table 4 shows the Title 24 Area Category Calculations for the executive suite.

TABLE 4. EXECUTIVE SUITE LIGHTING REDESIGN AREA CATEGORY METHOD CALCULATIONS

Area Category	Watts / Square Foot	Area in Square Foot	Allowed Watts
Open Offices	0.9	6,497	5,847
Private Offices	0.9	5,656	5,090
Multipurpose Room	1.4	875	1,225
Toilets	0.6	1,301	781
Kitchen	1.6	152	243
Workroom	1.2	154	185
Decorative Additional Wattage Allowed			696
Totals		14,635	14,067

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. 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.

The total of all control credit watts for the executive suites is 3,609 W. This is comprised of 2,183 Watts for non-daylight controls and 1,426 Watts for daylight controls. Table 5 illustrates the calculations associated with the non-daylighting power adjustment factors while Table 6shows the daylighting power adjustment factors.

TABLE 5. NON-DAYLIGHT POWER ADJUSTMENT FACTORS FOR CONTROLS

Room Area	Lighting Control Description	Room Area	Watts of Controlled Lighting	PAFs	Control Credit Watts
Multi-purpose	Multi- Level motion dimming	875	2826	0.25	706
Office	Multi-level motion dimming	6497	4064	0.25	1,016
Private Office	Multi-level motion dimming	3393	1842	0.25	461
Total	Non-Daylight				2,183

TABLE 6. DAYLIGHT POWER ADJUSTMENT FACTORS FOR CONTROLS

Room Area	Location	Daylight Area	Visual Transmittance	Effective Aperture	General Lighting Power Density	Watts of Controlled Lighting	PAFs	Control Credit Watts
Offices	Perimeter	6,497	0.50	0.383	0.9	407	0.35	1,426
Total	Daylight							1,426

In the executive offices lighting redesign project, the PAFs and resulting control credit watts (3,609 Watts) were used to downwardly adjust the installed lighting power (16,282 W) as outlined in
Equation 1.

EQUATION 1. ADJUSTED INSTALLED LIGHTING POWER FOR GO4 RELIGHTING PROJECT

Installed Lighting Watts – Lighting Control Credit = Adjusted Installed Lighting Power
16,282 W – 3,609 W = 12,673 W

CONNECTED LOAD COMPARISON

Table 7 shows the connected and calculated lighting power density (LPD) of the existing and retrofitted lighting systems, along with the 2008 Title 24 code requirements calculated with and without power adjustment factors. As previously noted, some practitioners use power adjustment factors to increase the allowable lighting connected load; however in this case the controls credits adjusted the allowed lighting connected load downward.

TABLE 7. CONNECTED AND CALCULATED LIGHTING POWER DENSITIES

	Existing Lighting	T-24 2008	Redesign as Installed	Redesign Adjusted for Controls Allowances
Connected Load	27,072 Watts	14,067 Watts	16,282 Watts	12,673 Watts
Calculated LPD (W/sf)	1.85 W/sf	0.96 W/sf	1.11 W/sf	0.87 W/sf
Compared to Existing Lighting System	-	-	- 40%	-53%
Compared to Title 24	+ 92%	-	+ 15%	- 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 +92%. 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 power adjustment factors) by -53% 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.

- While the connected load of the new system exceeded Title 24 by +15% 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 for controls to reduce energy. It also shows the flexibility that Title 24 controls allowance provides contractors in their design by permitting a higher connected load if it is controlled. Designers and contractors then have more options for system selection for the space, and the focus becomes the control of the lighting rather than the nominal wattage.

- This estimate of the contribution of 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 executive suite lighting redesign project allows for a comparison of the real change to the space energy use. Table 8 shows the average and peak lighting power compared to the existing system. As explained earlier, all of the measured results can be considered conservative estimates because they include an unidentified persistent load in the circuit panel.

TABLE 8. 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	0.79	1.33	0.94	0.63	0.58
Executive Suite Redesign	Measured	0.44	0.66	0.50	0.38	0.36
Existing System Compared to Redesign		- 38%	- 50%	- 47%	- 40%	- 38%

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

- When compared with the existing system, the new system consistently reduced power by at least 38-50%, with the range varying by occupied and unoccupied periods and weekday versus weekend days.
- The high values for the overnight and weekend power are assumed to be due to the unexplained persistent load in the circuit panel. This same load is expected to be present in the day average and peak numbers.

MEASURED LIGHTING PERFORMANCE COMPARED TO CODE LIGHTING POWER DENSITY CALCULATIONS

Comparing measured results to the code-installed capacity provides insights as to how effective Title 24 power adjustment factors are in estimating the contribution of savings from controls. Table 9explains the difference between the code calculations and the conservative measured results.

TABLE 9. 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	0.96	0.96	0.96
EXECUTIVE SUITE LIGHTING REDESIGN	Measured	0.44	0.50	0.66
Percent Change		- 54%	- 48%	- 31 %

- The absolute peak power measured during the performance period January 3, 2011through April 1, 2010 was 0.66 W/sf on January 28th, 2011 at 9:45 a.m.
- The peak lighting demand of 0.66 W/sf is at least 31% better than the 2008 Title 24 level LPD of 0.96 W/sf. The average occupied power density measured in the field performed at least 48% better than code calculations.
- This suggests that code calculations with power-factor adjustments do not accurately reflect the measured results that were achieved with advanced lighting controls in this project.
- 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 exceeds (is better than) the performance level of a code-minimum system. It also serves as the basis of utility incentives when code is triggered by a project. Although the code has increased in stringency thus making it more difficult to achieve dramatic saving beyond the new higher baseline, 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 power adjustment factors to reduce the effective connected load to a level called the 'Adjusted Installed Capacity' in this report.

Code requirements in 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 would be used in a whole building model to project overall building performance.

For this energy analysis SCE relied on the use-profiles outlined in the Database for Energy Efficiency Resources[2], 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) 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 make 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.

As explained earlier, it was determined that an unusual persistent load was present on the electrical panel that supplied lighting energy to the space. A detailed investigation was undertaken and it was found that non-lighting circuits had been added to the panel without proper notation.

Figure 6 visually demonstrates the comparison between the metered and code-level performance using a weekday use-profile. In addition, Figure 6 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, then co-plots these with the relevant connected load levels, shown as straight horizontal lines as they are fixed numbers in W/sf. Again, the measured results are considered conservative due to a persistent load of unknown size that was discovered in the panel. This would have the effect of lowering the entire measured performance line.

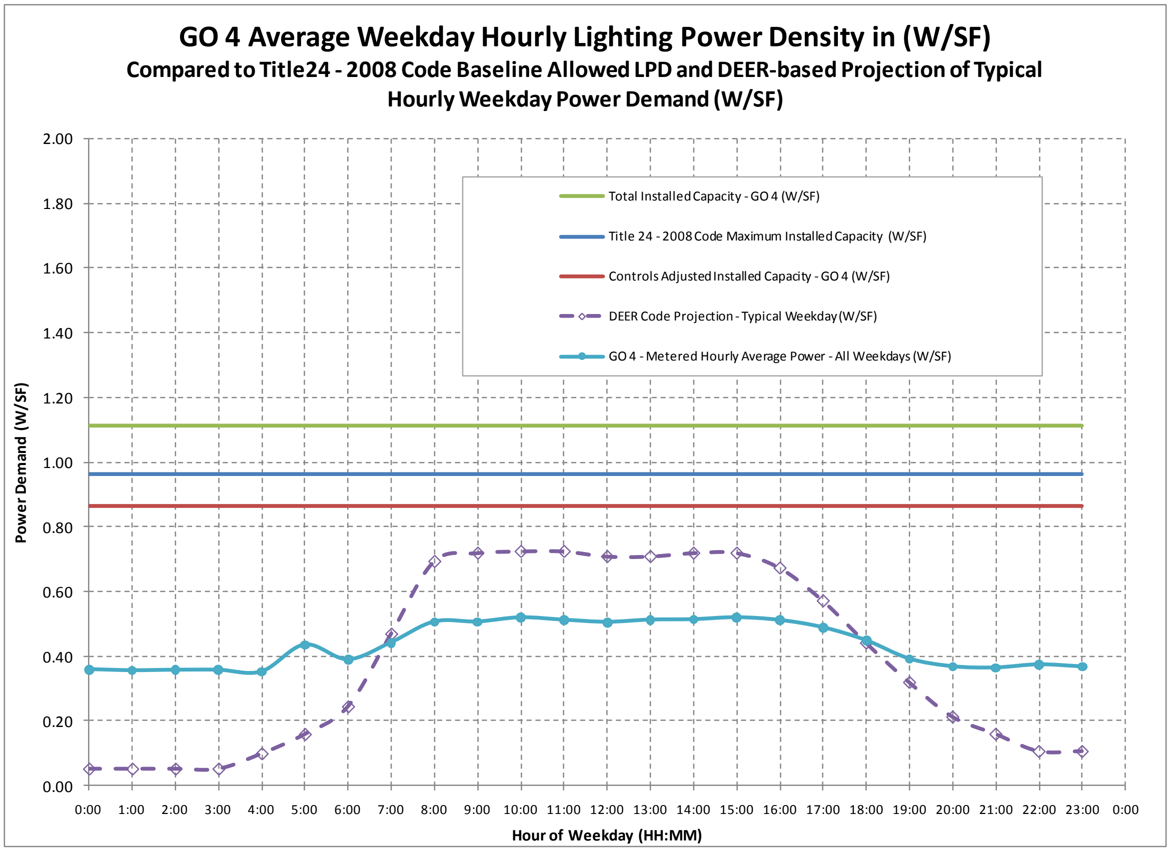

FIGURE 6. A CHART OF WEEKDAY ES RELIGHTING AVERAGE POWER DENSITIES WITH VARIOUS CODE BASELINE COMPARISONS

PLUG LOAD DATA

While no plug-load control measures were installed at GO4, plug-load energy use was monitored before and after installation of the lighting retrofit; results are reported for academic reference. The data reveals that plug-load energy use is quite low in the GO4 office. This may be due to the low occupant density in the space.

Table 11 shows daily metrics for the performance of the GO4 plug loads, both before and after the lighting redesign project.

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	0.32	0.69	0.38	0.26	0.23
GO4 Lighting Redesign	Measured	0.38	0.70	0.46	0.29	0.26
Existing System Compared to Redesign		- 17%	- 2%	- 21%	- 12%	- 16%

DISCUSSION

REDESIGN COMPARED TO CODE

In California, Title 24 establishes a maximum lighting connected load level. Power Adjustment Factors (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 executive suite lighting redesign 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 31% less than code calculations.

LIGHTING REDESIGN COMPARED TO EXISTING CONDITIONS

The new system consistently reduced power compared with the existing system. This ranged between 38% and 50%, 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, as the California Energy Use Survey[3] suggests that lighting represents 27% of commercial office energy use in California.

REDESIGN COMPARISON TO PREDICTED CODE ENERGY PERFORMANCE

Code calculations in W/sf 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[4] database provides well-documented estimates of energy and peak demand savings and has been designated by the California Public Utility Commission as its source for deemed and impact costs for program planning. It uses a methodology for predicting energy performance given various space types that were used to estimate a code-predicted energy use of the executive suite office over time.

FEEDBACK ON MEASURED PERFORMANCE

Feedback on measured performance is critical to optimizing savings. The 15-minute interval data collection provided an opportunity to engage in metering-based feedback. Test staff was able to review the daily download of metered data and provide feedback on system performance to lighting designers and facility managers. In this case, the feedback loop led to the identification of an unknown persistent load in the panel that was not properly notated.

A temporary installation or use of existing metering for targeted system adjustment purposes may be a valuable approach to study in subsequent pilots or similar research projects.

PLUG LOADS

Plug loads are an opportunity for savings. The plug-load results revealed that overall energy use and power density due to plug loads was quite low in the GO4 office. This is likely due to the low occupant density. Despite this low plug-load use, it appears there are still opportunities to capture additional energy savings by turning off equipment 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.

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 of the commercial energy use in California. In SCE service territory, offices represent 18% of the commercial square footage (385,110,000 SF) and 21% of the total commercial energy use (6,162 GWh) [5].

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.

CONCLUSIONS

The measured results of this GO4 project provide evidence that a high-performance lighting design with controls delivers savings considerably beyond code-calculated estimates.

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. Test staff used a Database for Energy Efficiency Resources (DEER) profile to estimate a code energy performance to 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

The digital lighting controls for all spaces with motion sensors, manual override, tuning and computer programmable control was the technology most responsible for reduced energy savings. The use of LED options, only recently available for down-lights, contributed significantly to the opportunity for savings. This demonstrates the importance of a 'system' rather than isolated technologies. Other findings include:

COMPARED-TO-CODE POWER CALCULATIONS

- The executive suite lighting redesign retrofit control system demonstrates that controls optimize energy savings potential and provide much better performance than is estimated by code calculations.
- The project confirms 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 lighting redesign calculated savings over the 2008 Title 24 baseline was just 9%.
- The measured power use of the new system performed significantly better than the code design power maximum (.96 W/sf).
    - Average power was at least 54% less (.44 W/sf) for a 24-hour period than the code-level average.
    - Power between the hours of 6:00 a.m. and 6:00 p.m. was at least 48% less (.50 W/sf) for a 12-hour period than the code-level power.
    - Peak power was at least 1% less (.66 W/sf) than the code-level power. This was the maximum measured in a 15-minute period and occurred on January 28, 2011 at 9:45 A.M.

- The code estimate of contribution of savings from controls does not reflect the measured performance of the high-performance lighting system with controls as measured in the field.

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 existing system are valuable program and market information.

- The previous system connected load exceeded the Title 24 2008 allowance by +92%. 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 power adjustment factors) by -53% 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 new system consistently reduced power compared with the existing system between -38% and -50%, 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 ensure that the lighting system’s energy savings are optimized.
- Metering data was critical in the assessment of this space and the identification of components that are reducing the energy savings target and potential.
- System-level metered data can readily provide an easy graphic display of problem areas such as night lighting energy use.

PLUG LOADS

- Plug-load energy use and power density are low at the executive suite office, likely due to the low occupant density, yet there still appear to be opportunities to reduce plug load energy use at night and on weekends.

THE WORK ENVIRONMENT

A lighting redesign has impact on the work environment through changes in illumination levels, contrasts and aesthetics. Some examples are:

- The previous lighting provided only 30-40 fc – inadequate by today's standards at the task level. Light levels at the desks of executive assistants were marginal for ordinary paperwork and inadequate for fine and detailed paperwork. The redesign improved light levels to a more uniform and effective level at the desktop.

- The existing compact fluorescent downlights in the conference room created a scallop pattern on the walls. The busy ceiling and inconsistent light on the walls were considered aesthetically inferior.

- The new conference room system has even illumination on the side and end walls, providing well-lighted surfaces and improved face lighting when cameras are in use. New recessed task accent and circulation lights serve highlighting and wayfinding needs for darker scenes and social events.

- The visual impact of the redesign of the project spaces, including hallways, reception and elevator area, creates an updated and more modern high-end look appropriate to Class A Executive Offices types, while increasing energy efficiency.

RECOMMENDATIONS

The results of this pilot and other OTF savings evidence should be provided to the Energy Efficiency Program staff members representing the various sponsors of the OTF collaborative. This report provides critical information that will inform utilities that are considering routes to incentivize highly-controlled lighting solutions and the broader OTF TI-directed program that also addresses office plug loads, energy feedback to occupants, and overall building energy.

A collaboration of the OTF consortium partners as well as industry actors should be considered to create and promulgate technical best practices and case studies resulting from this and other demonstration projects. This should entail some type of metering-based feedback and acceptance testing to ensure lighting controls is 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. Without this metering-based feedback, the unidentified persistent load would not have been identified in this pilot project.

The controls allowance for 2008 Title 24 was not accurate in assessing the benefit of the 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.

A more detailed study of highly controlled lighting solutions and plug loads is necessary. Suggested studies include:

- Measurement of power and energy performance throughout the year to better understand if there are significant seasonal variations in various locations.
- 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.

APPENDIX A: AVERAGE WEEKDAY POWER DENSITY

NAME	GO4
Sq.Footage	14,635
From	1/3/11
To	4/1/11

Time	DEER Code Projection - Typical Weekday (W/SF)	GO 4 - Pre-Retrofit: Metered Hourly Average Power - All Weekdays (W/SF)	GO 4 - Post-Retrofit: Metered Hourly Average Power - All Weekdays (W/SF)	GO 4 - Pre-Retrofit w/ Adjustment for 0.17 W/SF Baseload	GO 4 - Post-Retrofit w/ Adjustment for 0.17 W/SF Baseload
0	0.05	0.59	0.36	0.42	0.19
1	0.05	0.57	0.35	0.40	0.18
2	0.05	0.60	0.36	0.43	0.19
3	0.05	0.65	0.36	0.48	0.19
4	0.10	0.62	0.35	0.45	0.18
5	0.16	0.62	0.44	0.45	0.27
6	0.25	0.64	0.39	0.47	0.22
7	0.41	0.76	0.44	0.59	0.27
8	0.64	0.95	0.51	0.78	0.34
9	0.67	0.97	0.51	0.80	0.34
10	0.67	0.99	0.52	0.82	0.35
11	0.67	0.99	0.51	0.82	0.34
12	0.67	0.99	0.51	0.82	0.34
13	0.67	0.99	0.51	0.82	0.34
14	0.67	1.00	0.52	0.83	0.35
15	0.67	0.99	0.52	0.82	0.35
16	0.61	0.97	0.51	0.80	0.34
17	0.52	0.89	0.49	0.72	0.32
18	0.39	0.79	0.45	0.62	0.28
19	0.28	0.66	0.40	0.49	0.23
20	0.18	0.61	0.36	0.44	0.19
21	0.14	0.60	0.36	0.43	0.19
22	0.09	0.63	0.37	0.46	0.20
23	0.09	0.62	0.37	0.45	0.20

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