CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Draft Measure Information Template – Lighting Retrofits

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team, March 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Draft CASE Report—
Lighting Retrofits

2013 California Building Energy Efficiency Standards

[California Utilities Statewide Codes and Standards Team, March 2011]

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FIGURES

1. Overview

a. Measure Title	Lighting Retrofits
b. Description	Non-residential spaces in which 10% or more of the luminaires or ballasts are replaced would be required to comply with the same requirements as new construction, in terms of lighting power densities and lighting controls. There would be an exception for small projects (less than 30 ballasts or luminaires) to avoid imposing onerous requirements on small businesses, and to avoid maintenance crews in large buildings having to pull permits for routine maintenance. There is a proposed exception such that lighting controls do not have to be installed in spaces that have asbestos in the ceiling. The added cost of dealing with asbestos removal would outweigh the value of savings from lighting controls.
c. Type of Change	The suggested change to the lighting retrofit requirements is a mandatory measure, required for any non-residential building that is performing a lighting retrofit. Buildings using both the prescriptive and performance method would need to comply.

<table>
<tr>
<td>d. Energy Benefits</td>
<td>
The energy benefits will be determined for the final report.
The proposed change will not significantly affect natural gas use. There is precedent for ignoring the interactive effects (i.e., that less lighting will reduce internal gains, thereby increasing heating and decreasing cooling needs) for the IOU lighting programs. This precedent is followed here, particularly because the savings will occur in the evenings and on Sundays, when commercial thermostats will be setback.
Analysis was done for two office buildings - a small office (8,200 sf) and a large office (34,000 sf). These were used as prototypes, because these are the types of non-residential buildings in which the proposed change will be the most expensive to implement. By showing that the proposed change is cost-effective in an office building, we show that the proposed change is cost-effective in all types of non-residential buildings.
These energy savings are based on the following assumptions:

Fraction of the total lighting load that would not be shut off by occupants during unoccupied times without an automatic shut off is 22%
Of the lights left on overnight 15% is non-egress lighting and 7% is for egress
Automatic shut off only applies to non-egress lighting
The number of hours in which offices are unoccupied is 8 hours each night, and all day Sunday, for a total of 4,056 hours per year
Retail is unoccupied 8 hours every night
Warehouses are unoccupied 8 hours every night

Additional savings not taken into account for these calculations include:

Savings from photocontrols
Savings from providing local area controls or multi-level control

<table>
<tr><th></th><th>Electricity Savings (kwh/yr)</th><th>Demand Savings (kw)</th><th>Natural Gas Savings (Therms/yr)</th><th>TDV Electricity Savings</th><th>TDV Gas Savings</th></tr>
<tr><td>Per Unit Measure</td><td>Not Applicable</td><td>Not Applicable</td><td>Not Applicable</td><td>Not Applicable</td><td>Not Applicable</td></tr>
<tr><td>Per Small Office Building (8,200 sf)</td><td>5,207</td><td>123</td><td>NC</td><td>$9,004</td><td>NC</td></tr>
<tr><td>Per Large Office Building (34,000 sf)</td><td>21,588</td><td>510</td><td>NC</td><td>$37,332</td><td>NC</td></tr>
<tr><td>Savings per square foot (Offices)</td><td>0.67</td><td>0.06</td><td>NC</td><td>$1.10</td><td>NC</td></tr>
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e. Non-Energy Benefits	The non-energy benefits of the proposed measure are not significant.

f. The proposed change does not have any potential adverse environmental impacts. Because the proposed energy measure will reduce electricity use, this will reduce electricity generation, and thereby have a small reduction in mercury emissions from coal-burning power plants, and in water consumption from electricity generation. However, because the primary benefit is energy reduction these environmental benefits are not considered here, and all material uses are shown as No Change (NC).

Material Consumption

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
Per Unit Measure	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Per Prototype Building	NC	NC	NC	NC	NC	NC

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

Water Consumption

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Unit Measure	Not Applicable
Per Prototype Building	NC

Water Quality Impacts

	Mineralization (calcium, boron, and salts	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	NC	NC	NC	NC
Comment on reasons for your impact assessment	See explanation above			

Air Quality

In lbs/Year, Increase, (Decrease), or No Change (NC)3:

	NOX	**SOX**	**CO**	**PM10**	**CO2**
Per square foot	0.00011	0.00064	0.00015	0.000050	0.39
Per Small office Model Building	1.0	5.7	1.4	0.4	3491
Per Large office Model Building	3.6	22	5.2	1.7	13189

g. Technology Measures	The proposed change does not encourage a particular technology, although it relies on a range of existing technologies that have not been included in previous Title measure analysis (for instance sentry switches for lighting, and wireless lighting controls). **Measure Availability:** The proposed requirements can be met using a range of currently-available technologies that are readily available throughout California. This was based on information collected from the RSMeans database and from interviewing representatives at several lighting manufacturers, including: (Cooper Controls, Douglas, Leviton, Hubbell, Square D, and WattStopper,). **Useful Life, Persistence, and Maintenance:** These control devices are not typically rated for a maximum life. We have assigned them a 15-year measure life in line with other lighting controls.
h. Performance Verification of the Proposed Measure	The proposed requirements should be verified on site to ensure that the lighting meets the lighting power density limits and that the controls function as intended. The same compliance forms that are used for new construction will work for retrofit projects, since the requirements for retrofits are a subset of the requirements for new construction. Nonresidential lighting compliance forms LTG-3C and LTG-2A and acceptance form LTG-1C are the relevant forms..

i. Cost-Effectiveness

The following shows the cost effectiveness of the proposed change. The supporting calculations are presented in the Cost Effectiveness Analysis in Section 3.6.

a	b	c		d		e		f	g	
Measure Name - Automatic Shut-off of non-egress lighting during unoccupied times	Measure Life (Years)	Additional Costs1– Current Measure Costs (Relative to Basecase) ($)		Additional Cost2– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional3 Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of4 Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per square foot	Per Proto Bldg	Per Unit	Per Proto Bldg	Per Unit	Per Proto Bldg		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
Small office – wireless shutoff (8,223 sf)	15	$0.51	$4,171	None	None	None	None	$8,412	$(4,241)	$(8,412)
Small office – line voltage shutoff (8,223 sf)	15	$0.54	$4,457	None	None	None	None	$8,412	$(3,955)	$(8,412)
Large office – wireless shutoff (34,000 sf)	15	$0.33	$11,350	None	None	None	None	$34,782	$(23,432)	$(34,782)
Large office – line voltage shutoff (34,000 sf)	15	$0.32	$11,034	None	None	None	None	$34,782	$(23,748)	$(34,782)

The proposed change will not significantly affect natural gas use. There is precedent for ignoring the interactive effects (i.e., that less lighting will reduce internal gains, thereby increasing heating and decreasing cooling needs) for the IOU lighting programs. This precedent is followed here, particularly because the savings will occur in the evenings and on Sundays, when commercial thermostats will be set back.

j. Analysis Tools	The proposed measure is mandatory, so analysis tools are not relevant, since the measure would not be subject to whole building performance trade-offs.
k. Relationship to Other Measures	This measure will not have a significant impact on other measures. Because lighting will be reduced, the heating needs of a building will increase slightly and the cooling needs will decrease slightly. However, because commercial buildings' cooling loads typically outweigh their heating loads in California, the interaction with HVAC measures would create additional savings, therefore the analysis presented here is conservative. In calculating the savings, we have reduced the available lighting power by 15%, to account for the "tuning" energy savings claimed by the Controllable Lighting CASE The proposed changes to the language of Title 24 should be read in conjunction with the changes proposed in other CASE reports for the 2013 standards. We have identified the following interactions between proposed measures: 1. **Annunciated Controls**: Energy Commission staff have proposed a change to Section 131(a) that would make "annunciated controls" no longer sufficient for the Area Controls requirement. The cost analysis for this CASE is based on distributed switches being installed during retrofits (i.e., to replace any existing annunciated switches). The costs in this report are therefore consistent with those that would be incurred if the Commission's proposed change to 131(a) is adopted. 2. **Egress Lighting:** The California Utilities are also proposing a change to the requirements for egress lighting, such that egress lighting would be required to be switched off when the building is unoccupied, and the lighting power density allowance for egress lighting would be reduced from the current value of 0.30W/sf of egress pathway to 0.05 W/sf. We have analyzed the costs of bringing existing lighting systems into compliance with this new requirement during a retrofit project, and have found it to be cost-effective.

2. Methodology

This section describes the methodology that we followed to assess the savings, costs, and cost effectiveness of the proposed code change. The key elements of the methodology were as follows:

- Review of Market Assessment and Program Evaluation Literature
- Online Survey of Retrofit Implementers
- Development of Office Models
- Energy Savings Analysis
- Cost Analysis
- Lifecycle Cost (LCC) Analysis
- Cost effectiveness
- Stakeholder meeting process

It is important to note that the terms alteration, renovation and retrofit are used throughout this report. They are all intended to refer to the same type of projects. The reason for the varying language is that retrofit is the term commonly used by contractors, building owners and other members of the stakeholder group and survey respondents that were involved with this project. Meanwhile, alteration is defined in Title 24 as "any change to a building's water-heating system, space-conditioning system, lighting system, or envelope that is not an addition. Alteration is also any change that is regulated by Part 6 to an outdoor lighting system that is not an addition. Alteration is also any change that is regulated by Part 6 to signs located either indoors or outdoors." Additionally a study is referenced in the bibliography (ADM 2001, 2002) which uses the term "renovation" to refer to the same alteration/retrofit projects upon which this report focuses.

This work was publicly vetted through our stakeholder outreach process, which through in-person meetings, webinars, email correspondence and phone calls, requested and received feedback on the direction of the proposed changes. The stakeholder meeting process is described at the end of the Methodology section.

2.1 Review of Market Assessment and Program Evaluation Literature

HMG conducted a review of literature pertaining to the lighting retrofits market. The purpose of the literature review was to gather supporting data to characterize the following aspects of the lighting retrofit market, to estimate the savings from the proposed measures, and to inform a discussion among the utilities and lighting stakeholders about the proposed code changes.

- The major types of alteration project that are conducted
- Typical factors influencing alteration projects
- Typical project characteristics
- Typical project costs
- Decision makers in the lighting retrofits process

To compile the literature review, HMG used various sources and relied heavily on studies posted in in the California Measurement Advisory Council (CALMAC) database. The results of the literature are provided in Section 3.1. A list of the studies used in the literature review, as well as elsewhere in this report, is provided in Section 5 Bibliography and Other Research.

2.2 Online Survey of Retrofit Implementers

An online survey was sent to lighting designers, lighting contractors, and lighting energy efficiency program implementers. The survey asked stakeholders to take the survey only if they had experience with retrofit projects, and requested that the survey be passed on to others with experience.

The survey covered the following broad areas:

- **Project characteristics**: building types, percentage of luminaires replaced, lighting power densities, changes to circuiting, existing controls, addition of controls.
- **Specific questions on retrofit control systems**: Frequency of use, problems and issues, wiring costs.
- **Compliance issues**: Whether to require egress controls, how to handle ballast-only changeouts.

The survey was sent out in February 2011. Twenty six (26) responses were received. The responses to the survey are provided in the analysis below.

2.3 Development of Office Models

To assess the energy savings, cost, and cost effectiveness of the proposed requirement, we developed models of a small office building and a large office building. Figure 1 shows the basic characteristics of the small and large office models.

	Occupancy Type (Residential, Retail, Office, etc.)	**Area (Square Feet)**	**Number of Stories**	**Other Notes**
Model 1	Small Office	8,200	1	Rectangular in shape, consists of several open office areas and one- and two-person offices linked by corridors
Model 2	Large Office	34,000	1	Rectangular in shape, consists of a core surrounded by a large concentric open office area, with some perimeter private offices.

Figure 1 Description of Office Models Used for Analysis

We chose to use two *office* buildings as models for two reasons. First, as shown by the results of the online survey and by the literature review, offices are the most common type of building in which major lighting retrofits occur. Second, it's usually more expensive to retrofit controls in offices than in the other common building types (retail stores, warehouses). This is because offices are often subdivided into many spaces, and because they have complex routing for wiring and include many finished walls and ceilings that are expensive to alter. Therefore, the measure costs calculated for offices are likely to be at least as high (per square foot) as for other building types, and therefore provide a conservative estimate of cost-effectiveness. This assumption is particularly true with respect to wireless controls, because wireless controls are particularly cost-effective at reducing the need for long runs of wire that would otherwise exist in large buildings such as warehouses or big retail stores. The layouts of the two model offices are shown in Appendix A--Model Building Layouts.

2.3.1 Small Office Model

The small office model is a building that was surveyed in 2005 by HMG, as part of a study on photocontrol systems conducted for the California investor-owned utilities and the Northwest Energy Efficiency Alliance (Pacific Gas & Electric, et al 2006). This building was chosen because it is typical of the layout of many small California offices, which have a number of open office areas and single-person or multi-person offices around the perimeter, linked together by internal corridors. This specific building was also chosen because as part of the 2005 study we collected very comprehensive data on its lighting and control systems, and daylight distribution, and because we have both a reflected ceiling plan and a furniture layout for the entire building.

2.3.2 Large Office Model

This building was chosen because, unusually, it has a mix of both perimeter private offices and perimeter open office areas. This allowed us to accommodate both those common configurations within the same building model, rather than using two models. For structural reasons it is arranged around a central core, like the vast majority of larger office buildings. A reflected ceiling plan and furniture layout were also available for this building.

2.3.3 Space Breakdowns for Each Model Building

The breakdown of rooms in the model small and large office buildings is shown in Figure 2. These tables allow for comparison of the space breakdowns, which show key differences between the two models, such as the higher ratio of office space to total floor area for the larger office (81% vs. 68.3%) and the higher percentage of space devoted to corridors and ancillary functions in the small office. As will be shown in the analysis below, these features contribute to the comparatively higher costs and lower savings achievable in the small office model. The space types in the table are used to develop LPDs and therefore estimates of the total lighting energy use of the model buildings.

The decision was made to analyze this measure on a whole building basis instead of space by space as has been done for Title 24 code historically. There are two reasons for this decision. First, automatic shutoff controls are a building-wide control. By their very nature they are not a space by space control system. Second, cost estimates for these systems, in dollars per square foot, are most accurate when the entire system is considered, because the costs and savings for each space within the building are different and must be weighted by square footage.

	Small Office Model			Large Office Model		
Type of room	**Number of Rooms**	**Net Area [sf]**	**% of Floor**	**Number of Rooms**	**Net Area [sf]**	**% of Floor**
Open Offices	5	4,358	53.0%	6	21,675	63.6%
Private Offices	5	1,260	15.3%	36	5,934	17.4%
Conference Rooms	2	402	4.9%	3	1,810	5.3%
Break Room				2	1690	5.0%
Restrooms	1	384	4.7%	4	685	2.0%
Mechanical/ Electrical				4	645	1.9%
Corridor	5	981	11.9%	5	600	1.8%
(Elevator) Lobby	2	342	4.2%	1	333	1.0%
Kitchen	1	241	2.9%			
Stairs				2	306	0.9%
Printer/copier	1	87	1.1%	1	214	0.6%
Server room	1	75	0.9%			
Storage	2	93	1.1%	6	118	0.3%
Janitor				1	77	0.2%
TOTAL:		8,223	100%		34,087	100%

Figure 2 Breakdown of Spaces in Model Buildings

2.3.4 Compliance Scenario Development

Compliance scenarios were developed for the model buildings to show that there are a variety of technologies, products and methods available to meet the proposed code requirement. The scenarios modeled include:

- Vacancy sensors
- Line voltage override switches with a timeclock enabled control panel
- Wireless switches, relays and a wireless switch-leg transmitter with a timeclock as the input

The vacancy sensor scenario was developed to meet Section 131(d)4 which requires vacancy sensors for specific space types (private offices <250 sf, multipurpose rooms <1,000 sf, and all conference rooms and classrooms).We also developed a scenario for partial retrofits that uses vacancy sensors wired in parallel. This solution would prove to be more cost effective than other compliance options for automatic shutoff if a single space within a building is being retrofitted independently.

The use of a line voltage override switch in conjunction with a new lighting control panel allows for local area controls to also provide for automatic shutoff without additional wiring costs, independent of the existing layout. This scenario was developed primarily to serve the open office areas without vacancy sensors.

The wireless solution can be used in buildings where there are no existing local area controls, or there is no desire to install a new lighting control panel. This scenario was developed primarily to serve the open office areas without vacancy sensors.

These scenarios were chosen because of their simplicity and consistency across a variety of existing conditions. Both open office area solutions can be applied regardless of ceiling type or furniture layout. Wired solutions also exist, but are not included in this report because they are not needed to prove cost effectiveness of the proposed measure.

Implementing the proposed requirements should be even more cost effective in other types of non-residential buildings, because the use of wireless controls for retrofits could reduce the need for long runs of wire that would otherwise exist in large buildings such as retail and manufacturing facilities. The size and variety of space types for which compliance scenarios were developed can be scaled up or down to meet the needs of many retrofit situations.

2.4 Energy Savings Analysis

The energy savings from this measure result from the installation of automatic shutoff controls. Despite the fact that this proposed measure requires that Controllable Lighting and photocontrols be retrofitted into buildings, we are *not* considering the savings from these two measures, because they are analyzed in their respective CASE reports.

There are two types of automatic shutoff systems for which we are analyzing the savings; floor level shutoff and vacancy sensors. Both strategies shutoff lighting that might otherwise have been left on overnight or over the weekend. Vacancy sensors are required by Title 24 Part 6 Section 131(d)4 in private offices and conference rooms, which also serve the function of area controls in those spaces.

To estimate statewide energy savings, we calculated the statewide square footage to which those savings are applied (based on construction forecast data from the California Energy Commission), and estimated the lighting power density of spaces in which those percentage savings occur, based on the LPD allowances being proposed for a concurrent report titled 2013 Title 24 Indoor Lighting Controls. This methodology is described in more detail in Section 2.4.1 Note that for statewide savings we *are* including the savings from Controllable Lighting and from photocontrols, because the CASE reports for those measures do not include statewide savings from retrofitting those controls.

To calculate the savings from overnight and weekend shutoff we conducted a night lighting field survey of office buildings in four areas of California, to generate an estimate of how much lighting is left on overnight, and therefore how much energy could potentially be saved. Details of the survey process are described below. This survey collected data on the percentage of lighting that was switched on in office buildings in the evening and night-time. The results of the night-time lighting field survey are presented in Section 3.1.

The approach to calculating the savings from vacancy sensors is described in detail in Section 2.4.4.

2.4.1 Assumed Lighting Power Density (LPD) in Offices

To estimate savings from the proposed changes, we need to estimate the typical lighting power density (LPD) for the model buildings. Figure 3 below shows the 2008 and Proposed 2013 Area Category LPD space types typically found in offices. The typical relative square footage for an office is also presented as "% Area", sourced from Table 6.2 of the Database of Energy Efficient Resources (DEER) final report (California Energy Commission 2005). These area breakdowns are similar to those of the models, presented in Figure 2.

The savings estimates assume the proposed 2013 Title 24 Area Category LPD allowances will be in buildings that have lighting systems retrofitted. The 2008 and 2013 Area Category LPD allowances are depicted in Figure 3.Areas utilizing vacancy sensors were assume to have a private office LPD of 1.1 W/sf, while areas equipped the other types of automatic shutoff controls described in Section 3.3.2 were assumed to have an open office are LPD of 0.8 W/sf Using proposed code as the baseline for retrofit savings results in a conservative estimate of savings, because it is a lower lighting power density for office buildings than the CEUS estimates (California Energy Commission 2006).

Area Type	% Area	2008 Area Category LPD (W/sf)	Proposed 2013 Area Category LPD (W/ft^2)
Conference Room	4%	1.2	1.2
Copy Room	2%	0.6	0.6
Corridor	10%	0.6	0.6
Lobby	5%	1.1	1.1
Mechanical/Electrical	4%	0.7	0.7
Private Office	25%	1.1	1.1
Open Office	45%	0.9	0.8
Restrooms	5%	0.6	0.6
Weighted Average		0.91	0.86

Figure 3 Area Category LPD allowance for Office Spaces, Title 24 2008

2.4.2 Existing LPD in Projects Affected By New Threshold

Data was obtained from the Energy Commission (California Energy Commission 2006) about space by space LPDs in existing buildings. The LPD reduction was calculated by determining the difference between the existing LPD in each space according to CEUS and the 2013 area category LPD allowance.

2.4.3 Night-Time Field Survey

Night-time lighting includes lighting for many purposes: for egress, for security, for cleaning crews, as well as lighting that has accidentally been left on. The analysis in this report attempts to separate egress lighting from non-egress lighting, because the non-egress lighting is the source of savings for this measure. Savings from requiring egress lighting to be controlled as part of the automatic shutoff requirement are addressed in a concurrent report; “Control of Egress Lighting”, and therefore are not included in this report.

A night time field survey was conducted of office buildings to estimate the percentage of lighting that was left on during a weeknight. This was done to estimate savings for automatic shut-offs for egress and non-egress lighting. The survey of commercial buildings was conducted at four separate locations in the state, on a weekday evening in the fall of 2010. Observations were made hourly between 6 pm and 11 pm by a surveyor who walked a pre-set path around the downtown area and made observations from the outside of the building of the amount of lighting that was on. The estimated lighting load (as a percentage of all lighting) was recorded for each floor or each building, at each time interval. Observations were conducted in downtown commercial districts in:

- Sacramento
- Oakland
- Santa Monica
- San Diego

Lighting levels were recorded for 770 floors in 71 buildings, resulting in a total of 3,627 observations. (Due to survey constraints not all floors were recorded at all time-intervals). A copy of the survey instrument is provided in Appendix D--Online Survey.

2.4.4 Methodology for Vacancy Controls Savings

The energy savings from vacancy sensors are calculated in two sections. For savings that occur during unoccupied hours, we have calculated the savings for the areas of the building equipped with vacancy sensors using the same assumptions about hours of savings and percent of lighting left on as identified for the automatic shutoff control system. The additional savings that result from vacancy sensors during <u>occupied</u> hours are based on a report prepared by HMG for Southern California Edison titled "Savings Estimates for Lighting Controls and Interactions" (Southern California Edison 2010). This report includes analysis of the savings and interactions that result from the layering of lighting controls, including: tuning, vacancy sensors, daylight harvesting and demand response.

It is important to note that the for the “partial retrofit” scenario using multiple vacancy sensors wired in parallel to meet the automatic shutoff control requirement, the savings are calculated using the same assumptions about hours of savings and percent of lighting left on as identified for the automatic shutoff control system. The additional potential savings during occupied hours from vacancy sensors are ignored for this scenario. This adds a level of conservatism and simplicity to the savings calculation.

2.4.5 Methodology for Photocontrols Savings

Compliance with Section 131(c) (photocontrols) is only proposed to be triggered in alteration projects where wiring is moved or replaced. The rationale for this is that the existing wiring layout is unknown, so it cannot be assumed that the lighting will already be circuited in rows parallel to the windows, which is common / best practice for photocontrols. The cost of recircuiting the luminaires in parallel rows would be prohibitive, since it would require hard conduit to be removed and replaced, and new wiring to be cut to length, as well as disconnecting and reconnecting the conductors to each fixture. However, if the wiring is being moved, added or replaced, it should be done so as to accommodate photocontrols.

Savings from photocontrols are *not* included in the analysis of the cost-effectiveness of this measure, but they *are* included in the estimate of total statewide savings. The rationale for this is that the Daylighting CASE report proves cost effectiveness for the installation of photocontrols. Conversations with manufacturers and contractors have indicated that installing photocontrols in retrofit projects requires the same equipment as installation in new construction, therefore the requirement for retrofits is not assessed separately. There may be a slight increase in labor time required in retrofit applications, but the results of the online survey described in Section 3.2.10 show that this increase is not significant. This allows photocontrols to remain cost effective as calculated in the Daylighting CASE report. The interested reader should consult the Daylighting CASE report (California Utilities Codes and Standards Team. 2010 – Daylighting) for additional detail.

2.5 Cost Analysis

To develop the strategies for retrofit projects to meet the proposed controls requirements, we conducted a series of informal interviews with technical staff from several major controls manufacturers. In these interviews, we established the following:

- Which of their systems were most commonly installed in retrofit projects
- Which systems provided the least expensive or most risk-free approach for retrofits
- Exactly which pieces of equipment should be installed where in the two model buildings, to achieve compliance with the requirements of Title 24 Section 131(a) through (d)
- The typical contractor price for the equipment
- How much labor is typically associated with installing each piece of equipment

To develop cost estimates, we conducted detailed cost analysis of the equipment and labor that would be required to install their systems in the two model buildings. We then combined this data with equipment costs and labor rates provided by RS Means CostWorks Online Construction Cost Data, to develop tailored cost estimates for each control system in each of the two model buildings.

2.6 Lifecycle Cost (LCC) Analysis

HMG calculated lifecycle cost analysis using methodology explained in the California Energy Commission report *Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards*, written by Architectural Energy Corporation, using the following equation:

$$\Delta LCC = Cost\ Premium - Present\ Value\ of\ Energy\ Savings$$

$$\Delta LCC = \Delta C - (PV_{TDV\text{-}E} * \Delta TDV_E + PV_{TDV\text{-}G} * \Delta TDV_G)$$

Where:

ΔLCC change in life-cycle cost

ΔC cost premium associated with the measure, relative to the base case

$PV_{TDV\text{-}E}$ present value of a TDV unit of electricity (3% discount rate)

$PV_{TDV\text{-}G}$ present value of a TDV unit of gas (3% discount rate)

ΔTDV_E TDV of electricity

ΔTDV_G TDV of gas

We used a 15-year lifecycle as per the LCC methodology for nonresidential lighting control measures. LCC calculations were completed for two building models in all sixteen (16) climate zones using four different shutoff control strategies. This provided a range of cost effectiveness to accommodate for varying scenarios.

We have not included any interactions effects from the proposed measure (e.g. reductions in air conditioning energy, or increases in heating energy). This makes the estimate of savings conservative, because in commercial buildings in California the annual cooling load almost always outweighs the annual heating load.

2.7 Cost Effectiveness Analysis and Statewide Savings Estimate

The cost effectiveness calculation was based on the cost and savings that result from implementing Sections 131(a) and (d) in all retrofit projects where more than 10% of light fixtures are being replaced, instead of waiting for wiring to be replaced as the current code requires. The cost effectiveness of Sections 131 (b) and (c) are independently justified in their respective CASE reports. Figure 4 shows which subsections of Section 131 are included in the calculation of cost effectiveness and statewide savings presented here.

Section	Cost Effectiveness Calculation?	Statewide Savings Calculation?
Section 131(a) Area controls	Included	Excluded
Section 131 (b) Controllable Lighting	Excluded, costs and benefits are independently justified in the Controllable Lighting CASE report.	Included
Section 131 (c) Daylighting	Excluded, costs and benefits are independently justified in the Daylighting CASE report.	Excluded
Section 131 (d) Automatic Shutoff controls	Included	Included
Section 146 LPD allowance	Excluded, costs and benefits were independently justified when LPD thresholds were adopted.	Included

Figure 4 Lighting Sections Included in Cost Effectiveness and Statewide Savings calculations

The statewide savings estimates also include the additional retrofit projects that would be required to comply with code by reducing the trigger from 50% of fixtures to 10% of fixtures in a space. The statewide savings that result from complying with Sections 131(a) and (c) were excluded because of the complexity of determining when those requirements would be triggered. Additionally, for area controls there is an absence of research that would support an estimate of savings. Therefore it was determined that any savings from these requirements would be excluded from the statewide savings estimation.

2.8 Stakeholder Meeting Process

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at one of three public Lighting Stakeholder Meetings.

At each meeting, the utilities' CASE team invited feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- First Lighting Stakeholder Meeting: March 18th, 2010, Pacific Energy Center, San Francisco, CA
- Second Lighting Stakeholder Meeting: September 21st 2010, California Lighting Technology Center, Davis, CA
- Third Lighting Stakeholder Meeting: February 24th, 2011, UC Davis Alumni Center, Davis CA

In addition to the Stakeholder Meetings, five Stakeholder Work Sessions were conducted to allow detailed review of specific technical issues. These meetings were held on the following dates:

- October 20th 2010: Lighting retrofits, uniformity of illuminance
- December 8th 2010: Egress lighting controls

3. Analysis and Results

This section describes our analysis and assumptions in detail.

3.1 Results of Literature Review

A summary of the key findings from the literature review is presented here. These findings inform our estimates of costs and savings per square foot, and our estimate of the statewide impact. The full findings are presented in Appendix C--Lighting Retrofit Market Literature Review.

- **Size of the market**: The retrofit market is approximately twice as large as the new construction market in terms of square feet, and approximately half as large in terms of dollar value. The retrofit market is more constant over time than the new construction market and does not vary as much with economic cycles. Based on average data from the 2002 Nonresidential Remodeling and Renovation Study prepared by ADM and TecMRKT Work for the California Energy Commission (ADM 2002), the projected size of the market for addition and alteration projects (synonymous with renovation and retrofit projects) during the 2014-2017 code cycle is 327 million square feet per year. Offices make up approximately 34% of that market by square footage (42% by energy use), with approximately another 10% made up by each of: retail, warehouses and schools.
- **Owned vs. leased space**: Around 75% of office square footage and 40% of retail square footage is owner-occupied, the rest is leased.
- **Frequency of alterations in a given space**: Alteration projects occur approximately once every ten years in office buildings (more frequently in leased space than in owned space), every fifteen years in retail space, and every eight years in schools and other institutional spaces. By comparison, in most spaces, three-quarters of tenants stay for at least six years, which makes the frequency of alterations very similar to the frequency at which tenancies change. This is consistent with the finding that alteration projects occur mostly when tenancies change.
- **Code compliance in alteration projects**: The NRRR study (ADM 2002) is evidence that Title 24 was a major factor (the most important of those listed) influencing design decisions in lighting alterations. Also, electrical engineers and other licensed professionals heavily influence lighting decisions. Therefore we believe that code compliance rates are likely to be high for alteration projects.
- **Typical project outcomes**: Offices are by far the largest single element of the lighting alteration market. The average existing lighting power density (LPD) in U.S. office space is 1.8W/sf[1], and the average for recent construction in California is 1.13W/sf (California Energy Commission 2006). Therefore, assuming (see paragraph above) that retrofitted offices are

1 American Society of Heating, Refrigeration and Air-Conditioning. “ASHRAE Standard 90.1 – 1989.” February 2010.

code compliant in terms of LPD, many retrofit projects are saving up to 50% of the office's annual lighting energy consumption.

- **Reasons for alteration project initiation**: The decision about whether or not to upgrade or remodel the lighting in a leased space is usually prompted by a change in tenancy or a change of use. The magnitude of a "lost opportunity" would therefore be approximately six years of potential savings. The gap of time between tenancies is likely to be the only opportunity to upgrade the space, since the disruption to the tenants would be too great to conduct a remodeling project during normal occupancy. Therefore the decision to upgrade lighting is probably not a discretionary one in most cases; instead, it "has to be done".

  The NRRR (ADM 2002) study found that price of equipment was less important than other drivers of design. But for those who chose not to remodel, cost was a major factor.

- **Who pays? Who makes decisions?** Despite the necessity of tenant upgrades described above, it is usually the tenant who pays for the work (in leased spaces) and therefore the tenant who makes decisions about how much lighting and/or controls equipment will be relocated or replaced. Often, the tenant has a "TI allowance" from the landlord, so the tenant may not be highly cost sensitive. Depending on the terms of their arrangement with the landlord, it is possible that the tenant may decide not to upgrade the lighting (or to upgrade without a permit) if the requirements of code are perceived as too onerous.

  Three-fourths of tenants stay in the same space for more than six years, which makes medium-term payback horizons (3-6 years) a possibility. Alteration projects typically occur once every ten years—more often in schools, less often in retail.

- **Typical scope of alteration projects**: The majority of retrofit projects are total "gut rehabilitations", involving two or three of the main elements of the space (lighting, HVAC, interior layout) according to NRRR Volume III (ADM Vol III 2002). The report found that "lighting changes were likely to be accompanied by changes in the HVAC distribution system 85% of the time and by changes in interior layout (system furniture and partitions) 69% of the time." This leads us to conclude that because these projects likely involve significant work above the ceiling and other parts of the building structure, changes to lighting control systems may be cost-effective in many cases.

  Around one fifth of projects reuse or relocate existing fixtures, while the majority replace the fixtures (ADM 2002).

  We have not found any information about the typical size of retrofit projects in terms of dollar value or square footage per project.

- **Retrofit of lighting controls**: None of the available data sources indicate the frequency with which lighting controls are included in alteration projects. Title 24 requires lighting controls upgrades only if certain segments of the lighting wiring are replaced. Because of this stipulation on the requirement, and because the wiring is unlikely to be replaced in most alterations, we believe that lighting controls upgrades are rare. HMG's experience with utility retrofit programs and the results of the Retrofit Lighting survey presented in Section 3.2 lead us to believe that controls retrofits are uncommon.

3.2 Analysis of Retrofit Lighting Survey

This section describes the results of an online survey that was distributed to lighting stakeholders for their input on various components of lighting retrofits in commercial buildings in California. The full survey text is shown in Appendix D--Online Survey.

3.2.1 Distribution of Retrofits

The survey asked "*What percentage of luminaire retrofit projects take place in each of the following building types (must sum to 100%)*".

Respondents filled in percentages for the following building types:

- Large offices (>20,000 sf)
- Small offices (<20,000 sf)
- Warehouses
- Retail
- Schools

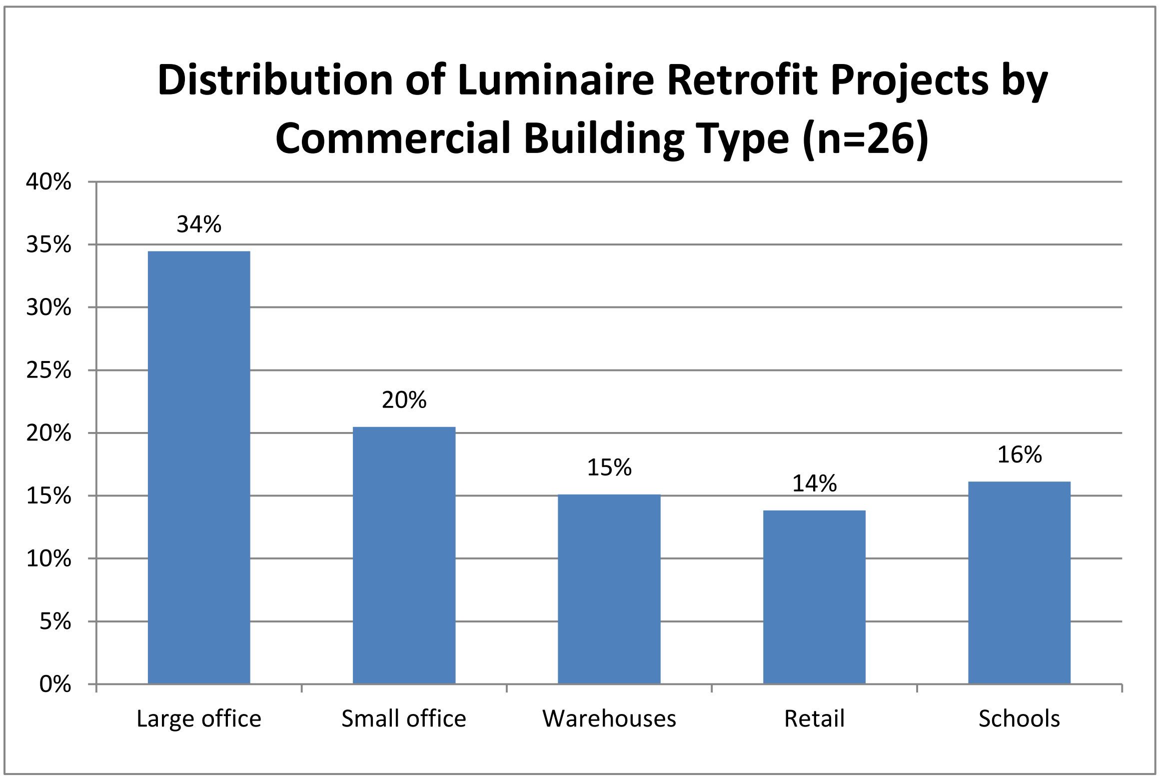

Figure 5 Distribution of retrofits by building type (n=26)

The distribution of retrofit projects in the sample of respondents contains a high number of office projects (54% of the total). The remainder is split fairly evenly between warehouses, retail, and schools.

This finding aligns with the results of the Nonresidential Remodeling and Renovation Study, (ADM Vol II 2002) which showed that lighting retrofits happen more frequently in office buildings than in other building types.

3.2.2 Percentage of Luminaires Replaced during Retrofit

Because the threshold for compliance with the LPD limits in Title 24 is based on the percentage of luminaires in the space that are moved or replaced, it is important to know what percentage of luminaries are typically moved or replaced during retrofit projects. The survey asked "*Thinking in terms of the whole project (e.g. the client's building, or the leased space): What percentage of your luminaire retrofit projects fall into each of the following categories (must sum to 100%)*". Space by space refers to separation by ceiling height partitions.

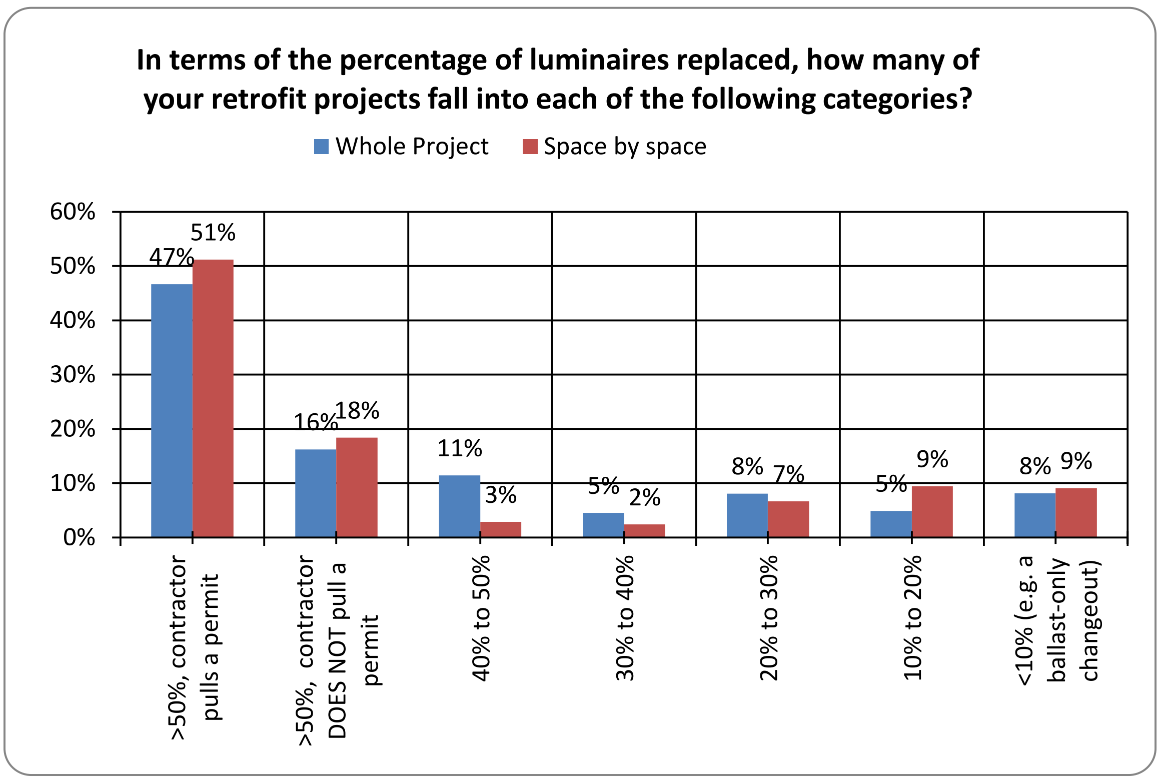

Figure 6 Distribution of luminaires replaced during retrofits

As expected based on the input from the Stakeholder Group, the majority of spaces (69%) and projects (63%) fall into the >50% category, i.e. retrofit projects are mostly "binary"; they are either maintenance projects in which only a few luminaires are replaced, or they are complete replacements.

However, 29% of projects and 21% of spaces fall into the 10%-50% range. This means that around a quarter of all alteration projects would be affected by reducing the compliance threshold from 50% of luminaires replaced down to 10%.

Savings and costs associated with complying with the LPD requirement are presented in Sections 3.4.5 and 3.5.4, respectively. Analysis for the retrofit of shutoff controls are presented separately in Sections 3.4.3, 3.5.1, and 3.5.2, as these two scenarios can be triggered independently of one another.

To inform the decision regarding the minimum threshold size of projects required to comply with Section 149, we combined the data shown in Figure 6 (distribution of luminaires replaced during retrofits) with the statewide distribution of office building sizes (drawn from the CEUS dataset (California Energy Commission 2011a)). In combining these datasets, we implicitly assumed that the two distributions were independent—something which is not true in practice, but we do not have enough information to inform a more accurate estimate.

The number of luminaires in each sample building was estimated by dividing the square footage of the building by 50 (i.e., assuming one luminaire per 50 square feet).

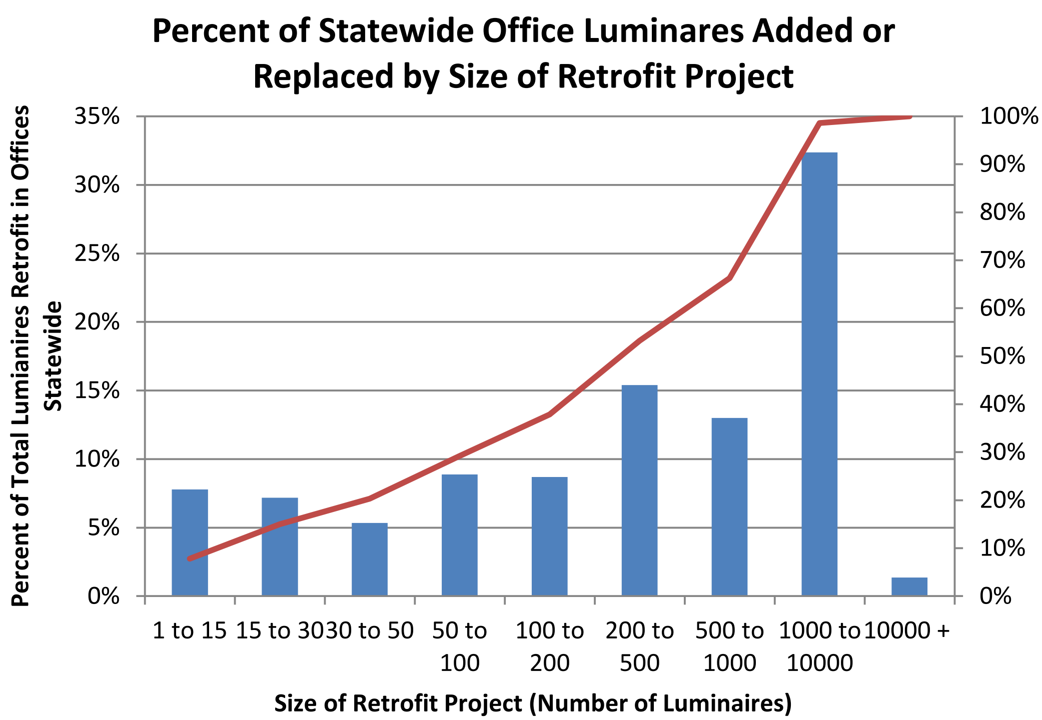

Figure 7 Percent of Statewide Office Luminaires Added or Replaced by Size of Retrofit Project

The results shown in Figure 7 indicate that less than 15% of the total luminaires retrofit in offices statewide are replaced or added in retrofit projects affecting less than 30 luminaires. Since offices include a broad distribution of building sizes, this indicates that setting the floor for number of luminaires being affected at 30 would capture a large percentage of all retrofit projects, while still allowing very small projects to proceed without triggering compliance with Section 149.

3.2.3 Existing building LPDs

The savings that can be expected from lighting retrofit projects come partly from the reduction in LPD from the existing lighting to the new lighting. To calculate the expected reduction we need to know typical LPDs in existing buildings.

The survey asked "*In what percentage of (Open Office, Private Office, Warehouse, Retail, etc.) luminaire retrofit projects does the existing lighting have the following power densities? (Should sum to 100%)*".

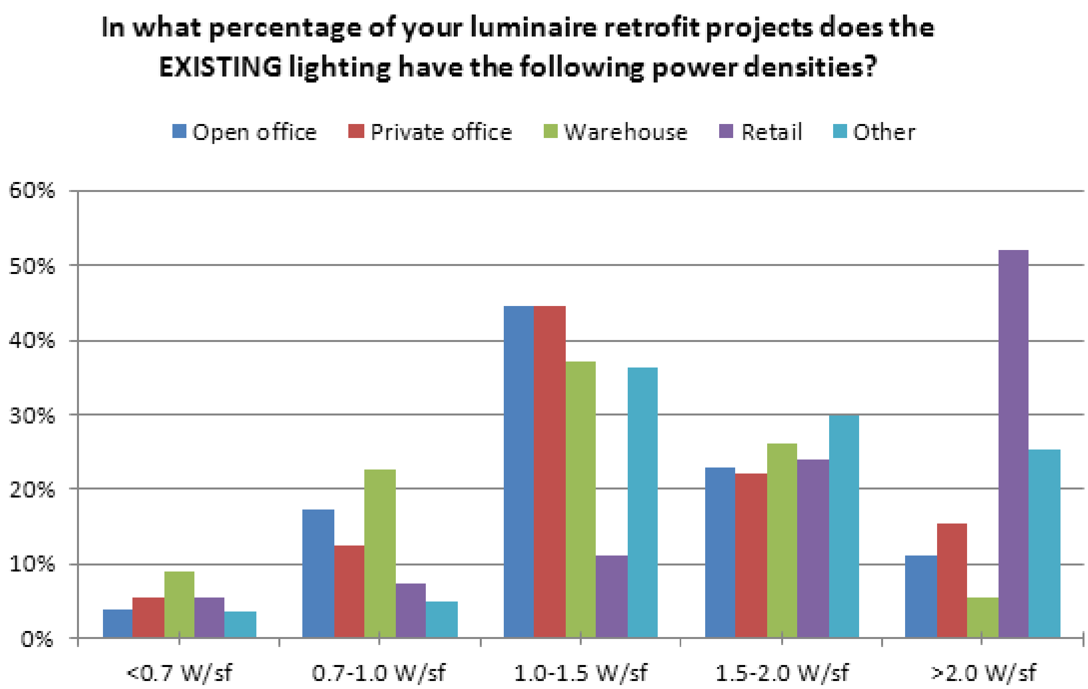

Figure 8 Existing Building LPD by building type

The results in Figure 8 show a general description of the existing LPDs in various building types at the time of lighting retrofits. These values were used to create a weighted average of LPDs, which is presented in Figure 9 and compared to the interior lighting LPDs reported by the California End Use Survey (CEUS). The LPDs obtained from the survey responses are consistently higher than the values from CEUS, which suggests that buildings are chosen for retrofit projects partially *because* they have high LPDs.

Building Type	Weighted average LPD based on On-Line Survey Response Results	Average LPD from CEUS
Open office	1.36	0.99 (large bldg), 1.39 (small bldg)
Private office	1.40	0.99 (large bldg), 1.39 (small bldg)
Warehouse	1.28	0.66
Retail	1.70	1.34
Other	1.55	1.06 (all commercial)

Figure 9 Comparison of LPD by building type; Retrofit Lighting Survey vs CEUS

3.2.4 Changes in Circuiting

Title 24 2008 contains various triggers for mandatory controls requirements. For instance, if a lighting panel is installed or replaced, if the existing wiring is being moved or new wiring added. Because of these existing triggers, some alteration projects are *already* required to install controls, and so to calculate the likely statewide impact of the proposed measure we need to remove those projects from the assessment of savings.

This question aims to understand what percent of the time a retrofit involves changes to circuiting, so that we may learn how much additional savings can be captured by changing the code as proposed.

The survey asked "*What percentage of the luminaires undergo the following changes in circuiting?*".

The three scenarios presented to the respondents were:

- **(a)** New or moved wiring is being installed to serve added or moved luminaires
- **(b)** Conductor wiring from the panel or from a light switch to the luminaires being replaced
- **(c)** A lighting panel is installed or relocated

The response options included the following ranges for percentage of luminaires:

- 0% - 5%, 5% - 10%, 10% - 25%, and >50%

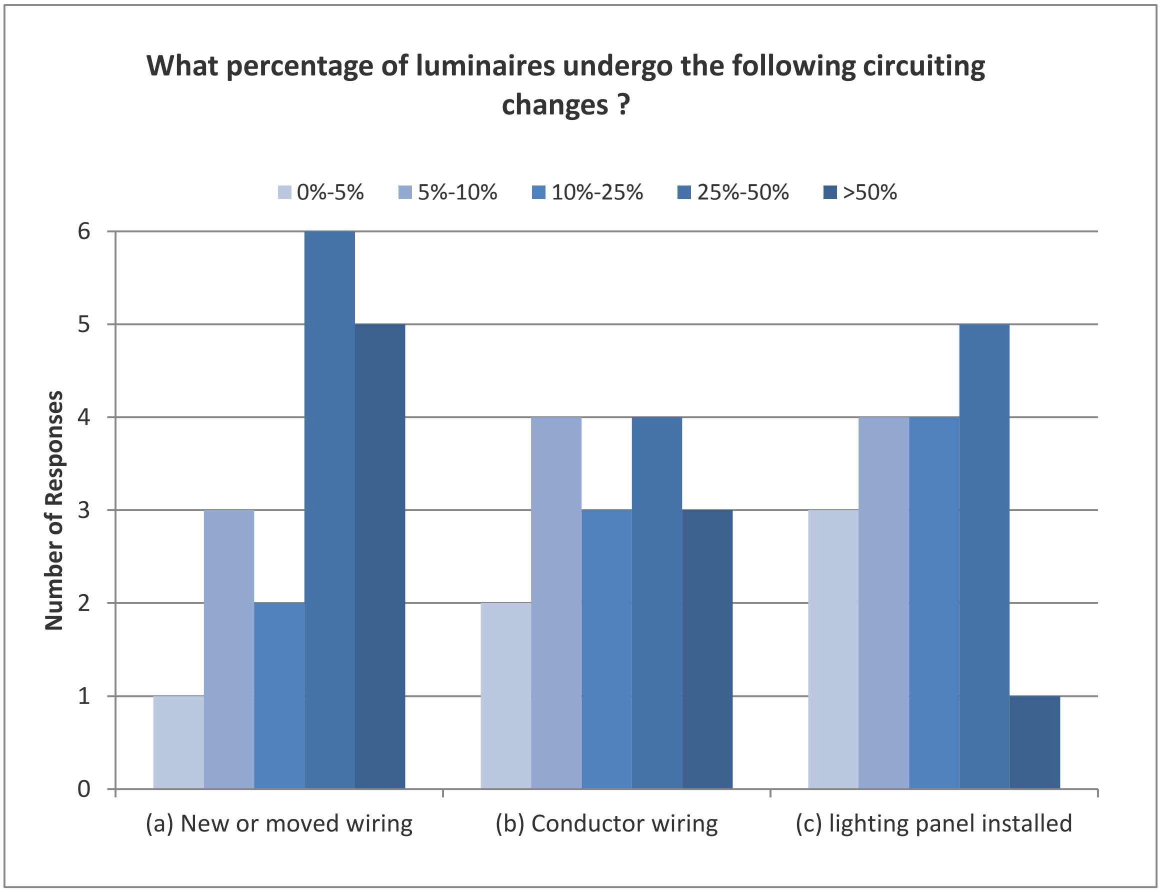

Figure 10 Percentage of Luminaires Undergoing Wiring Changes

Type of wiring change	Percentage of projects
New or moved wiring is being installed to serve added or moved luminaires	39%
Conductor wiring from the panel or from a light switch to the luminaires is being replaced	29%
A lighting panel is installed or relocated	22%

Figure 11 Weighted distribution of wiring changes

We estimate that around 40% of projects include changes to circuiting that trigger the current Title 24 requirement to retrofit controls. Because there is likely to be a lot of overlap between the projects that include these different types of circuiting changes, the responses to this question tell us that wiring changes occur in around 40% of retrofit projects. These findings are utilized in the calculation of statewide savings to adjust the savings estimate.

3.2.5 Types of Controls Commonly Installed in Retrofits

This question investigates the same issue as the previous question, but asks in a different way. It directly asks how often certain types of lighting control are installed in alteration projects. This question gives us slightly more information than the previous one because, as well as telling us what percentage of projects should be removed from the statewide estimate of savings, it also tells us which types of controls are most commonly installed. This information informs the choice of control solutions that are used to calculate the costs for this measure.

The survey asked *"how common are each of the following control types, in your retrofit projects?*"

Control options included in answer:

- Area controls (wall switches or vacancy sensors)
- Multi-level (bi-level) switching
- Photocontrols
- Automatic shutoff controls (e.g. night sweep)

The percentage of projects they could choose from were:

- 0% - 5%
- 5% - 10%
- 10% - 25%
- >50%

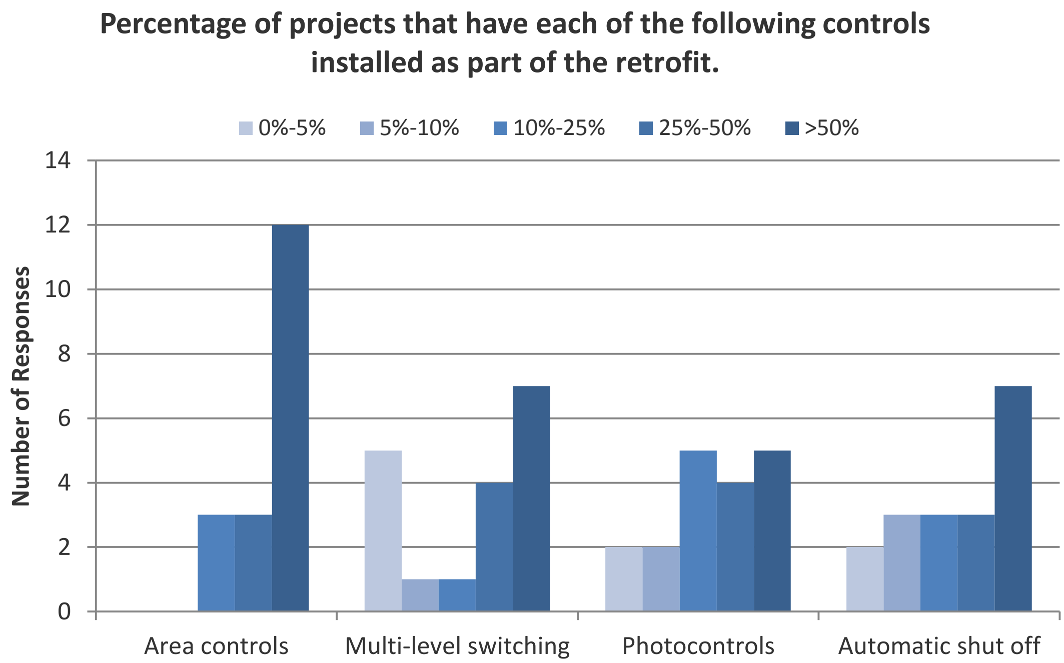

Figure 12 Percentage of projects with controls installed

Figure 13 shows that 40% of retrofit projects already include installation of automatic shut off controls, which are the main source of savings from the proposed measure. This is consistent with the findings in the previous question. The rest of the controls types are broken down explicitly in Figure 13.

Type of Controls	**Percentage of projects**
Area controls (wall switches or vacancy sensors)	59%
Multi-level (bi-level) switching	40%
Photocontrols	35%
Automatic shut off controls (e.g. night sweep)	**40%**

Figure 13 Percentage of Retrofit projects currently installing controls, by controls type

3.2.6 Percentage of Office Retrofit Projects with no Existing Area Controls

For the last several iterations of Title 24, commercial buildings have been required to have "area controls", i.e. light switches located in the same room as the lights they control (or, as an exception, "annunciated" switches). However, there are some older buildings that do not have area controls installed, and in these buildings the costs of this proposed measure have to include the cost of *adding* area controls where they do not already exist. The absence of area controls also increases the savings that would be obtained in those buildings.

The survey asked "*In what percentage of office retrofit projects does the existing building have NO area controls, (i.e., there are no wall switches or occupancy sensors within sight of the luminaires they control)?*"

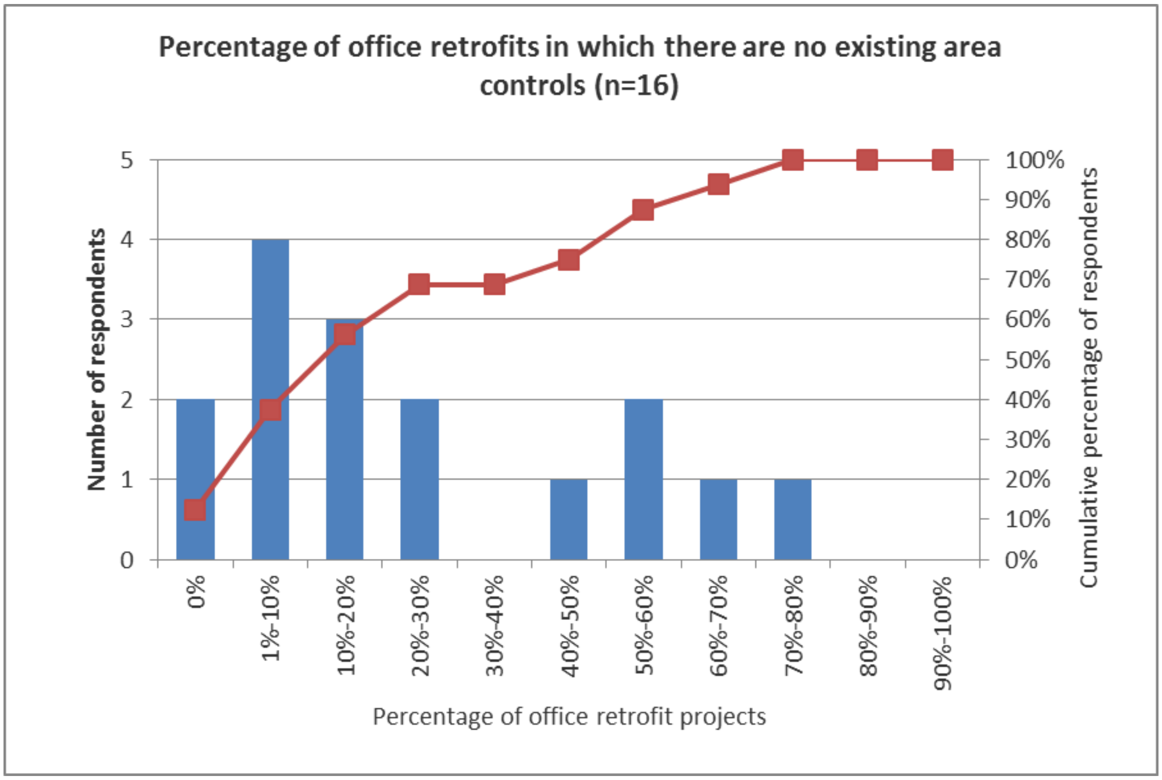

Figure 14 Percentage of office retrofit projects without any existing area controls

The results to this question indicate that there is a portion of retrofit projects where the existing office layout does not have local area controls. There was a lot of variation in individual response between respondents, i.e. many respondents said that area controls are rare in existing buildings, while many other respondents said that area controls are common. We believe that some respondents may have misinterpreted the question, because we don't believe it's plausible that (for instance) 70%-80% of buildings do not have area controls. The weighted average of these results indicates that 26% of projects will need to add local controls (weighted average is calculated by multiplying each answer band (for instance ("40%-50%") by the percentage of respondents who gave that answer (in that case, 1/16 or 6.3%). This information is incorporated into the estimates of costs and savings from the proposed measure.

3.2.7 Percentage of Retrofit Projects that Add Controls

To inform our cost analysis, we needed to know what types of area control are typically added in spaces that don't already have them. Title 24 Section 131(a) contains the requirements for area controls, and it allows several different strategies to meet the requirement.

The survey asked "*In existing office buildings that do NOT already have area controls, what percentage of projects have each of the following controls installed as part of the retrofit*". The response options were:

- No controls - the space remains non-compliant with the Title 24 2008 "area controls" requirement
- "Annunciated switches" are added to a central switch panel, i.e. switches that are labeled and have an indicator light
- Additional wall switches are added in various locations throughout the space, within sight of the luminaires they control
- Additional occupancy sensors are installed throughout the space

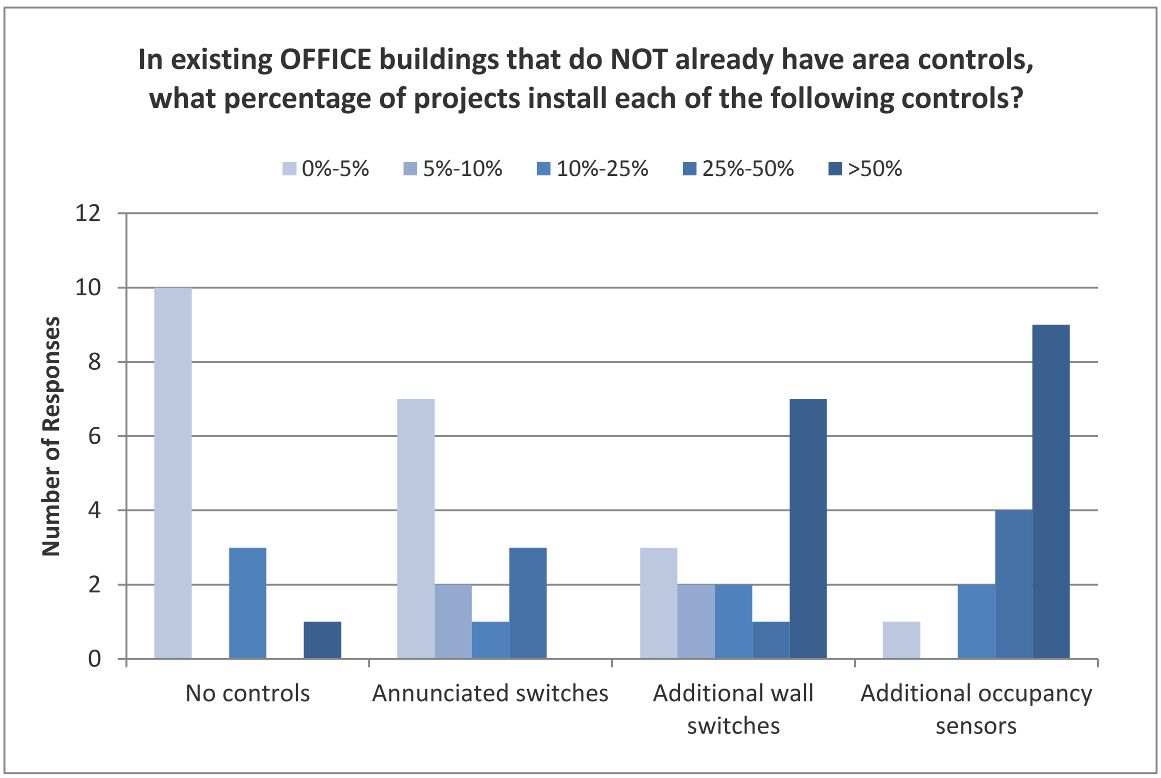

Figure 15 Percentage of projects without area controls that add them during retrofit

The responses show that in spaces without area controls, wall switches and occupancy sensors are installed in around 50% of retrofit projects (based on a weighted average calculation). In these spaces, the respondents said that they rarely do not add any area controls. Adding annunciated switches or not adding controls is not common.

3.2.8 Effect of Adding Cost to Retrofit Projects

In the Stakeholder meetings several people raised the concern that if Title 24 requirements add significant up-front cost to lighting alteration projects, then those projects might simply be cancelled and the potential savings lost entirely. This effect would have to be factored into the estimate of savings for the measure. To investigate the likely effect of adding up-front cost to alteration projects, we asked how many projects would likely be cancelled, if various levels of cost were added.

The survey asked "*What would be the effect of adding additional costs for lighting controls to office retrofit projects? Note that "cancelled" means that the lighting would not be retrofitted (not that the entire project would be cancelled).*"

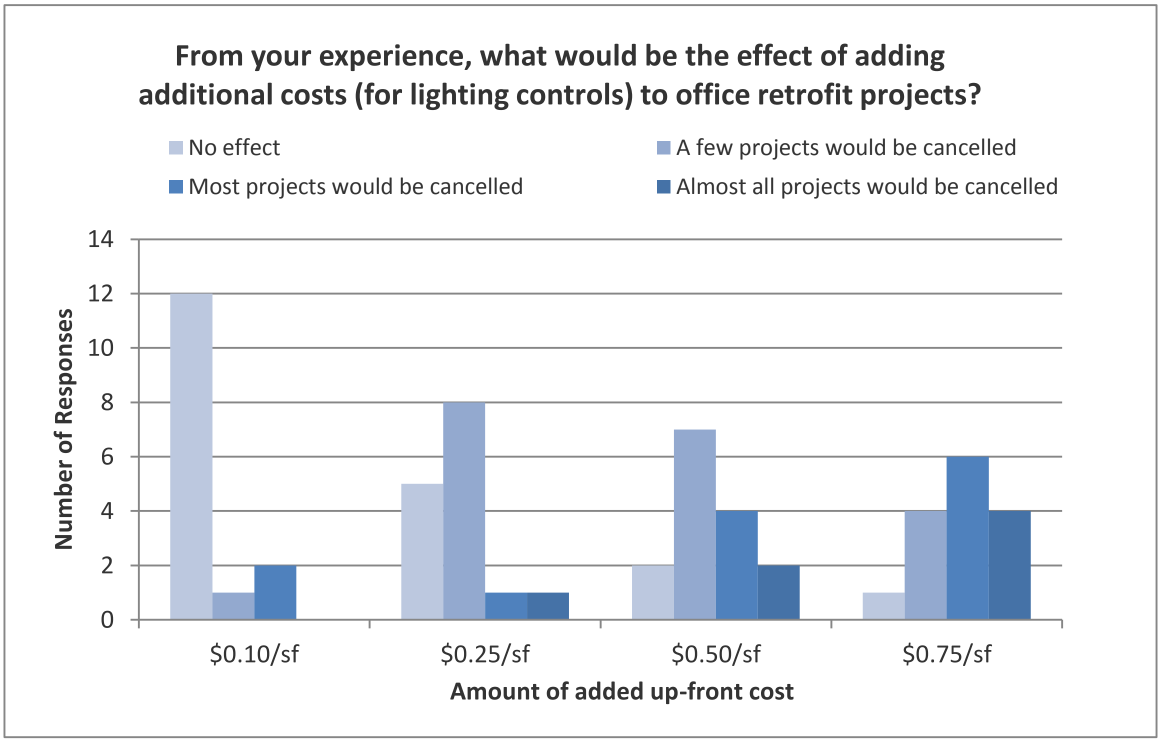

Figure 16 Effect of additional costs on retrofit office projects

These responses indicate that additional up-front costs of $0.50-$0.75/sf would cause a majority of projects to be cancelled. Conversely, an added cost of $0.25/sf or less would produce a minimal effect, meaning it is unlikely projects would be cancelled.

3.2.9 Wireless Time Clock or Sentry Switch Systems

Our initial investigations into cost-effective controls strategies for retrofit projects yielded two likely types of system. These two types were discussed with stakeholders. This question investigates how frequently those types of systems are installed.

The survey asked "*In what percentage of your retrofit projects is a system like this installed?*". The two systems were:

- A timeclock-based "sentry switch" shut-off system that mechanically actuates manual wall switches to the off position (and therefore gives users the ability to manually switch the lights back on). This system also provides a "blink" warning prior to shutoff.
- A timeclock-based wireless shut-off system that uses wireless switches to convey user overrides to the lighting control system. This system also provides a "blink" warning prior to shutoff.

The survey asked respondents to give their answer in terms of the percentage of their projects in which each of these control systems in installed.

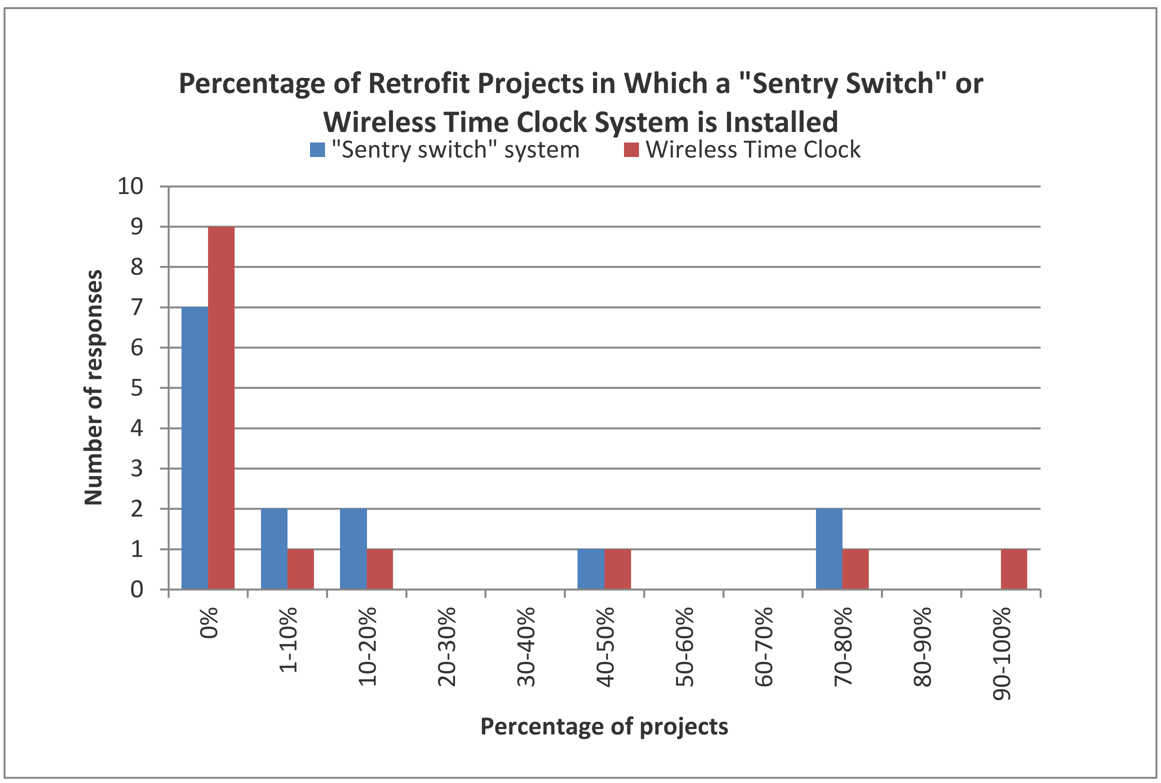

Figure 17 Percentage of retrofit projects with wireless timeclock or sentry switch system

Figure 17 shows that some of the respondents used these systems frequently, but most respondents either were not familiar with these systems, or in a few cases used alternatives such as fully addressable lighting systems. Based on these responses, the weighted average of number of respondents multiplied by the corresponding percent of projects shows that sentry switch and wireless timeclock systems are used in approximately 19% and 17% of retrofit projects, respectively.

3.2.10 Low Voltage Wiring Cost Assumptions

The survey asked respondents for their feedback on a key assumption of the cost analysis for this measure, which is the assumption that it does not cost significantly more to install control wiring in retrofits than in new construction.

The question was as follows: "In calculating costs, we are assuming that low voltage wiring (for dimming or step switching control) can be installed during a tenant improvement project at a cost that is not significantly different from a new construction project. This is because low voltage wiring can easily be routed through suspended ceilings or exposed ceilings, without needing to be attached to the structure. Do you think this is a reasonable assumption?"

Approximately 71% (10 out of 14 respondents) agreed that low voltage wiring can be retrofitted at a cost that is not significantly higher than in new construction. Four respondents disagreed and cited the need for organization/support of the wires. None of the respondents mentioned that the wires may need to be installed behind existing finished surfaces (such as plaster ceilings or walls), which would certainly add cost.

Note that these issues also exist with low voltage wires in new construction, although they may be more complicated in retrofits because the overall organization of the wiring may not be visually evident, i.e. the wiring may be hidden behind the existing ceiling or walls.

3.2.11 Waive Egress Lighting Control Requirement for Retrofits

As part of a separate code change proposal, the utilities are proposing to require mandatory control of egress lighting, to save energy at times when the building is unoccupied. If this mandatory requirement were applied to retrofit projects, in many cases it would require building owners to either re-wire the egress lighting to be on a separate circuit, or to install egress lighting control devices (i.e. emergency ballasts or transfer switches), which would incur significant extra cost.

The survey asked "Do you agree that the requirement to shut off egress lighting should be waived for retrofit projects?

Approximately two-thirds (10 out of 15 respondents) agreed that egress lighting controls should not be required for retrofit projects. Of the five who disagreed, one suggested that a credit could be given for egress controls, and the other four suggested that the code should find ways to require egress controls where possible, on the basis that this measure has high savings and can be simple to implement in many cases.

3.2.12 Ballast-Only Projects

Many retrofit projects involve a "ballast-only" changeout, i.e., the lamps and ballast are replaced, but the rest of the fixture (housing, optics) are left in place. Requiring these projects to comply with the controls requirements of Section 131 would significantly increase the statewide savings achieved by this measure, but at present, ballast-only projects are not required to pull an electrical permit, so we have engaged in extensive discussion with the Energy Commission over its policy regarding permit requirements, and with a few stakeholders regarding whether permits would in fact be enforced in practice for ballast-only changeout projects.

The survey asked "Ballast-only projects are not required to pull a building permit in California and therefore these projects are unlikely to be inspected for compliance with the energy code. Do you think that ballast-only projects should be subject to the mandatory (Section 131) and prescriptive (Section 146) lighting requirements of Title 24?

Among the 14 respondents, opinion was split 50-50 about whether these projects should be required to comply with Title 24 requirements.

Three of the people who said ballast-only projects should be exempt cited the increased cost or time involved with proving compliance or pulling a permit, i.e., that this would make change out projects less likely to go ahead.

Two of the people who said that ballast-only projects should not be exempt made comments; one suggested that these projects should be required to comply with controls requirements because of the high magnitude of savings that could be achieved, while the other suggested that the whole definition of a "ballast change out" is problematic in the case of T8 fluorescent to LED retrofits, i.e., is an LED replacement a lamp or a ballast?

3.2.13 Other Considerations Regarding the Proposed Code Changes

Five respondents had other comments regarding the proposed code changes. These comments are paraphrased below, along with a response to the comment.

- *"An increased need to pull permits adds to the cost of retrofit projects and may discourage people from conducting these projects."*

  The proposed change to the replacement threshold, and the possible change to include ballast-only retrofits (which we are not proposing), would both require permits to be pulled for more projects than under the current (2008) Code. However, as described in Section 3.1, recent market assessments have shown that many lighting retrofits are a part of major tenant improvements, for which permits would be pulled anyway. However, lighting retrofit projects that occur due to utility retrofit program incentives may be discouraged by the need to pull permits. Pulling a permit would require compliance with the current Title 24 code, which could pose problems with the program claiming savings from the retrofit.

- *"Give a credit for retrofits that include task lighting with occupancy sensors."*

  Task lighting is already mostly exempted from the LPD requirements, and this allowance may increase from 0.2 W/sf to 0.3 W/sf for the 2013 code. Note that task lighting that is "planned" is NOT exempted from the shut-off requirement (Section 131(d)) and therefore should, in theory, be equipped with vacancy sensor control or an automatic shut-off. Task lighting should perhaps be specifically exempted from this requirement.

- *"The rate of reduction of lighting power densities (LPDs) has been too rapid."*

This measure does not deal with lighting power densities. The only proposed reduction in LPDs for this round is for open office areas, which would be reduce to 0.8 W/sf. Code developers are aware of the sensitivities of the design community toward reductions in lighting power density allowances, and this is always a critical part of the code development discussion.

- *"Code should require the use of wireless, open source controls."*

  Note that code is highly unlikely to make requirements that are so specific, but because controls are so effective at saving energy, code now requires a high degree of control for lighting, and it may be that addressable and/or or wireless controls become a cost-effective way of meeting these requirements while reducing design effort.

3.3 Analysis of Scenarios for Model Buildings

This section describes how we developed typical lighting control designs for meeting the proposed requirements in the model buildings.

To develop equipment needs for the various compliance strategies, we started by identifying equipment that would be required to meet code. The approach for meeting the requirements in enclosed rooms (including private offices, conference rooms, restrooms, etc.) is dictated by current Title 24 Section 131(d). For these spaces, a vacancy sensor is a mandatory requirement. Consequently, we developed one strategy for these areas, which represents a fixed cost. Conversely, there is some flexibility in meeting the requirements in the open office areas and corridors, because the "shut off" requirement (Section 131(d)) can be met by a time sweep control, vacancy sensor, a signal from a security system or building management system, or a variety of other automatic inputs. Consequently, multiple strategies were developed which meet the requirements in these areas, and associated costs were estimated representing a variable cost, as presented in the following sections.

3.3.1 Strategy for Enclosed Rooms

Title 24 Section 131(d)(4) requires vacancy sensors for offices 250 square feet or smaller, multipurpose rooms less than 1,000 square feet, and classrooms and conference rooms of any size. Consequently, we assumed that each private office and break room (a multi-purpose room) would need to be equipped with a wall vacancy sensor. We assumed that each conference room would be equipped with a ceiling mounted vacancy sensor. We also assumed that each restroom would be equipped with a ceiling mounted occupant sensor, as this has become standard practice, according to the feedback we received from conversations with stakeholders. We used the breakdown of rooms for small and large offices identified in Figure 2 to determine the total number and type of sensors needed. We assumed that the occupant sensors in the private offices, conference rooms, and restrooms would be line voltage and installed without a power pack (i.e., would not need to be networked, because these rooms are not part of the path of egress).

In private offices, we assumed that these sensors would be installed in previously existing wall boxes. Thus, we assumed that a wall based vacancy sensor could fit into an existing gang plate, meeting the requirements for both area and automatic shutoff controls, while requiring minimal rewiring. We assumed 20 feet of wiring would be required to wire the low-voltage wall switch to the ceiling vacancy sensor located in each conference room and restrooms. The vacancy sensors are local zone controllers.

3.3.2 Strategies for Open Areas

This section describes various ways of meeting Section 131(d) requirements for open areas, including the open offices (i.e., cubicle areas) and corridors.

- Strategy A: Wireless receivers with built-in relay and override switch replacing existing area controls
- Strategy B: Wireless receivers and wireless switches replacing annunciated wall switches
- Strategy C: New central control panel with automatic control switches replacing existing line voltage wall switches
- Strategy D: Ceiling vacancy sensors with low voltage wall switches replacing local area controls

Each of these strategies is described in more detail in the relevant sections below.

A necessary first step was calculating the number of relays and switches needed in the open areas of each model building. All of the scenarios have either wireless receivers or some type of switch (e.g., low voltage wall switch, wireless wall switch, or line voltage override system switch) providing area controls and manual override for the automatic shutoff control. This section describes how we determined the minimum number of switches or receivers required in each model building. We made the following assumptions for the existing lighting and controls in the model spaces, based on the survey data presented in Section 3.2.

- There are existing wall switches within sight of the fixtures they control, in 75% of buildings
- The remaining 25% of buildings have "annunciated" switches, i.e., A central bank of switches with indicator lights and labels to show which rooms they control
- Recent updates to Title 24 now require that all spaces have area controls; annunciated light switches are no longer an acceptable substitute (Exception: retail spaces)
- Existing buildings may or may not have bi-level switching--this does not affect the costs of the required equipment. Bi-level switching has been required by Title 24 since 2001.

For costing the four strategies (A-D) described above, we calculated the number of relays and wall switches required to serve the lighting in each model building.

The calculation of the number of relays (circuits) assumes a lighting power density of 1.5 W/sf in small offices and 1.2 W/sf in large offices, 277V line voltage, and a limit of 10 amps per circuit. The circuit layout in retrofits is based on the assumption that there were less stringent LPD requirements in previous years. Estimates for installed LPD based on a sampling across all vintages in California (California Energy Commission 2006), are 1.34 W/sf for small offices and 0.99 W/sf for large offices. Based on the assumption that the older, less efficient buildings are the ones being retrofitted, we are using a slightly higher LPD for the calculations of circuits existing in retrofit spaces than the LPD reported by CEUS.

$$\frac{1.34\frac{W}{sf}x\ 4{,}358sf}{277V\ x\ 10\ amps/circuit} = 2.11$$ circuits (round up to 3) for the small office open office areas and

$$\frac{1\frac{W}{sf}x\ 21{,}675sf}{277V\ x\ 10\ amps/circuit} = 9.39$$ circuits (round up to 10) for the large office open office areas.

This equation indicates that a minimum of 3 circuits are required to serve the lighting load for the open office area of the small office, and 10 circuits for the open area of the large office.

Based on the layout of the open office areas in the small office, we determined that five (5) switches would be required to meet the requirements of 131(d)(2)(b), even though the circuiting calculation depicted above indicates that only 3 circuits would be required. Section 131(d)(2)(b) requires that each switch must be located so that the lights or area being served are visible, and Section 131(d)(2)(e) requires that each switch must serve no more than 5,000 sf. At the rate of 1 switch per 5,000 square feet or space enclosed by ceiling height partitions, we estimate that 5 and 10 wall switches are required for the small and large open office areas, respectively.

In addition to these open office spaces, each room without a vacancy sensor must also have a wall switch providing area control and automatic shutoff override. The cost calculation assumes that there are 7 additional switches to serve the remaining rooms in the small office not required to have vacancy sensors and 13 additional switches to serve the remaining spaces in the large office, to meet the requirements of Section 131(d). The assumptions for number of relays/switches required for the open office areas of both the small and large offices are summarized in Figure 18. The model building layouts are available in Section 6 Appendix A--Prototype Building Layouts.

	# of relays / override switches in open office area (max 5,000 sf)	**# of relays / override switches for corridors**	**Total # of relays / override switches required**
Small Office	5	7	12
Large Office	10	13	23

Figure 18 Number of Relays and Switches Required in Model Buildings

Strategy A: Wireless receivers with built-in relay and override switch

The wiring diagram for wireless switch leg transmitters and receivers is shown in Figure 19. Strategy A uses a wireless transmitter connected to a time clock to send a signal to wireless receivers that control the open office areas, according to Title 24 Section 131(d)(3). In Figure 19 the installation of a wireless switch leg transmitter uses an existing on/off switch as an input. In the retrofit scenario, the input from the on/off switch is replaced by a time clock, enabling automatic shutoff control. In strategy A, each wireless receiver is installed in an existing wall switch box. The receiver has a built-in relay and override switch so that it can provide both area control and shut-off control, meeting the requirements of Sections 131(a) and (d).

Each wireless relay receives the signal to shut off from a transmitter that has been wired to a time clock. Based on conversations with the manufacturer, the range of a transmitter is 300 feet with no interference; usually 150 feet in standard construction (with internal walls and other interference). To ensure robustness, a layout using a 100-foot range is assumed for the purposes of costing. Based on this range, one (1) transmitter is needed for the small office and three (3) wireless transmitters would be needed to reach all wireless receivers in the large office assuming worst case scenario for existing wall switch locations.

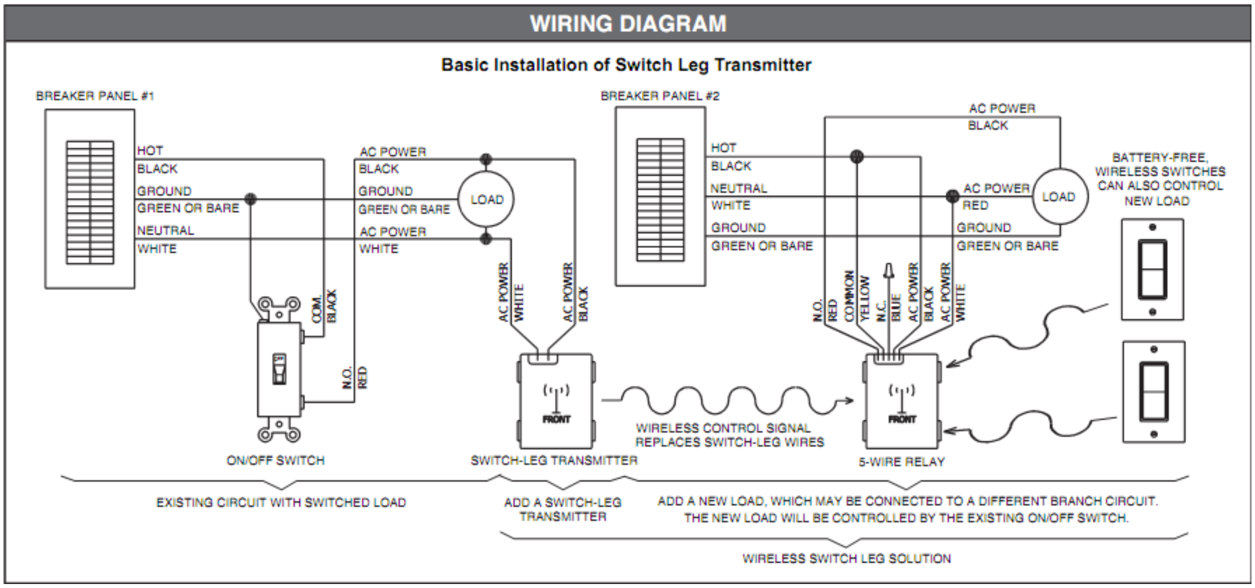

Figure 19 Wiring Diagram for Installation of a Wireless Switch Leg Transmitter

For the wireless transmitters and receivers, the manufacturer estimated that it would take one hour to completely remove, install, and pair one transmitter and receiver (we assume 15 minutes for each transmitter and 45 minutes for each receiver). One time clock is connected to each transmitter. In the large office we assumed that the time clocks are attached to the wall in the electrical room, and control wire connects each time clock to one transmitter; requiring 240 linear feet of wire for the three time clocks and three transmitters, a conservative estimate. Clocks receive power from a nearby outlet box. In the small office, it is assumed that only 20 feet of control wire is needed to connect the time clock to the wireless transmitter, as it would presumably be located in the ceiling above the electrical room, or some other relatively central location.

Strategy B: Wireless receivers and wireless switches replace annunciated wall switches

This strategy is similar in design to the wireless system in Strategy A. The difference here is that we are assuming that the existing conditions included one bank of annunciated light switches serving all of the open areas, rather than having wall switches distributed through the building, in the spaces they control.

For this strategy, automatic shut-off is provided by central time clocks that send out a wireless signal using transmitters (same as Strategy A). But instead of using wireless receivers with a relay and override switch all in one, there would be two distinct components: 1). A wireless receiver/relay mounted on a junction box in the ceiling, which actually controls the lights, and 2). A self-powered wireless switch mounted on the wall. The self-powered switch is simply attached to the wall surface and does not require a source of power; it draws power from the energy of the occupant pushing the switch.

Each receiver / switch pair provides both shut-off control and area control for the area it serves. The wireless relay and wireless switches are depicted in the right half of Figure 19.

Strategy C: Line Voltage Override System

Line voltage override systems (LVOS) are designed to implement automatic shut-off control as required by Section 131(d). The system consists of wall switches that physically move to the off position in response to a signal transmitted along the hot wire from a central time sweep controller. The wall switches are able to "blink" the lights off for a few seconds, several minutes in advance of the actual shut-off, to give occupants the opportunity to pre-emptively override the shut-off. If the override is activated, the lights remain on until the next signal is sent to shut off the lights, which would need to be within two hours to comply with Title 24.

LVOS switches also provide area control (i.e., off-switching) for each area of the building, as required by Section 131(a).

This system requires a dedicated lighting relay panel, so part of the cost of this measure is the replacement of the existing relay panel. One central control panel is used for the small office, and one control panel for each floor of the large office. To calculate the cost of the panel, we need to know how many relays are required in each case, i.e. how large the panel needs to be. The number of relays required is shown in Figure 18.

Strategy D: Partial Building Vacancy Sensor

In scenarios where a single open office area in a building has triggered the requirement for automatic shutoff controls, it may not be cost effective to use one of the other strategies described above. However, multiple vacancy sensors can be connected in parallel to the lighting load, so that if any one of them detects an occupant, the entire lighting load will remain on. No special device would be required; the vacancy sensors can just be connected to the same junction box. This arrangement would be limited to serving the lighting on a single circuit, but at 1.0W/sf that circuit could cover 5,000 sf. More realistically, in practice it would be limited to three or four vacancy sensors due to wire nut size limitations (based on the number of wires that can be pushed into a wire nut). Therefore, in practice this approach would be limited to about a 2,000 sf zone. This assumes a 500 sf zone covered by each vacancy sensor. If the space being retrofit is this small, area controls are probably preexisting. If there are no existing area controls, or the controls need to be replaced to accommodate controllable lighting, a line-voltage dimmer switch can be wired in series with the occupancy sensors to provide area control.

3.4 Energy Savings

The primary source of energy savings for this measure is the installation of automatic shut-off controls that automatically turn off the lights overnight and on weekends; when the building is unoccupied, based on the results of the night lighting field study. In line with the California Energy Commission's 2013 cost-effectiveness method, we calculated energy savings using time-dependent valuation (TDV) assuming a 15-year measure life. We are using "TDV:2011v3" provided by the Architectural Energy Corporation.

Limited additional savings would also be obtained from the following two sources, but are not included in the analysis for the following reasons:

- **Photocontrols**: Photocontrols are only being required in alteration projects where wiring is added, moved or replaced. Costs and savings of installing photocontrols in retrofits are very similar to new construction, and are therefore covered in the concurrent Daylighting CASE (California Utilities Codes and Standards Team 2010 – Daylighting)
- **Area Controls**: The majority of buildings already have area control provided by wall-mounted switches. The survey results in Section 3.2 indicate that approximately 60% of current retrofit projects involve area controls. We do not expect this measure to change that rate in such a way that additional savings should be claimed in this proposal.

3.4.1 Results from Night Lighting Field Survey

This section analyzes the results of the night-time lighting survey. It discusses the patterns and trends in the data, potential sources of error, potential energy savings, and other relevant information.

The methodology of this study is described in Section 2.4.1. As can be seen in Figure 20 there was a great deal of variety in how much lighting was left on at night, on each floor of the surveyed buildings. Many buildings had no lighting on at all (except for exit signage); a few had all of their lighting on, and there was a broad spread in between those two extremes. The percentages shown are the percentage of observed stories, not the percentage of observed buildings).

Figure 20 also shows that there was a trend of lighting being switched off over time (from 6pm to 10pm), i.e., the lower-percentage bands (towards the bottom of the chart) get progressively wider over the five time periods, while the higher-percentage bands get narrower.

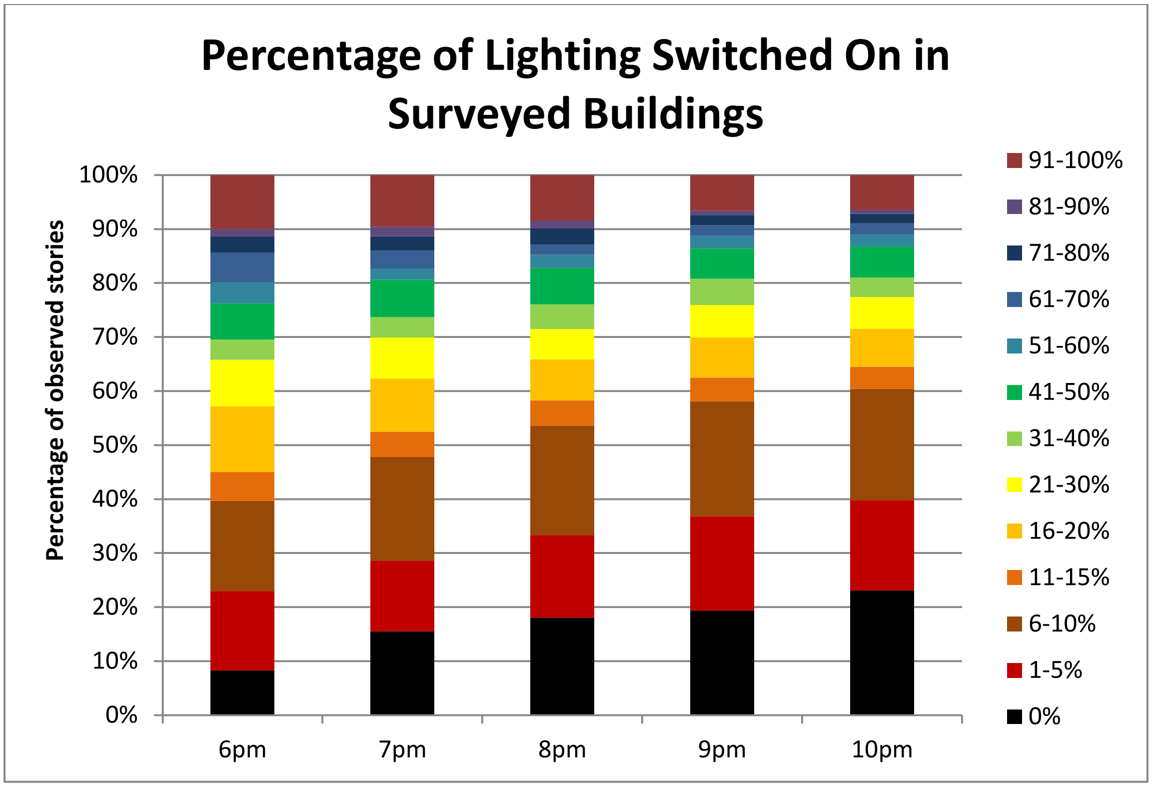

Figure 20 Percentage of Lights Switched On in Surveyed Buildings

To accurately calculate potential savings, we separate out egress lighting from general lighting because egress lighting is usually not controlled by the shut-off system. An estimate of the egress lighting load was made based on the following assumptions:

- If 10% or less of the lighting was switched on, that load was counted as being egress lighting.
- If more than 10% of the lighting was switched on, the first 10% of the load was counted as egress lighting.

An estimate of the non-egress lighting load was made by using the following calculation:

- The egress lighting load (see above) was subtracted from the total load

Figure 21 shows how the estimates of egress and non-egress lighting changed over time from the beginning to the end of the survey time period. The amount of egress lighting switched on remained approximately constant (at around 7%), since in practice most egress lighting is held on 24/7. Conversely, the amount of non-egress lighting declined steadily (from 24% to 15%) over the survey period. The fact that egress lighting declined much less over time than non-egress lighting gives us confidence that the analysis (above) successfully separated egress from non-egress loads. Based on this data, we conclude that around 15% of the installed LPD is left on overnight after 11pm, and is therefore available to be saved using shut-off controls.

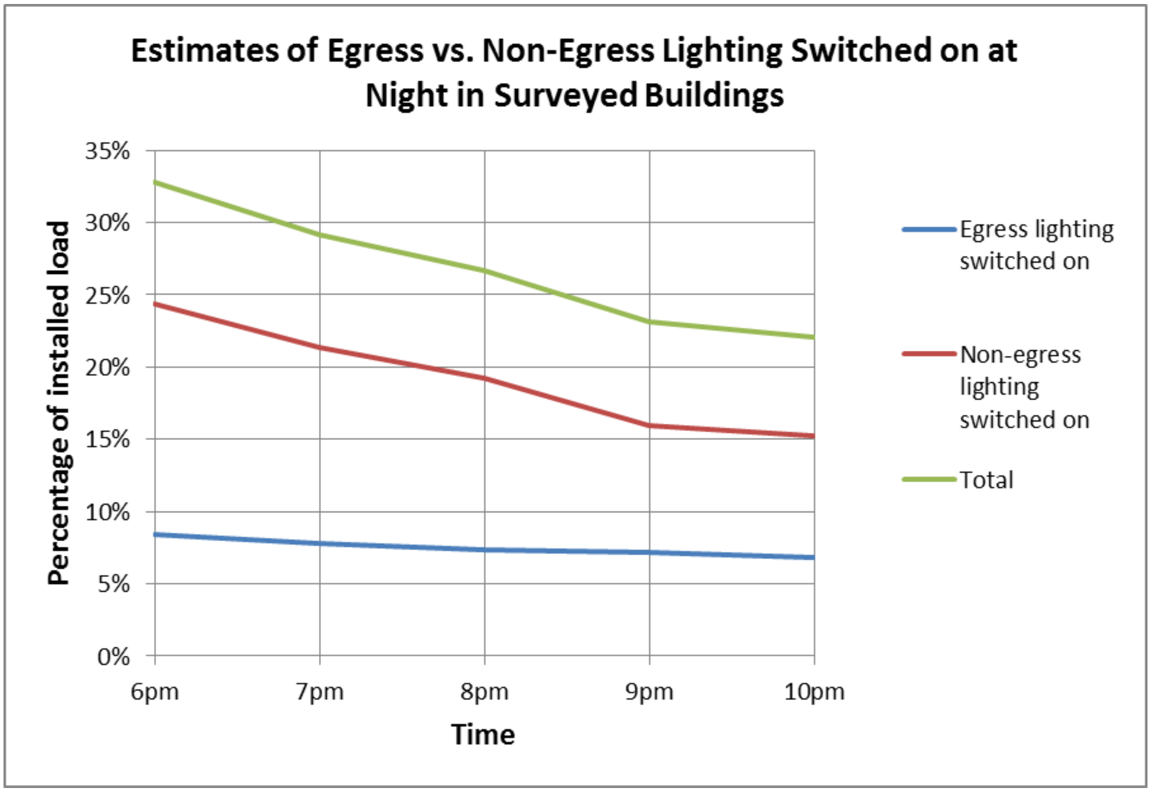

Figure 21 Estimates of Egress vs. Non-Egress Lighting Left On at Night in Surveyed Buildings

3.4.2 Comparison with CEUS Data

The California Commercial End-Use Survey (CEUS 2005) conducted in 2005 includes hourly short-term metering data on indoor lighting, from a subsample of buildings. The number of buildings for which short term metering data was obtained is shown in Figure 22.

Building type	Number of "short term metering" (STM) sites
Small office	71
Large office	38
Retail	100
Warehouse (Ref./non-ref)	56

Figure 22 CEUS Sample of Short-Term Metering Data

Figure 23 shows hourly lighting energy use profiles from the CEUS dataset. The CEUS report contains only an average profile, which does not allow us to separate egress lighting from non-egress lighting. Regardless, the profiles for each building type indicate that the CEUS data is in agreement with the findings of the night-time survey. The night-time survey sample was comprised mostly of large offices, with a number of smaller offices included. Our night-time survey found that an average of 22% of lighting was on at 10pm, whereas the CEUS data shows 38% for large offices and 15% for small offices at 10pm.

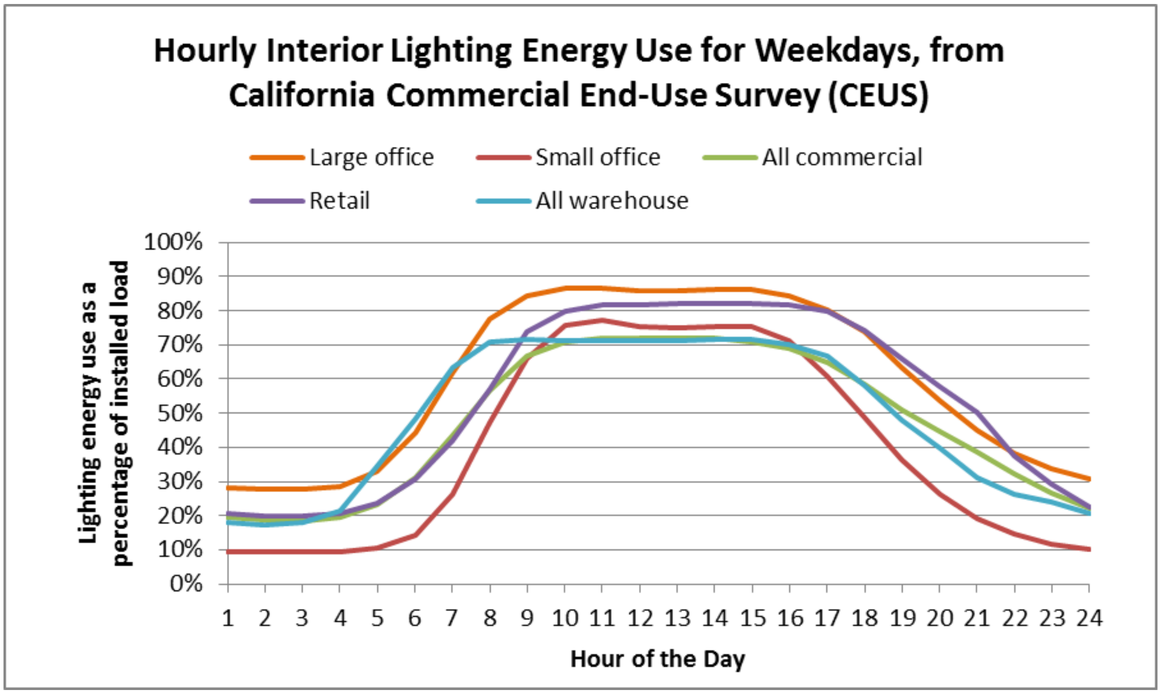

Figure 23 Hourly Interior Lighting Schedule for Weekdays, from CEUS

We have found no research data on real-world energy savings for automatic shut-off control systems. We expect that 50% of potential savings is a reasonable conservative estimate for savings from non-egress shut-off controls. The reasons why actual savings may be less than the savings estimated from the night-time survey and from CEUS include:

- Some lights may be left on overnight for cleaning crews and may not be able to be shut off
- Shut-off control systems may not work perfectly in practice
- Building operators may override shut-off controls due to perceived security concerns

3.4.3 Lighting Energy Savings for Offices

Annual energy savings from automatic shutoff of non-egress lighting was calculated to be 0.45 kWh/sf, and 1.07 kWh/sf for vacancy sensors. The TDV value of this energy savings was calculated to be $0.65/sf for floor level automatic shutoff controls, and $1.90/sf for vacancy sensors, over the 15-year measure lifetime.

The lighting schedule used to calculate energy savings from floor level automatic shutoff controls in the office models is depicted in Figure 25. The baseline weekday lighting schedule was obtained from the Final Report on Bi-Level Lighting (ADM 2002), and the unoccupied hours (10pm-6am and all-day Sunday) were replaced with the value of 15% of lighting left on, as reported in the night time field survey in Section 3.4.1. The open office schedule was applied to spaces that were using one of the open office floor level lighting control strategies. The savings calculation assumes the energy used by lights left on during unoccupied hours is saved by the automatic shutoff control.

The lighting schedule used to calculate energy savings from vacancy sensors in the office models is depicted in Figure 25. The private office lighting schedule was utilized for spaces that were assumed to be equipped with vacancy sensors. The savings calculation for vacancy sensors assumes that 21% of the lighting energy use during regular business hours can be saved by the vacancy sensor, in addition to energy savings during unoccupied hours, which used the same analysis and assumptions as the automatic shutoff control scenario, but with a higher LPD (1.1 W/sf) reflecting the area category allowance for private offices.

	Measure Schedule – (% lights on)		**Baseline Schedule – (% lights on)**	
Hour of day	**Monday - Saturday**	**Sunday**	**Monday - Saturday**	**Sunday**
0	0%	0%	15%	15%
1	0%	0%	15%	15%
2	0%	0%	15%	15%
3	0%	0%	15%	15%
4	0%	0%	15%	15%
5	0%	0%	15%	15%
6	78.00%	0%	78%	15%
7	87.00%	0%	87%	15%
8	92.00%	0%	92%	15%
9	94.00%	0%	94%	15%
10	94.00%	0%	94%	15%
11	95.00%	0%	95%	15%
12	94.00%	0%	94%	15%
13	94.00%	0%	94%	15%
14	94.00%	0%	94%	15%
15	94.00%	0%	94%	15%
16	93.00%	0%	93%	15%
17	87.00%	0%	87%	15%
18	83.00%	0%	83%	15%
19	80.00%	0%	80%	15%
20	33.00%	0%	33%	15%
21	15.00%	0%	15%	15%
22	0%	0%	15%	15%
23	0%	0%	15%	15%

Figure 24 Lighting Schedule for Open Office Area

	Measure Schedule - % lights on		Baseline Schedule - % lights on	
Hour of day	**Monday - Saturday**	**Sunday**	**Monday - Saturday**	**Sunday**
0	0%	0%	15%	15%
1	0%	0%	15%	15%
2	0%	0%	15%	15%
3	0%	0%	15%	15%
4	0%	0%	15%	15%
5	0%	0%	15%	15%
6	11.88%	0%	15%	15%
7	15.05%	0%	19%	15%
8	32.47%	0%	41%	15%
9	44.35%	0%	56%	15%
10	49.90%	0%	63%	15%
11	48.31%	0%	61%	15%
12	45.94%	0%	58%	15%
13	46.73%	0%	59%	15%
14	46.73%	0%	59%	15%
15	45.94%	0%	58%	15%
16	35.64%	0%	45%	15%
17	22.18%	0%	28%	15%
18	13.46%	0%	17%	15%
19	11.88%	0%	15%	15%
20	11.88%	0%	15%	15%
21	11.88%	0%	15%	15%
22	0%	0%	15%	15%
23	0%	0%	15%	15%

Figure 25 Lighting Schedule for Enclosed Office Rooms

The potential savings from shutting off non-egress lighting is estimated as follows: We assume that non-egress lighting can be switched off for 8 hours overnight (10pm - 6am) on weekdays and Saturday, and all day Sunday for a total of 3744 hours per year. This calculation applies to an office building with a complete building LPD of 0.8 W/sf.

$$0.8\frac{W}{sf} * 15\% * 3744\frac{hrs}{yr} = Automatic\ shutoff\ savings$$

The energy savings calculation from automatic shutoff controls is summarized below:

$$0.8\frac{W}{sf} * 15\% * 3744\frac{hrs}{yr} * \frac{1kWh}{1{,}000Wh} = 0.45\frac{kWh}{sf*yr}$$

The savings from automatic shutoff controls in offices is calculated assuming 15% of installed load left on overnight, as reported in the night lighting field survey reported in Section 3.4.1.

The baseline scenario of an office building without automatic shut off controls was estimated to use 3.72 kWh/sf/yr. This was calculated by assuming an LPD of 0.8 W/sf, and using the lighting schedule from the Title 24 Nonresidential ACM table N2-8 for occupied hours, and the estimate of 15% lights left on during unoccupied hours as reported by the night lighting survey in Section 3.4.1. The lighting schedule for the measure scenario (with automatic shutoff controls) was identical to the baseline scenario during occupied hours, and set to off during the unoccupied hours (10pm-6am Monday-Saturday and all day Sunday). This produced an estimated annual lighting energy of 3.27 kWh/sf. The measure savings is calculated as the difference between the two scenarios; 3.72 – 3.27 = 0.45 kWh/sf/year.

The energy savings calculation from vacancy sensors is summarized below:

$$1.1\frac{W}{sf} * 21\% * (Baseline\ \%\ lights\ On) * 5016\frac{hrs}{yr} + 1.1\frac{W}{sf} * 15\% * 3744\frac{hrs}{yr} * \frac{1kWh}{1000Wh} = 1.07\frac{kWh}{sf*yr}$$

The savings from these two equations is weighted according the breakdown of space types within the office models. The weighting for the office models used for analysis was 70% of the floor space had automatic shutoff controls installed using a time clock and 30% of the floor space were rooms equipped with vacancy sensors.

Figure 26 shows the lighting schedule used to calculate the savings for automatic shutoff controls. The blue line is the baseline office lighting schedule, which assumes that without automatic shutoff controls, 15% of the lights will be on overnight and all day Sunday. The red line is the scenario with automatic shutoff controls, which reduces the lighting schedule to 0% during unoccupied hours. The savings during weekdays is the area between the red and blue lines; 15% of the lighting load. There are 8 hours of savings on weekdays and Saturdays, and 24 hours of savings on Sundays.

Figure 27 shows the lighting schedule used to calculate the savings for vacancy controls. The unoccupied hours are treated the same as in the automatic shutoff control scenario, while occupied hours are reduced by 21%, based on a report prepared by HMG for Southern California Edison titled "Savings Estimates for Lighting Controls and Interactions" (Southern California Edison 2010). The 21%

The TDV value of savings from automatic shutoff controls in open office areas over the 15-year lifetime of the measure, assuming the hours of control described above, is calculated to be approximately $0.65/sf. The TDV value of savings from vacancy sensor in private offices and other rooms as required by Title 24, over the 15-year lifetime of the measure, assuming the hours of control described above, is calculated to be approximately $1.90/sf.

These values are weighted according to the breakdown of open office space and private office space in typical offices, as depicted in; weighted for $9,760 for a 8,200 sf small office and $40,500 for a 34,000 sf large office.

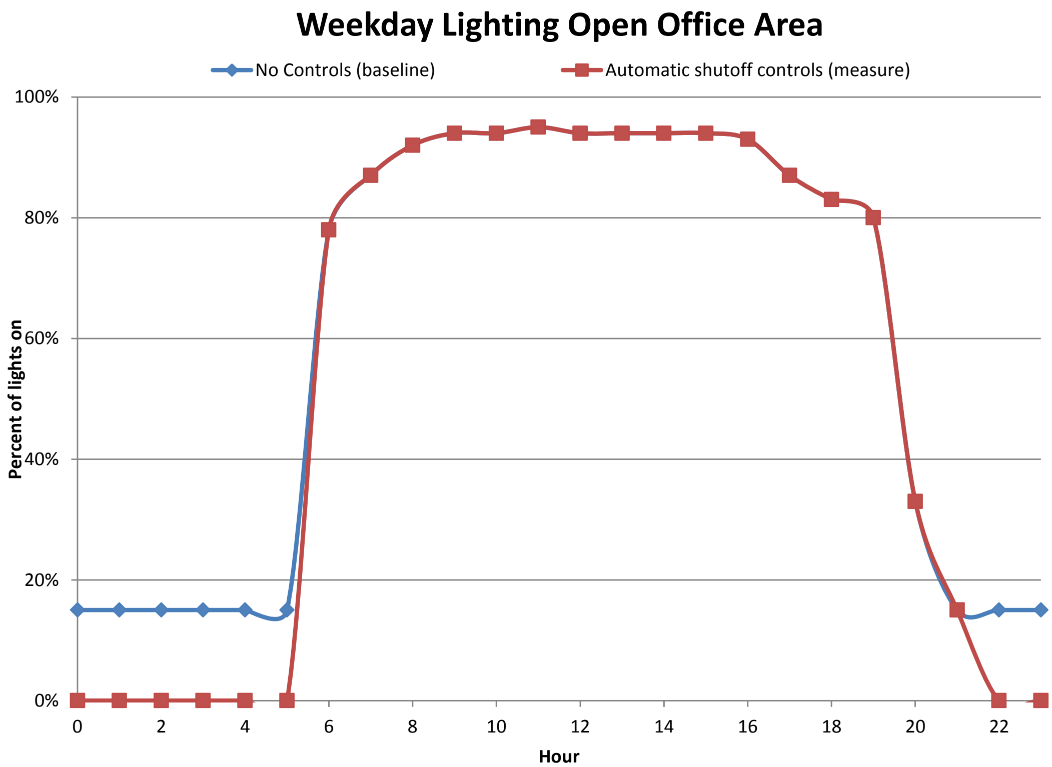

Figure 26 Open Office Area Weekday Lighting Schedule

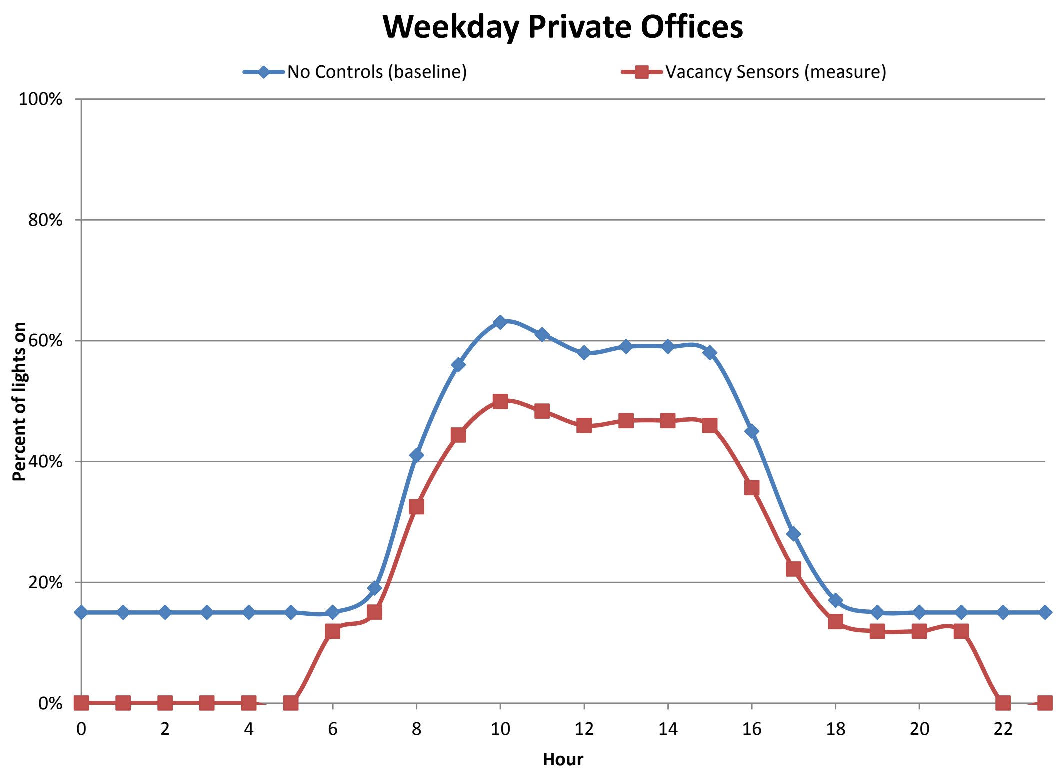

Figure 27 Private Office Weekday Lighting Schedule

3.4.4 Lighting Energy Savings for Other Building Types

A rudimentary savings analysis was performed for retail stores. It was assumed that shutoff controls could save 50% of the current lighting energy usage during unoccupied times. The reason that savings were halved for retail is that in common practice some retailers intentionally leave lights on to display their goods, even during unoccupied hours. This reduction of the savings estimate acknowledges the reduced savings potential for the retail sector. It was assumed that most retail stores are unoccupied between the hours of 10pm and 6am every day. This results in energy savings of 0.52 kWh/sf and nonresidential 15-year TDV savings of $0.73/sf. This assumes an installed LPD of 1.34 W/sf (California Energy Commission 2006). The baseline schedule presented in Figure 28 is based on the Title 24 Retail Occupancy Schedules (Table N2-12 in the NACM).

$$50\% \ * \ 1.34\frac{W}{sf} \ * \ 26.6\% \ * \ 2920\frac{hrs}{yr} * \frac{1kWh}{1{,}000Wh} = \ 0.52\frac{kWh}{sf-yr}$$

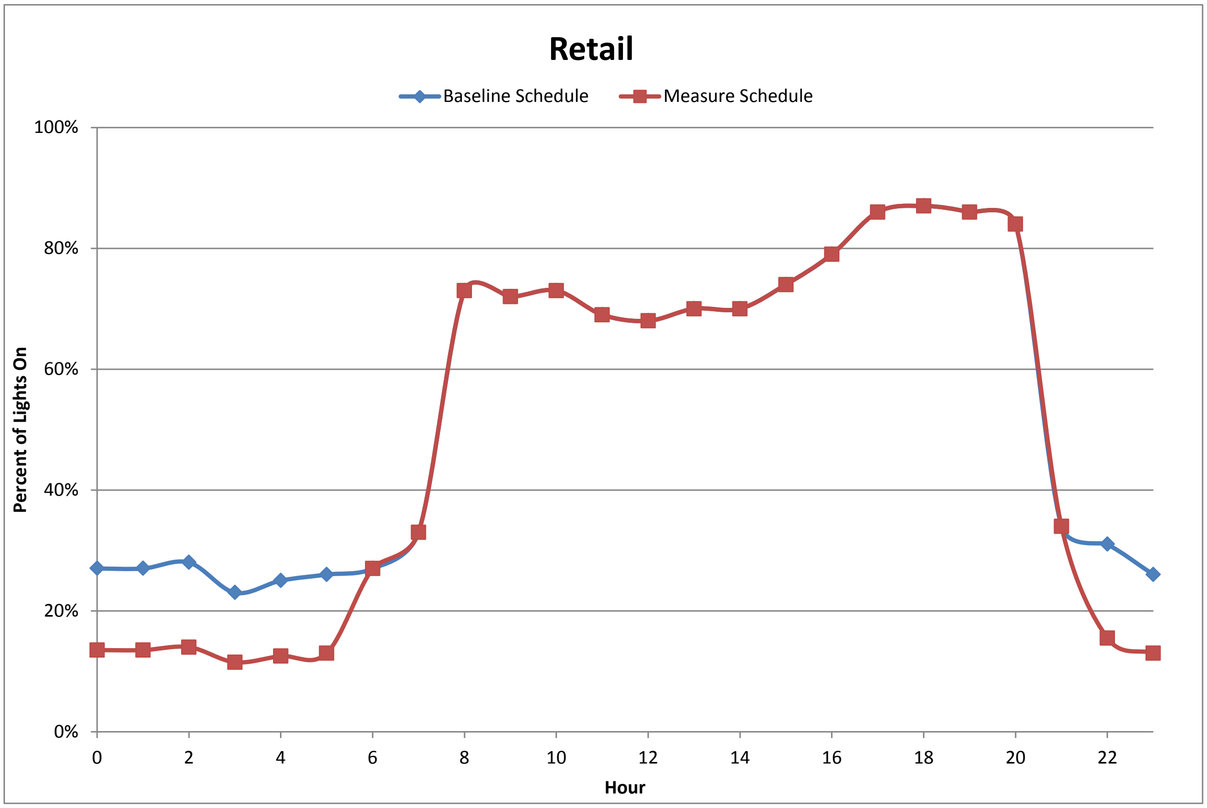

Figure 28 Retail schedule with shutoff controls

3.4.5 Projects Affected By New Threshold

The LPD reduction was calculated by determining the difference between the existing LPD in each space according to CEUS and the 2013 area category LPD allowance. Figure 29 shows the percent of statewide commercial floor space and how much higher the existing LPDs are than current Title 24 LPD requirements.

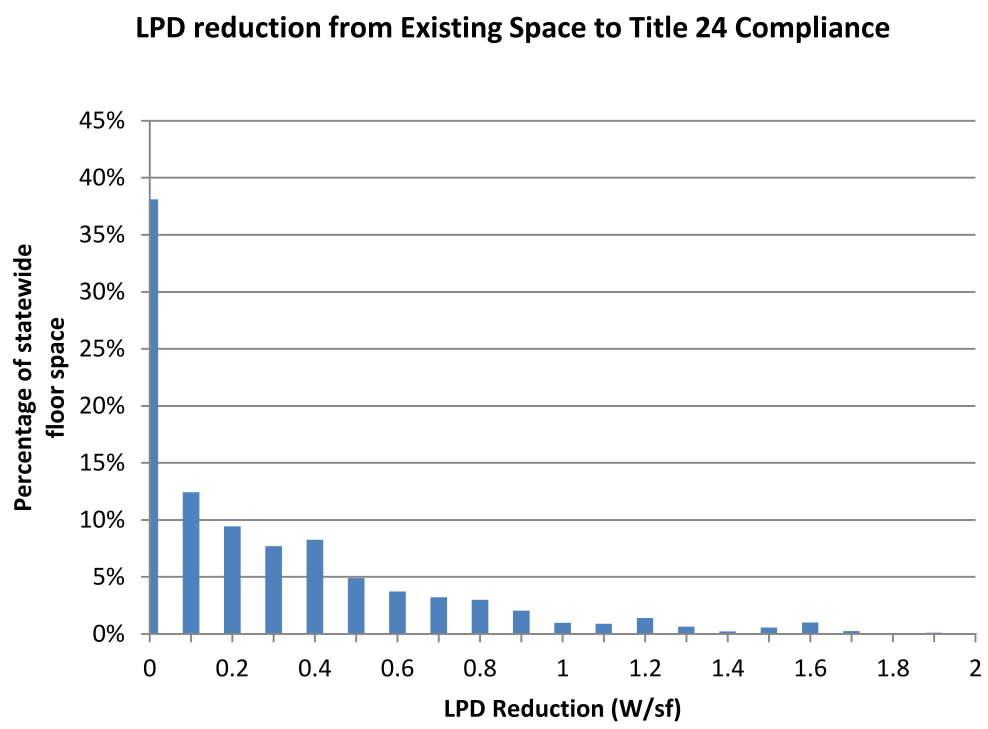

Figure 29 LPD Reduction Required in Existing Buildings for Compliance with Title 24 Area Category Method

According to Figure 29, approximately 38% of statewide commercial floor space already meets the current Title 24 LPD requirements. The average reduction in LPD that would be required for the remaining 62% of statewide commercial floor space that does not already meet the LPD requirement, weighted by floor space is 0.51 W/sf.

The average reduction in LPD that would be required for the 62% of statewide commercial floor space that do not already meet the LPD requirement, weighted by floor space, is 0.51 W/sf. Information about the LPD of commercial buildings was obtained from the Energy Commission (California Energy Commission 2010). Figure 29 shows the percent of statewide commercial floor space and reduction required of the existing LPDs in each space to be in compliance with the 2013 Title 24 LPD requirements.

The energy savings from a reduction of 0.51 W/sf was obtained by modeling annual lighting energy use using the CEUS "All Commercial" lighting energy use schedule (California Energy Commission 2006) as depicted in Figure 30. This results in annual energy savings of 2.1 kWh/sf.

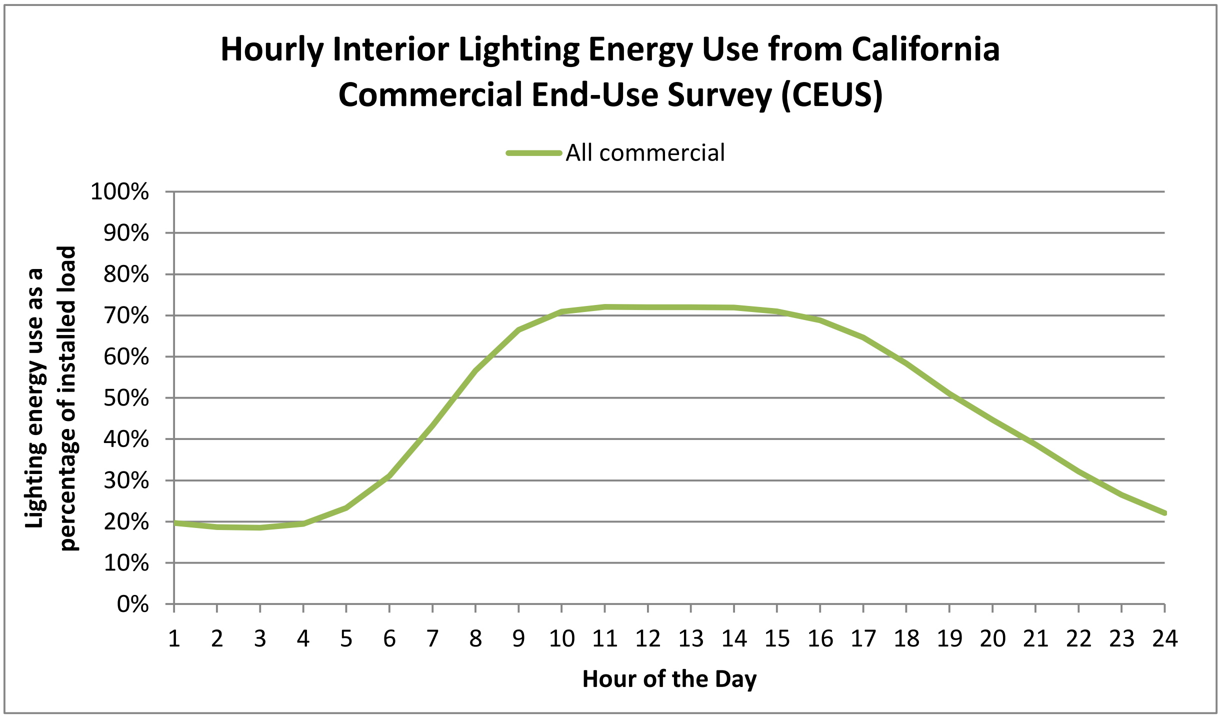

Figure 30 Hourly Interior Lighting Schedule from CEUS

The TDV value of a 1.0 W/sf reduction, assuming a 15 year measure life and the CEUS "All Commercial" lighting energy use schedule (California Energy Commission 2006), is $8.29 TDV$/sf. Thus the average savings from reducing the lighting power in commercial buildings in California by 0.51 W/sf is $4.19 TDV$/sf.

There is an additional savings of 15% of the now compliant LPD in situations where compliance with Section 131(b) – Controllable Lighting is also required. This layer of savings is applied after the space is brought into compliance with the allowed LPD threshold. Cost effectiveness of controllable lighting on the basis of reducing the maximum light output by 15% (tuning) at time of installation is justified in the concurrent Controllable Lighting CASE study. This CASE report claims the statewide savings that result from requiring 15% tuning of the lighting in retrofit spaces that previously did not require compliance with Section 131(b).

3.4.6 Peak Demand Savings

Peak demand savings for automatic shutoff controls result mainly from the reduction in load from vacancy sensors in private offices. A report prepared by HMG for SCE titled "Savings Estimates for Lighting Controls and Interactions"(Southern California Edison 2010) shows the savings that result from various control strategies. This information is presented in Figure 31. Subtracting the open office savings from Tuning from the open office savings for Tuning + VS (vacancy sensors) show us that vacancy sensors save 21% during occupied hours when used in combination with diming ballasts and tuning controls.

Tuning – adjustment (down) of the maximum light output for a dimming ballast.

VS = vacancy sensor

DH = daylight harvesting

DR = demand response enabled lighting control systems

Controls	**Open Office**	**Private Office**	**Classroom**	**Retail**
Tuning	20.0%	20.0%	20.0%	20.0%
Tuning + VS + DH + DR	61.3%	58.8%	63.2%	35.9%
Tuning + VS + DH	61.0%	58.4%	62.8%	35.5%
Tuning + VS + DR	48.4%	41.4%	46.1%	20.6%
Tuning + DH + DR	40.5%	44.3%	45.8%	35.9%
Tuning + VS	48.0%	40.8%	45.6%	20.0%
Tuning + DH	40.0%	43.8%	45.4%	35.5%
Tuning + DR	20.7%	20.8%	20.7%	20.6%

Figure 31 Savings Factors for Various Measure Interactions (Southern California Edison 2010)

The measure interactions depicted in Figure 31 include the requirements from Section 131 subsections b, c, d and g.

- Section 131(a) defines and requires area controls for each area enclosed by ceiling height partitions.
- Section 131(b) defines and requires multi-level lighting controls.
- Section 131(c) defines and requires photocontrols in daylight areas.
- Section 131(d) defines and requires automatic shutoff controls.
- Section 131(g) defines and requires demand responsive lighting controls.

Section 131(d) requires automatic shutoff controls, including the ability to manually override the shutoff, and specifically occupant sensors in offices 250 sf or smaller, multipurpose rooms less than 1,000 sf, and classrooms and conference rooms of any size. To calculate the demand savings per square foot, we multiply the percentage savings from vacancy sensors in private offices (21%) by the average percent of lights on during the peak period, which is 51% according to the lighting schedule for private offices presented in Figure 25. The peak period is defined as 12pm-6pm on weekdays by the CPUC for purposes of utility energy efficiency program evaluation. This is multiplied by 85% to represent the lighting power adjustment from tuning (required by the proposed changes to Section 131(b) from the Controllable Lighting CASE study), multiplied by the LPD for private offices (1.1 W/sf). This term is multiplied by the breakdown of private offices as a percent of total floorspace in office buildings (25%) according to the DEER final report (California Energy Commission 2005) which results in an average demand savings of 0.03 W/sf, as depicted in the equation below:

$$\text{Demand savings from vacancy sensors } = 21\% * 51\% * 85\% * 1.1\,\frac{\text{W}}{\text{sf}} * 25\% = 0.03\,\frac{\text{W}}{\text{sf}}$$

Peak demand savings from meeting the requirements of Sections 131(b) and 146 (tuning and LPD threshold) were calculated using the weekday schedule for warehouses and hotels shown in Figure 32. The lighting schedules for offices and retail were consistent with those presented in Figure 24 for offices and Figure 28 for retail.

Hour of day	All warehouse	All commercial
0	20%	20%
1	18%	19%
2	17%	19%
3	18%	19%
4	22%	23%
5	34%	31%
6	48%	43%
7	63%	57%
8	71%	67%
9	72%	71%
10	71%	72%
11	71%	72%
12	71%	72%
13	71%	72%
14	71%	71%
15	71%	69%
16	70%	65%
17	67%	58%
18	58%	51%
19	48%	45%
20	40%	39%
21	31%	32%
22	26%	26%
23	24%	22%

Figure 32 Commercial Weekday Lighting Schedules from CEUS

The demand savings from meeting the LPD requirements was calculated as the wattage reduction (average 0.51 W/sf) multiplied by the % of lights on during the peak period as defined by the CPUC.

The demand savings from tuning for each building type was calculated as the wattage reduction (15%) multiplied by the % of lights on during the peak period as defined by the CPUC, multiplied by the allowed LPD for the building type being evaluated.

3.5 Analysis of Measure Costs in Model Buildings

The labor rate used for all scenario cost estimates is $86.11 per hour for an electrician. This rate was calculated using the numerical average of the multipliers for the California cities listed in Figure 33, and multiplying by the national average rate for an electrician, $72.85, from Means CostWorks (RSMeans 2010).

Location	**Labor Rate ($/hr)**	**RS Means Multiplier**
National Avg	$ 72.85	-
Sacramento	$ 83.85	1.151
San Francisco	$110.44	1.516
Los Angeles	$ 88.95	1.221
Riverside	$ 80.28	1.102
San Diego	$ 75.55	1.037
Other CA cities	$ 77.59	1.065
California avg	**$ 86.11**	**1.182**

Figure 33 Electrician Labor Rate and Multipliers from RS Means

3.5.1 Fixed Costs: Strategy for Enclosed rooms

The total costs presented in the following tables assume a markup rate of 28% for equipment costs. This was based on conversations with manufacturers, who said to assume a 25% - 30% markup from contractor costs to the consumer.

The breakdown of costs for the small office enclosed rooms is shown in Figure 34. Each ceiling mounted vacancy sensor is assumed to require 20 feet of wire to provide a low voltage wall switch for purposes of area control. Thus this estimate assumes 80 feet of wiring for a total cost of $1,375.

Room	Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
			Estimated Hrs	Labor Cost			
Private Office	Occupancy sensor - wall	$45	0.35	$30	$88	5	$439
Misc rooms <500 sf (server room and printer/copier room)	Occupancy sensor - wall	$45	0.35	$30	$88	2	$175
Break room / kitchen	Occupancy sensor - wall	$45	0.35	$30	$88	1	$88
Conference Rm	Occupancy sensor - ceiling	$50	1.13	$98	$162	2	$323
Restroom	Occupancy sensor - ceiling	$50	1.13	$98	$162	1	$162
Conference and Restrooms	low voltage wall switch	$15	0.20	$17	$36	3	$109
	wiring (in 100 ft) for ceiling occ sensors	$18	1.27	$109	$132	0.6	$79
Enclosed Rooms Strategy Total Cost							$1,375
Cost/sf (8,200 sf)							$0.56

Figure 34 Fixed costs for small office lighting retrofit (enclosed rooms)

The breakdown of costs for the large office enclosed rooms is shown in Figure 35 assuming 140 feet of wiring for a total cost of $5,171.

Room	Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
			Estimated Hrs	Labor Cost			
Private Office	Occupancy sensor - wall	$45	0.35	$30	$88	36	$3,159
Misc rooms <500 sf (printer/copier room)	Occupancy sensor - wall	$45	0.35	$30	$88	1	$88
Breakroom	Occupancy sensor - wall	$45	0.35	$30	$88	2	$175
Conference Room	Occupancy sensor - ceiling	$109	1.1	$98	$237	3	$711
Restroom	Occupancy sensor - ceiling	$109	1.1	$98	$237	4	$948
Conference and Restrooms	low voltage wall switch	$15	0.2	$17	$36	7	$255
	wiring (in 100 ft) for ceiling occ sensors	$18	1.27	$109	$132	1.4	$185
Enclosed Rooms Strategy Total Cost							$5,522
Cost/sf (34,000 sf)							$0.53

Figure 35 Fixed costs for large office lighting retrofit in enclosed rooms

3.5.2 Variable Costs: Strategies for Open Areas

For each strategy described in Section 3.3.2 we developed two cost estimates for the open office area, one in the small office model and one in the large office. We calculated the total cost and cost per square foot for the entire model office buildings (i.e., added to the $1,375 for the small office fixed costs or $5,522 for the large office fixed costs described in Section 3.5.1).

Component	**Equip Cost to Contractor (per unit)**	**Labor Costs (per unit)**		**Total Cost (per unit), including Mark-Up**	**No. of units**	**Total Cost**
		Estimated Hrs	**Labor Cost**			
Wireless switch-leg transmitter, external antenna	$117	0.25	$22	$172	1	$172
Wireless receiver (built in relay, override switch) - in open offices	$109	0.75	$65	$205	5	$1,023
Wireless receiver (built in relay, override switch) - in other rooms	$109	0.75	$65	$205	7	$1,432
Timer	$68	0.20	$17	$104	1	$104
wiring (in 100 ft) to timers	$18	1.27	$109	$132	0.2	$26
Outlet box	$2	0.40	$34	$38	1	$38
Total for open office area	N/A					$2,795
Strategy A Cost/sf	N/A					$0.48
Total for Enclosed Rooms (from Figure 32)	N/A					$1,375
Total for small office bldg	N/A					$4,170
Cost per sq ft (8,200 sf)	N/A					$0.51

Figure 36 Costs for Small Office Open Strategy A

The breakdown of equipment and costs for Strategy A can be found in Figure 36 and Figure 37 for the small and large offices, respectively. The tables also show how many switches are required in various areas of the building, based on the building plans shown in Section 6 – Appendix A and the switch counts shown in Figure 18.

Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
		Estimated Hrs	Labor Cost			
Wireless switch-leg transmitter, external antenna	$117	0.25	$22	$172	3	$515
Wireless receiver (built in relay, override switch) - in open offices	$109	0.75	$65	$205	10	$2,046
Wireless receiver (built in relay, override switch) - in other rooms	$109	0.75	$65	$205	13	$2,660
Timer	$68	0.2	$17	$104	3	$312
wiring (in 100 ft) to timers	$18	1.3	$109	$132	2.4	$318
Outlet box	$2	0.4	$34	$38	1	$38
Total for open office area	N/A					$5,888
Strategy A Cost/sf	N/A					$0.25
Total for Closed Rooms (from Figure 33)	N/A					$5,522
Total for large office bldg	N/A					$11,410
Cost per sq ft (34,000 sf)	N/A					$0.33

Figure 37 Costs for Large Office Open Strategy A

The breakdown of equipment and costs for Strategy B can be found in Figure 38 and Figure 39 for the small and large offices, respectively. The tables also show how many switches are required in various areas of the building, based on the building plans shown in Section 6 – Appendix A and the switch counts shown in Figure 18.

Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
		Estimated Hrs	Labor Cost			
Wireless switch-leg transmitter, external antenna	$117	0.25	$22	$172	1	$172
Wireless receiver for circuit control - in open offices	$113	0.75	$65	$209	5	$1,043
Wireless receiver for circuit control - in other rooms	$113	0.75	$65	$209	7	$1,460
Wireless wall switch	$78	0.1	$9	$109	12	$1,303
Timer	$2	0.2	$17	$20	1	$20
wiring (in 100 ft) to timers	$18	1.3	$109	$132	0.2	$26
Outlet box	$2	0.4	$34	$38	1	$38
Total for open office area	N/A					$4,062
Strategy B Cost/sf	N/A					$0.70
Total for Enclosed Rooms (from Figure 34)	N/A					$1,375
Total for small office bldg	N/A					$5,438
Cost per sq ft (8,200 sf)	N/A					$0.66

Figure 38 Costs for Small Office Open Area Strategy B

Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
		Estimated Hrs	Labor Cost			
Wireless switch-leg transmitter, external antenna	$117	0.25	$22	$172	3	$515
Wireless receiver for circuit control - in open offices	$113	0.75	$65	$209	10	$2,086
Wireless receiver for circuit control - in other rooms	$113	0.75	$65	$209	13	$2,712
Wireless wall switch	$78	0.1	$9	$109	23	$2,498
Timer	$2	0.2	$17	$20	3	$61
wiring (in 100 ft) to timers	$18	1.3	$109	$132	2.4	$318
Outlet box	$2	0.4	$34	$38	1	$38
Total for open office area	N/A					$8,226
Strategy B Cost/sf	N/A					$0.35
Total for Enclosed Rooms (from Figure 35)	N/A					$5,522
Total for large office bldg	N/A					$13,748
Cost per sq ft (34,000 sf)	N/A					$0.40

Figure 39 Cost for Large Office Open Area Strategy B

The breakdown of equipment and costs for Strategy C is presented in Figure 40 and Figure 41 for the small and large offices, respectively. The tables also show how many switches are required in various areas of the building, based on the building plans shown in Section 6 – Appendix A and the switch counts shown in Figure 18.

Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
		Estimated Hrs	Labor Cost			
control panel (includes 4 relays)	$400	8	$689	$1,201	1	$1,201
sentry switches in open office areas	$100	0.33	$29	$157	5	$783
sentry switches in other rooms	$100	0.33	$29	$157	7	$1,097
Total for open office area	N/A					$3,081
Strategy C Cost/sf	N/A					$0.53
Total for Enclosed Rooms (from Figure 34)	N/A					$1,375
Total for small office bldg	N/A					$4,456
Cost per sq ft (8,200 sf)	N/A					$0.54

Figure 40 Cost for Small Office Open Area Strategy C

Based on conversations with manufacturers, the cost to the contractor of the control panel is approximately $100 per relay. RS Means, and conversations with controls equipment suppliers, indicate that a full day (8 hours) would be required to remove the existing control panel (if there is one) and install the new control panel. We have assumed that no additional wiring would be needed for this strategy, as the line voltage override system switches are electronically held, responding to the signal sent over the existing power line.

Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
		Estimated Hrs	Labor Cost			
control panel (includes 10 relays)	$1,000	8	$689	$1,969	1	$1,969
sentry switches in open office areas	$100	0.33	$29	$157	10	$1,567
sentry switches in other rooms	$100	0.33	$29	$157	13	$2,037
Total for open office area	N/A					$5,572
Strategy C Cost/sf	N/A					$0.23
Total for Enclosed Rooms (from Figure 35)	N/A					$5,522
Total for large office bldg	N/A					$11,094
Cost per sq ft (34,000 sf)	N/A					$0.33

Figure 41 Cost for Large Office Open Area Strategy C

The equipment and cost for Strategy D, which can be applied to a 2,000 sf zone or smaller, can be limited to the installation of line voltage vacancy sensors. It is assumed that 20 feet of line voltage wire would be required for each occupancy sensor or switch added to the space. The cost for passive, infrared vacancy sensors ($65) were estimated by contractors interviewed for a report the Heschong Mahone Group worked on for SDG&E about Automated Lighting Controls and Switching Requirements in Hotel and Multifamily Building Corridors (San Diego Gas & Electric 2009). Multiplying the labor estimate of 1.13 hours by an additional 50% provides an estimate of about 1.75 hours to install (RS Means 2010), which is a reasonable overestimation to allow for the additional work involved in retrofit application, for example cutting through drywall, etc. The total cost for each vacancy sensor is then $210; which serves between 500 and 1,000 sf. At the low end estimate of 500 square feet per vacancy sensor, this strategy costs $0.40/sf, which is cost competitive with the other strategies presented above. If the space being retrofit is this small, area controls are probably preexisting. However if area controls are needed, we can assume one dimmer switch per 1,000 sf, which is estimated to take 35 minutes to install and cost $129 total (RS Means 2010). This adds $0.13/sf to the cost of compliance. The components and prices shown in Figure 42 are for a 1,000 sf space. For a 2,000 sf space, all of the costs would double, as would the area covered, providing a constant cost per square foot of $0.53/sf.

Component	Equip Cost to Contractor (per unit)	Labor Costs (per unit)		Total Cost (per unit), including Mark-Up	No. of units	Total Cost
		Estimated Hrs	Labor Cost			
Occupancy sensor - ceiling	$50	1.13	$98	$162	2	$323
line voltage dimmer switch (1000W)	$65	0.53	$46	$129	1	$129
line voltage wiring (per 100 linear ft)	$18	1.27	$109	$132	0.6	$79
Strategy Total Cost	N/A					$531
Strategy Cost/sf	N/A					$0.53

Figure 42 Cost for Partial Building Retrofit Strategy D

3.5.3 Additional Costs for Photocontrols

To meet the requirements of Title 24 Section 131(c), photocontrols would need to be incorporated into each of the four strategies above. Photocontrols have already been proven cost-effective in new construction in certain spaces, and are included as a mandatory requirement for new construction in the 2008 code.

We propose that photocontrols should be adopted as a mandatory requirement in retrofit projects, because the amount of labor required to install photocontrols is not very different from the amount of labor required in new construction, under the following assumptions:

- Buildings have ceilings that are accessible and present no impediment to the installation of ceiling-mounted sensors and controllers (t-bars, or open ceilings).

- Photocontrol systems are typically localized systems and do not require wired connections to other spaces through walls or other partitions.
- Most new construction photocontrol systems are installed after the installation of the ceiling system, i.e., under circumstances very similar to most retrofit projects (except with the ceiling tiles absent).
- Photocontrol systems typically do not allow occupants to manually dim the lamps, so no wiring to a wall switch is required.
- Photocontrol systems typically do not interact with automatic shut-off controls or area controls (wall switches), i.e. photocontrols are "downstream" of these other systems.

Some photocontrol systems do not match this description, so in those cases building owners may need to pay more for the additional amenity and/or energy savings created by those systems.

Additionally, photocontrol systems installed during a retrofit may be better-commissioned than those installed in new construction, because interior finishes and furniture layouts are more likely to be known, and these affect commissioning setpoints and therefore enhance energy savings and the robustness of photocontrol systems.

For the large office model building, adding four photocontroller to serve the open areas immediately adjacent to the exterior of the building would add $1,009 to the cost of a strategy. This amounts to approximately $0.03 per square foot for the entire large office model. The small office model would require adding three photocontrols to serve the open areas immediately adjacent to the exterior of the building. This would add $757 to the cost of the compliance strategy, or approximately $0.09 per square foot for the entire small office model. The cost effectiveness of adding photocontrols is addressed separately in the Daylight CASE Report (California Utilities Codes and Standards Team. 2010 – Daylighting).

3.5.4 Cost Summary

Based on the analysis of the model small office building, the proposed lighting retrofit of automatic shutoff controls could be achieved at a cost of $0.50 - $0.67 per square feet. The range of costs for the large office model building is approximately half that of the small office. Cost estimates are summarized in Figure 43.

Model	**Total cost for shutoff and area controls ($/sf)**		
	Scenario A	**Scenario B**	**Scenario C**
Small office (8,200 sf)	$0.50	$0.67	$0.54
Large Office (34,000 sf)	$0.33	$0.40	$0.32

Figure 43 Summary of Cost Estimates for Each Scenario for Model Office Buildings

Note that in the Online Survey we asked about the likely effect of adding cost to a retrofit project, and the answers (Section 3.2.8) show that respondents believed that above $0.50/sf, the added cost would lead to some retrofit projects being cancelled entirely. This value of $0.50/sf is very close to the estimated cost of compliance for the controls measure in Figure 43.

The total installed costs associated for various fixture types that would allow for compliance with the LPD requirements per space type are described in Figure 44. It is assumed that the cost of removing an existing fixture requires 10 minutes of an electrician's time, which at the rate of $86/hour would cost $14.35 per fixture. Existing fixtures serve approximately 50 square feet each, based on existing LPDs, therefore fixture removal costs approximately $0.29/sf. Additional disposal of ballasts costs $5 for hazardous waste processing fees, adding approximately $0.10/sf. This $0.39/sf cost of removing existing fixtures and ballasts is added to the installed costs for each fixture type. The installed costs are from CostWorks Online Construction Cost Data (RS Means 2010).

Fixture Type	Installed Cost	Area Served (sf)	Installed Cost/sf	Total cost/sf
Fluorescent ballast replacement	$113.00	80	$1.41	$1.80
Grid mounted 2x4' fixture, two lamp	$172.50	80	$2.16	$2.54
Surface mounted 2x4' fixture, two lamp	$194.00	80	$2.43	$2.81
Continuous row suspended, steel	$292.00	80	$3.65	$4.04
Continuous row suspended, Aluminum	$477.00	80	$5.96	$6.35
High bay 400W MH Al reflector	$698.00	660	$1.06	$1.44
High bay 250W MH prismatic glass	$522.00	416	$1.25	$1.64
Low bay 150W MH Al reflector	$537.00	250	$2.15	$2.54

Figure 44 Installation Costs by Fixture Type

Note that the incremental cost of replacing luminaires is significantly higher than the $0.50/sf threshold, above which the Online Survey respondents told us that projects would begin to be cancelled due to the increased cost. Therefore we conclude that the requirement to install additional luminaires is likely to reduce the number of retrofit projects that are carried out, unless utility rebates can offset the increased cost.

3.5.5 Other Factors that Affect Cost

This cost analysis is intended to be conservative. The cost of real systems is strongly dependent on the existing equipment installed in the space, so there are several potential sources of cost savings that we have not included in the cost figures above.

In specific circumstances there may be some economies of scale among the various requirements of Section 131. For example, in areas where the requirements for occupant sensors and photocontrols are triggered, it may be more cost effective to use an existing product that offers the functionality of both a photosensor and occupant sensor, at lower cost than the two sensors individually. The cost efficiency is magnified when the reduction in required labor time (and cost) to install one device rather than two is considered. This only applies to scenarios where the lighting is circuited in a manner conducive to the use of photocontrols for daylight harvesting.

If there is a standard sized circuit panel enclosure in place, it can be relatively easy to replace the interior of the panel with a newer model, which would include time clock functionality for compliance with the automatic shut off requirement. This may significantly reduce the cost of the equipment, and time required for replacement of the circuit panel, from one full day down to a few hours.

Another possible option is to replace individual breakers with "smart" breakers, which provide increased functionality. This is generally possible if the previously existing breaker panel matches the manufacturer and model type of the new breakers to be installed. However this would require the addition of a control bus and controller to take advantage of the capabilities of the new breakers.

Some manufacturers offer lighting control systems in which occupants can use their desk phones or computer desktops to send a signal to override the automatic shutoff. Based on rough estimates of per-square-foot costs obtained from manufacturers, such systems cost about 25% more than standard lighting controls utilizing a wall-mounted override switch for automatic shutoff, and most likely require a training session for the occupants. But it can be cost-effective in large offices, particularly multi-story buildings with primarily open-office layouts.

3.6 Cost Effectiveness

Cost effectiveness of installing area controls and automatic shut off controls are analyzed in Section 3.6.1 below, followed by cost effectiveness of projects meeting the Title 24 LPD requirements presented in Section 3.6.2. These scenarios are evaluated separately because they can be triggered independently of one another.

3.6.1 Cost-Effectiveness of Controls Requirements

The costs and savings for the whole building approaches are weighted according to the space breakdowns presented for the model buildings in Figure 45. Both the small office and large office models have a weighting of 70% open office area and 30% enclosed rooms. This is very close the statewide average presented in the DEER final report (California Energy Commission 2005) of 64% open office area and 36% enclosed rooms.

	Small Office Model			Large Office Model		
Type of room	Number of Rooms	Net Area [sf]	% of Floor	Number of Rooms	Net Area [sf]	% of Floor
Private Offices	5	1,260	15%	36	5,934	17%
Restrooms	1	384	5%	4	685	2%
Conference Rooms	2	402	5%	3	1,810	5%
Printer/copier	1	87	1%	1	214	1%
Server room	1	75	1%			
Break Room				2	1690	5%
Kitchen	1	241	3%			
Enclosed Rooms	**11**	**2449**	**30%**	**46**	**10333**	**30%**
Open Offices	5	4,358	53%	6	21,675	64%
Mechanical/ Electrical				4	645	2%
(Elevator) Lobby	2	342	4%	1	333	1%
Stairs				2	306	1%
Corridor	5	981	12%	5	600	2%
Janitor				1	77	0%
Storage	2	93	1%	6	118	0%
Open Area	**14**	**5,774**	**70%**	**25**	**23,754**	**70%**
TOTAL:		**8,223**	**100%**		**34,087**	**100%**

Figure 45 Model Space Weighting: Open Area and Enclosed Rooms

The table in Figure 46 presents the cost and savings for the various control strategies analyzed for both the small and large office models. The first strategy listed "Vacancy Sensors (enclosed rooms)" refers to the cost and savings of installing vacancy sensors in rooms where they are required by Title 24 Section 131 (private offices <250sf, multipurpose rooms <1,000sf, and all conference rooms and classrooms) and where it is common practice (restrooms, copier/server rooms, etc). The costs and savings for this strategy are averaged with the specified open office area strategy for the whole building approaches which are presented at the bottom of the table.

For the model small or large office building undergoing a retrofit, the proposed change could be implemented at costs ranging from $0.33 -$0.68/sf, and yield a TDV savings of around $1/sf. Partial retrofits (Strategy D) are estimated to cost $0.51/sf and save $0.65 TDV$/sf. Thus, the TDV savings are higher than the estimated cost. These calculations use the 15-year Nonresidential TDV values, as described in Section 2.6.

The results of the lighting stakeholder survey in Section 3.2 indicate that the majority of commercial retrofits take place in offices (54%) while approximately 15% of retrofits take place in retail stores, schools and warehouses. For this reason we have focused on proving cost effectiveness of this measure in offices. The cost and savings estimates for the other building types are assumed to be cost effective because cost effectiveness is demonstrated for small offices.

All of the strategies presented have a benefit cost ratio greater than one, indicating that they are cost effective; except for Strategy B in the small office model. Strategy B assumes that there are no existing local area controls anywhere in the open office area. Rooms included in that area are storage and janitor closets, corridors and lobbies. This is a worst-case scenario that is unlikely to be encountered in practice. Applying Strategy B to the open office area, without retrofitting vacancy sensors in any enclosed rooms, has a benefit cost ratio of less than one (0.92). However, in a scenario such as this, it is likely that the entire floor plan is going to be retrofit, and therefore the whole building approach using strategy B in the open office area would be applied, which is cost effective, with a benefit cost ratio of 1.54 for the small office model.

Strategy	Small Office Model Cost ($/sf)	Large Office Model Cost ($/sf)	Small Office Model Annual Energy Savings (kWh/sf)	Large Office Model Annual Energy Savings (kWh/sf)	Small Office Model Savings (TDV $/sf)	Large Office Model Savings (TDV $/sf)	Benefit Cost Ratio (Small Office Model 8,200sf)	Benefit Cost Ratio (Large Office Model 34,000sf)
Vacancy Sensors (enclosed rooms)	$0.56	$0.53	1.06	1.06	$1.90	$1.90	3.38	3.55
Strategy A (wireless receivers with built in relays and switches, w/ timeclocks)	$0.48	$0.25	0.45	0.45	$0.65	$0.65	1.34	2.61
Strategy B (wireless relays and switches replace annunciated switches, w/ timeclocks)	$0.70	$0.35	0.45	0.45	$0.65	$0.65	0.92	1.87
Strategy C (control panel w/ line voltage override system)	$0.53	$0.23	0.45	0.45	$0.65	$0.65	1.21	2.76
Strategy D (Vacancy sensors for partial retrofit – up to 2,000 sf)	$0.53	$0.53	0.45	0.45	$0.65	$0.65	1.22	1.22
Whole building approach with strategy A	$0.51	$0.33	0.63	0.63	$1.02	$1.02	2.02	3.06
Whole building approach with strategy B	$0.66	$0.40	0.63	0.63	$1.02	$1.02	1.55	2.54
Whole building approach with strategy C	$0.54	$0.32	0.63	0.63	$1.02	$1.02	1.89	3.15

Figure 46 Area Controls and Shutoff Cost, Savings, and Benefit Cost Ratio

3.6.2 Cost-Effectiveness of Changes to LPD Compliance Threshold

The average reduction in LPD (weighted by floor space) for California commercial buildings to meet current Title 24 LPD allowances is 0.51 W/sf, as discussed in Section 3.4.5. The costs associated with the various luminaire types that can be used to meet the LPD requirements are presented in Figure 47, based on the analysis presented in Section 3.5.4.

Replacement luminaire type	Total cost/sf	Savings TDV$/sf	B/C Ratio
Fluorescent ballast replacement	$1.80	$4.19	2.3
Grid mounted 2x4' fixture, two lamp	$2.54	$4.19	1.6
Surface mounted 2x4' fixture, two lamp	$2.81	$4.19	1.5
Continuous row suspended, Steel	$4.04	$4.19	1.0
Continuous row suspended, Aluminum	$6.35	$4.19	0.7
High bay 400W MH Al reflector	$1.44	$4.19	2.9
High bay 250W MH prismatic glass	$1.64	$4.19	2.6
Low bay 150W MH Al reflector	$2.54	$4.19	1.7

Figure 47 Cost, Savings, and Benefit Cost Ratio of Reducing Installed LPDs

All of the luminaire types presented in Figure 47 have a benefit-cost ratio of 1 or greater, indicating cost-effectiveness, except for continuous row suspended steel luminaries. However, continuous row suspended aluminum luminaries are cost effective, and perform equally as well as steel. The difference between these two luminaire types is purely aesthetic; any decision to use steel instead of aluminum is based on consumer preference, not performance.

Compliance with the LPD threshold may also be triggered during ballast-only change outs. The number of ballasts that trigger this compliance will be determined for the final report. It is important to note that this would require a change to the existing language under section 149(b)1 which states:

> *"NOTE: Replacement of parts of an existing luminaire, including installing a new ballast or new lamps, without replacing the entire luminaire is not an alteration subject to the requirements of Section 149(b)1."*

This proposal would change this "note" so that ballast-only change outs above a specific threshold would be considered an alteration subject to the requirements of Section 140(b)1.

There would potentially be an added cost of wiring the control signal to the new ballast through the existing luminaire body. This would typically require threading the control wire through a knockout in the luminaire body and attaching a rubber grommet to the knockout.

3.7 Statewide Annual Savings

To assess statewide savings potential we obtained data from the CEC[2] regarding total construction and new construction by building type.

To calculate the square footage of lighting retrofits within existing buildings, we used the measure life for lighting systems assumed within Title 24 (15 years) and the approximate life of a commercial building (30 years). Typically, therefore, each building has one lighting retrofit within its 30 year life. This means that lighting retrofits occur in 3.3% of commercial floor space per year. Figure 48 shows the floor space by building type according to the calculation described above for data from the NonRes Construction Forecast.

$$Retrofits = Total\ Construction - New\ Construction \ * 3.3\%$$

All figures are in millions of square feet.

Building Type	2014 New Construction (million sf)	2014 Total Construction (million sf)	2014 Retrofits (million sf)
Large office (>30,000 sf)	28	1286	42
Small office (<30,000 sf)	9	397	13
Warehouses	34	1115	36
Retail	32	1176	38
Schools	10	554	18
Hotels	9	331	11
Others	61	2476	80
Total	183	7336	236

Figure 48 California Retrofit Floor Space by Building Types for 2014

According to these calculations, 55 million square feet of offices will be retrofit in 2014, which accounts for approximately 23% of all commercial floor space retrofit. The category "Other" accounts for a relatively large proportion of retrofits, approximately 34%, and includes Hospitals, Colleges and Miscellaneous building types.

To calculate hours of lighting energy use, we utilized CEUS data (California Energy Commission 2006), dividing the energy intensity for indoor lighting (kWh/sf/yr) by the installed lighting power density (W/sf) for each building type. This produces a rough estimate of the number of hours of

[2] "NonRes Construction Forecast by BCZ v7"; Developed by Heshcong Mahone Group with data sourced September, 2010 from Sheridan, Margaret at the California Energy Commission (CEC).

lighting energy use per year, which can be applied to W/sf savings figures to generate energy savings estimates.

$$Annual\ hours\ of\ lighting\ energy\ use/yr = \frac{Energy\ intensity\ \ kWh\ \ sf\ \ yr}{Installed\ LPD\ \ W\ \ sf} * \ \frac{1000Wh}{1kWh}$$

A subset of the total floor space identified as annual retrofits will be affected by the proposed code changes. Different sections of the code have different factors applied to the floor space numbers to generate accurate savings estimates. For the controls requirements (Section 131), this proposal increases the amount of floor space in retrofits that will be required to comply with code in 2 steps. The first step is changing the trigger for compliance with Section 131 from replacing 50% of the wiring in a space to being triggered by 50% of the fixtures in a space being replaced. The second step is the trigger for compliance with Section 131 and 146 changing from 50% of fixtures in a space to 10% of fixtures in a space.

The statewide savings for triggering Section 146, which are the LPD requirements, only apply to the incremental projects captured by changing the threshold from 50% of fixtures replaced to 10% of fixtures; which captures 21% of retrofits projects according to our survey of lighting professionals. We also used data regarding existing building LPDs (California Energy Commission 2006) to determine that 38% statewide floor space has an LPD that meets Section 146 requirements. The remaining 62% of floor space would trigger the requirement.

$$floorspace\ affected\ by\ Section\ 146 = Retrofits * 21\% * 62\%$$

The results of our survey of lighting professionals also indicates that 51% of lighting retrofit projects replace more than 50% of the fixtures in a space and pull a permit. We also learned that in 30% of retrofit projects, at least 50% of the luminaires have wiring installed; which was the previous code trigger for compliance with Section 131. We filter out those 30% of projects that would have been required to comply under the previous code language, and then add the 21% of projects that replace between 10% and 50% of the fixtures in a space.

$$floorspace\ affected\ by\ Section\ 131 = Retrofits * \ \ 51\% * 70\% \ \ + 21\%$$

To account for spaces that already are in compliance with Section 131(d), we adjust the above number by 50%, since we really do not know what percentage of buildings being retrofit already have automatic shutoff controls installed.

This measure also applies to the common areas of hotels and high-rise multifamily buildings; which will primarily be corridors. A concurrent report titled “Automated Lighting Controls and Switching Requirements in Hotel and Multi-family Building Corridors” analyzes the cost for requiring occupancy sensors in the corridors of hotels and multi-family buildings. The analysis performed for that report estimates corridors to account for 6.2% of floor space in multi-family buildings based on a sample of projects enrolled in PG&E and SCE multifamily new construction programs between 2006 and 2008. This same 6.2% is also applied to hotels without additional analysis as a conservative estimate. The CASE study for bi-level controls for the 2008 code based its calculations on corridors making up 20% of hotel floor space, which is a much higher estimate than we have used.

The effect of the proposed code language in Section 4.2is depicted as a table in Figure 49. Each section of the lighting controls and LPD requirements are listed, identifying the percent of the time the various retrofit scenarios occur and the percent of retrofit luminaires affected by each scenario.

Percent of retrofit projects by project size in the top row of Figure 49 is based on survey responses presented in Section 3.2.2. The percent of projects were weighted by the average number of luminaires represented by each project size category. This produced an approximation of percent of luminaires retrofit statewide for each project size category, presented in the second row. We then divided each project category into projects that replace wiring, and projects that do not replace wiring. The estimate of wiring changes 39% of the time was based on survey responses presented in Section 3.2.4. The category of individual luminaires added or replaced was developed to help estimate the percent of luminaires retrofit statewide that would have to comply with Section 131(b), which is the only Section that is applied on a per luminaire basis instead of per space. The other Sections presented in the Figure 49 are applied to enclosed spaces, using the percent of luminaires retrofit as a trigger. “Existing Req” indicates situations where the 2008 code language was already requiring compliance with that particular section of the lighting requirements. The new scenarios requiring compliance with the applicable lighting requirements are indicated by the phrase “New Req”. In situations where less than 10% of the luminaires or ballasts in a space are added or replaced, compliance with the lighting controls requirements are required only if the lighting load is increased, which generally will apply to spaces adding luminaires. Sections 131(b) and (c) are only triggered when the lighting power density changes from less than 0.5 W/sf to greater than 0.5 W/sf. That specific scenario also triggers compliance with the skylighting requirements in Section 143(c).

	Lighting Retrofit Projects In Enclosed Spaces						Individual Luminaires Replaced or Added			
	More than 50% of luminaires replaced		**Between 10% and 50% of luminaires replaced**		**Less than 10% of luminaires replaced or ballasts only**		**More than 30% of luminaires in the space**		**Less than 30% of the luminaires in the space**	
Percent of Projects	69%		22%		9%		74%		26%	
Estimated Percent of Luminaires Retrofit	90%		9%		2%		93%		8%	
Replace Wiring	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Estimated Percent of Luminaires Retrofit	35%	55%	3%	5%	1%	1%	36%	56%	3%	5%
Section 130	Existing Req	Existing Req	**New Req**	**New Req**	Existing Req if load increased above 0.5 W/sf	Existing Req if load increased above 0.5 W/sf	N/A - These are space requirements that do not apply to individual luminaires			
Section 146	Existing Req	Existing Req	**New Req**	**New Req**	Existing Req if load increased above 0.5 W/sf	Existing Req if load increased above 0.5 W/sf				
Section 131(a)	Existing Req	**New Req**	Existing Req	**New Req**	Existing Req	**New Req if load is increased**				
Section 131(b)	Existing Req	Not required	Existing Req	Not required	Existing Req	**New Req if load is increased above 0.5 W/sf**	Existing Req	**New Req**	~~*Previously required, but no longer*~~	Not required
Section 131(c)	Existing Req	Not required	Existing Req	Not required	Existing Req	**New Req if load is increased above 0.5 W/sf**	N/A - These are space requirements that do not apply to individual luminaires			
Section 131(d)	Existing Req	**New Req**	Existing Req	**New Req**	Existing Req	**New Req if load is increased**				

Figure 49 Effect of Code Change by Lighting Section Required

Each scenario that is a new requirement was included in the estimate of statewide savings, presented in Figure 50. Any scenario that already previously required compliance with a specific lighting requirement section is not included. Also excluded are scenarios that depended upon the increase of lighting load, or specifically increasing lighting load above 0.5 W/sf. There was not sufficient research about the frequency of that type of retrofit, and therefore it was excluded from the calculation of savings.

Energy Savings from Section 131(d) – Automatic Shutoff controls was not calculated for hotels as the majority of floorspace in hotels are dwelling units and corridors, which are exempt from Section 131(d). There was insufficient information available about lighting schedules for the public areas of hotels that are affected by Section 131(d) to estimate energy savings. The tuning and LPD savings for hotels are based on an installed lighting wattage of 0.86 W/sf as reported by CEUS (California Energy Commission 2006) and approximately 10% of floorspace being public areas as opposed to hotel rooms based on the DEER prototype for hotels (California Energy Commission 2005).

Demand savings are calculated as the average demand reduction during the peak period. We used the CPUC definition of peak period that is used for energy efficiency program evaluation, which includes all non-holiday weekday hours from 12pm-6pm between July and September. The peak demand savings from Section 131(d) – Automatic Shutoff are based on installation of vacancy sensors in 25% of the floorspace of offices. Other building types are not required to have vacancy sensors, and therefore no demand savings is estimated from that requirement in those building types.

	Energy savings per square foot (kWh/ft2/yr)			**Statewide energy savings (GWh/yr)**			**Statewide peak load reduction (MW/yr)**		
Building Type	**Section 131(b) - Tuning**	**Section 131(d) – Auto-Shutoff**	**Section 146 - LPDs**	**Section 131(b) - Tuning**	**Section 131(d) – Auto-Shutoff**	**Section 146 - LPDs**	**Section 131(b) - Tuning**	**Section 131(d) – Auto-Shutoff**	**Section 146 - LPDs**
Office	0.45	0.67	1.90	13.09	21.92	9.19	2.87	0.82	1.25
Retail	0.81	0.52	2.28	16.41	11.81	7.68	2.71	-	1.27
Warehouse	0.31	-	1.75	5.96	-	5.58	1.21	-	1.13
Hotels	0.53	-	2.06	0.30	-	0.19	0.05	-	0.03

Figure 50 Statewide Estimates of Annual Savings

4. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

4.1 Code Change Proposals

All the requirements for lighting alterations are contained in Section 149(b)1I, so the code changes described below would all be implemented through changes to that code section.

Reduce the threshold for lighting power density compliance from 50% to 10% of lighting replaced.

Title 24 2008 requires that a space must meet the lighting power density requirements of Section 146 if more than 50% of the luminaires are being removed or replaced. We propose to reduce that percentage to 10% (see Section 3.2.2).

Remove the exception for ballast replacements

Title 24 2008 defines a lighting alteration to exclude ballast replacements in existing luminaires. We are proposing to change this language so that ballast replacements count as alterations. The cost-effectiveness calculations show that requiring ballast changeouts to comply with Code is extremely cost-effective, even if the end-user was not already intending to change the ballasts.

However, the Code should not place an undue permitting burden for small projects, either on building owners/tenants, or on Code officials and building departments. We have therefore proposed to exempt any projects in which fewer than 30 ballasts or luminaires are being replaced.

The Code should also avoid requiring people to pull permits for routine maintenance, and the replacements of small numbers of ballasts is part of the routine maintenance carried out in many buildings. The 30-ballast threshold also aims to ensure that routine maintenance is not impacted by the Code.

In terms of electrical safety, allowing an exception for lighting retrofit projects is consistent with the policies of most building departments. Building departments do not require permits for ballast replacements, because the electrical load can only decrease, not increase as a result of the changeouts.

Require "Area Controls" in All Altered Spaces

We are proposing to make the lighting controls requirements of Section 131(a) mandatory in retrofit projects in which more than 10% of the luminaires or ballasts are replaced, as long as the project involves 30 or more luminaires. Under 2008 code, these controls are only required if the wiring to the fixtures is being replaced. The applicable sections are as follows:

- **Section 131(a)** covers "Area Controls", and requires:

1. Each area enclosed by ceiling-height partitions shall have an independent switching or control device. This switching or control device shall be:
2. Readily accessible; and
3. Located so that a person using the device can see the lights or area controlled by that switch, or so that the area being lit is annunciated; and

4. Manually operated, or automatically controlled by an occupant-sensor that meets the applicable requirements of Section 119.

We believe that this proposed change would affect only a few spaces, because almost all buildings already have "area controls" (i.e., light switches).

Require "Controllable Lighting" for All Replaced Ballasts and Luminaires

This requirement would apply only to luminaires that have been moved or replaced (i.e., it would not apply to luminaires that remain in place during the project).

- **Section 131(b)** covers multi-level lighting, and in the 2013 code will likely require dimming (or four-step switching) for almost all luminaires. We believe that requiring multi-level controls for luminaires that have been moved or replaced would incur some added cost for additional light switches and possibly additional circuits, but the cost of the dimming ballasts and at least some of the wiring would not be included in this proposed measure. This is because it is already included in the Controllable Lighting CASE.

Require Photocontrols When the Wiring to the Fixtures is Altered

- **Section 131(c)** covers photocontrols. In the 2013 code, photocontrols will likely be required in spaces 250 sf and larger. We believe that photocontrols can be installed as a retrofit measure for the same cost as in new construction, if the wiring is being replaced at the same time. This is because the existing wiring may not be circuited correctly for photocontrols (parallel to the windows), and rewiring in parallel would be prohibitively expensive.

Require "Shut-off Controls" in all altered spaces

We are proposing to make it mandatory to install shut-off controls that control *all* the lighting in spaces in which more than 10% of the lighting is being moved or replaced, as long as the project involves 30 or more luminaires. Under 2008 code, shut-off controls are only required in retrofit projects if the wiring to the electrical room is being replaced.

Shut-off controls are defined under Title 24 Section 131(d). This Section requires time clock control, vacancy sensor control, or some other automatic control. Additionally, offices 250 square feet or smaller, and multipurpose rooms of less than 1000 square feet, and classrooms and conference rooms of any size, must be equipped with occupant sensors.

Note Regarding the Controllable Lighting CASE

If the Controllable Lighting CASE is not adopted for the 2013 Code, the existing requirements in Section 131(b) may continue to require multi-level switching, which is generally accomplished by the use of bi-level (dual circuit) wiring. Therefore it makes sense that complying with Section 131(b) would only be required in alteration projects where the wiring is affected, triggered in the proposed Section 149(b)1I5 ("Where conductor wiring from a lighting panel or from a light switch to the luminaires is being added or replaced, the spaces it serves shall meet the requirements of Section 131(a, b, c and d").

4.2 Recommended Code Language

4.2.1 Section 131 (d):

In addition to the manual controls installed to comply with Section 131(a) and (b), for every floor, all indoor lighting systems shall be equipped with separate automatic controls to shut off the lighting. These automatic controls shall meet the requirements of Section 119 and may be an occupant sensor, automatic time switch, or other device capable of automatically shutting off the lighting **when the building is unoccupied.**

4.2.2 Section 149(b)1

1. Prescriptive approach. The altered envelope, space conditioning, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110 through 139; and

~~*NOTE: Replacement of parts of an existing luminaire, including installing a new ballast or new lamps, without replacing the entire luminaire is not an alteration subject to the requirements of Section 149(b)1.*~~

A. Alterations to the building envelope other than those subject to Section 149(b)1B shall comply with the applicable subsections…

I. Alterations to existing indoor lighting systems shall meet the following requirements:

NOTE: Replacement of only the lamps and/or reflector(s) of the luminaire is not an alteration subject to the requirements of Section 149(b)1.

~~*1. Alterations that increase the connected lighting load, replace, or remove and re-install a total of 50 percent or more of the luminaires in an enclosed space, shall meet the requirements of Sections 130 and 146; and*~~

1. Enclosed spaces in which alterations increase the connected lighting load shall meet the requirements of Sections 130, 131(a and d), 134 and 146. In addition, enclosed spaces in which the installed lighting power density increases from less than 0.5 Watts per square foot ~~*Alterations that have less than 0.5 watts per square foot and increase the existing lighting power density*~~ to 0.5 watts per square foot or greater shall meet the requirements of Section~~*s*~~ ~~*119, 130,*~~ 131, ~~*134,*~~ **and the skylighting requirements of Section** 143(c)~~*, and 146*~~.

2. Enclosed spaces in which a total of 10 percent or more of the luminaires or ballasts are replaced, or removed and re-installed shall meet the requirements of Sections 130, 131(a and d), 134 and 146.

EXCEPTION 1 to Section 149(b)1I2: Alterations in which less than 30 luminaires or ballasts are replaced in the entire building.

3. **Luminaires or ballasts that are added or replaced shall meet the requirements of Section 131(b), and Section 134.**

EXCEPTION 1 to Section 149(b)1I3: Enclosed spaces in which 30 percent or fewer of the luminaires or ballasts are replaced.

~~*2. The following wiring alterations shall meet the requirements of Sections 119, 131, and 134:*~~

~~*i. Where new or moved wiring is being installed to serve added or moved luminaires; or*~~

~~*ii. Where conductor wiring from the panel or from a light switch to the luminaires is being replaced, or*~~

~~*iii. Where a lighting panel is installed or relocated.*~~

4. Where a lighting panel is installed or replaced, the spaces it serves shall meet the requirements of Section 131(d).

5. Where conductor wiring from a lighting panel or from a light switch to the luminaires is being added or replaced, the spaces it serves shall meet the requirements of Section 131(a,c and d).

~~*3*~~**6**. For an alteration where an existing enclosed space is subdivided into two or more spaces, the new enclosed spaces shall meet the requirements of Sections 131(a) and (d)**.**~~*; and*~~

EXCEPTION 1 to Section 149(b)1I: Spaces in which existing ceilings, ducts or walls are constructed, insulated or sealed with asbestos shall not be required to comply with Section 131.

EXCEPTION 2: Luminaires installed in hard ceilings shall not be required to comply with Section 131(b and c).

EXCEPTION 3 to Section 149(b)1I: Spaces with hard ceilings and without existing area controls shall not be required to comply with 131.

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6. Appendix A--Model Building Layouts

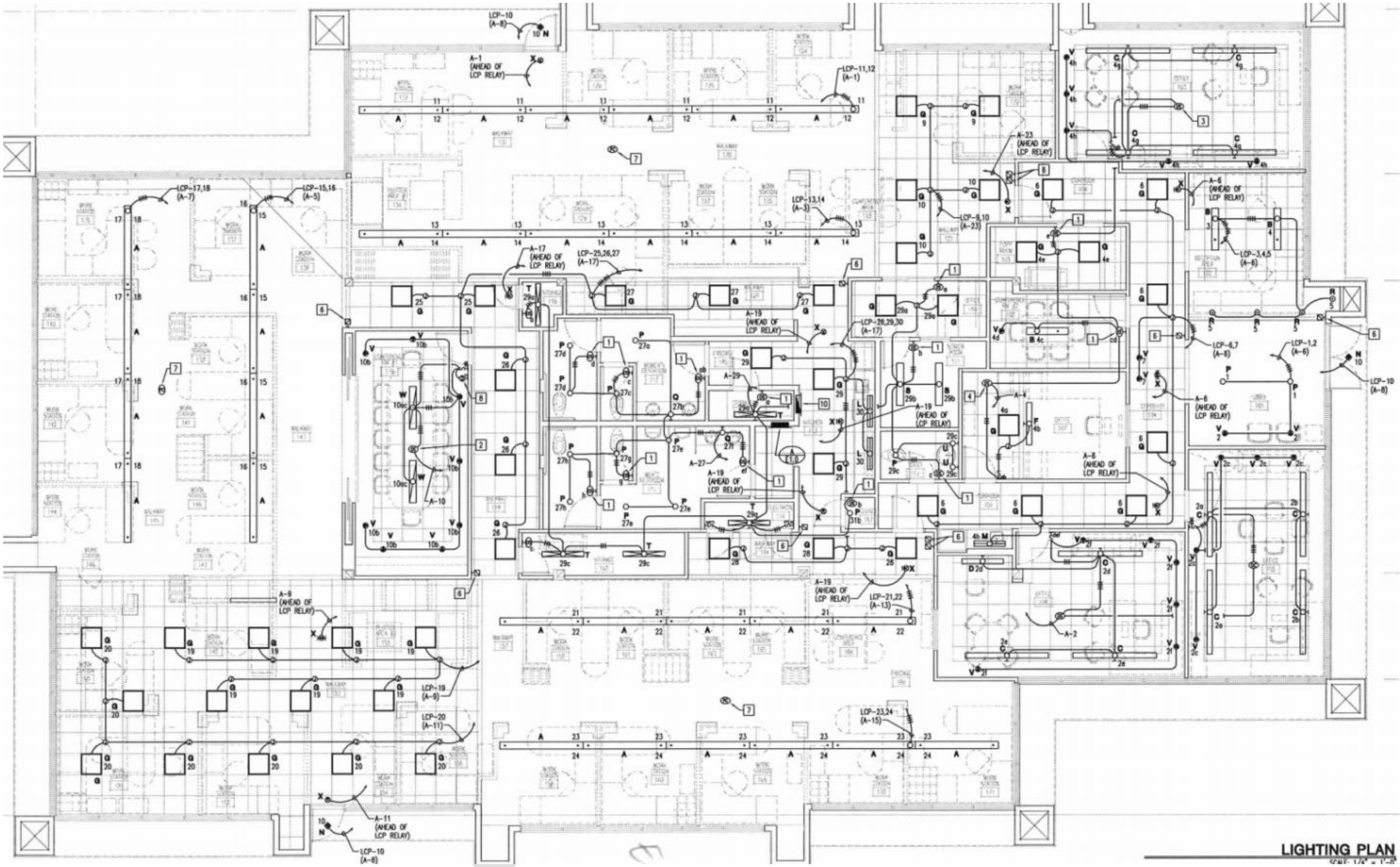


Figure 51 Small Office Prototype Reflected Ceiling and Floor Plan

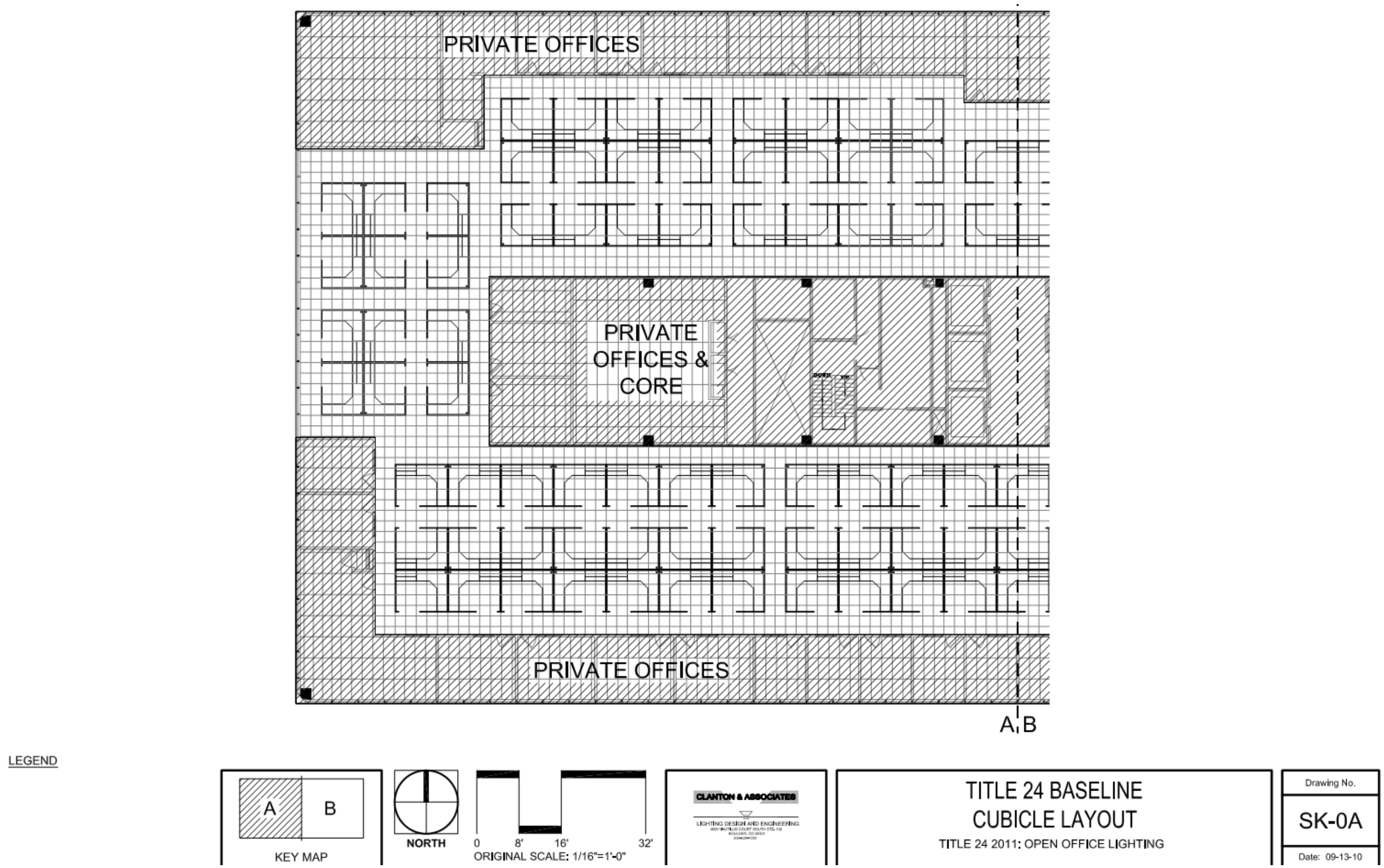


Figure 52 West Wing of Large Office Prototype Floor Plan

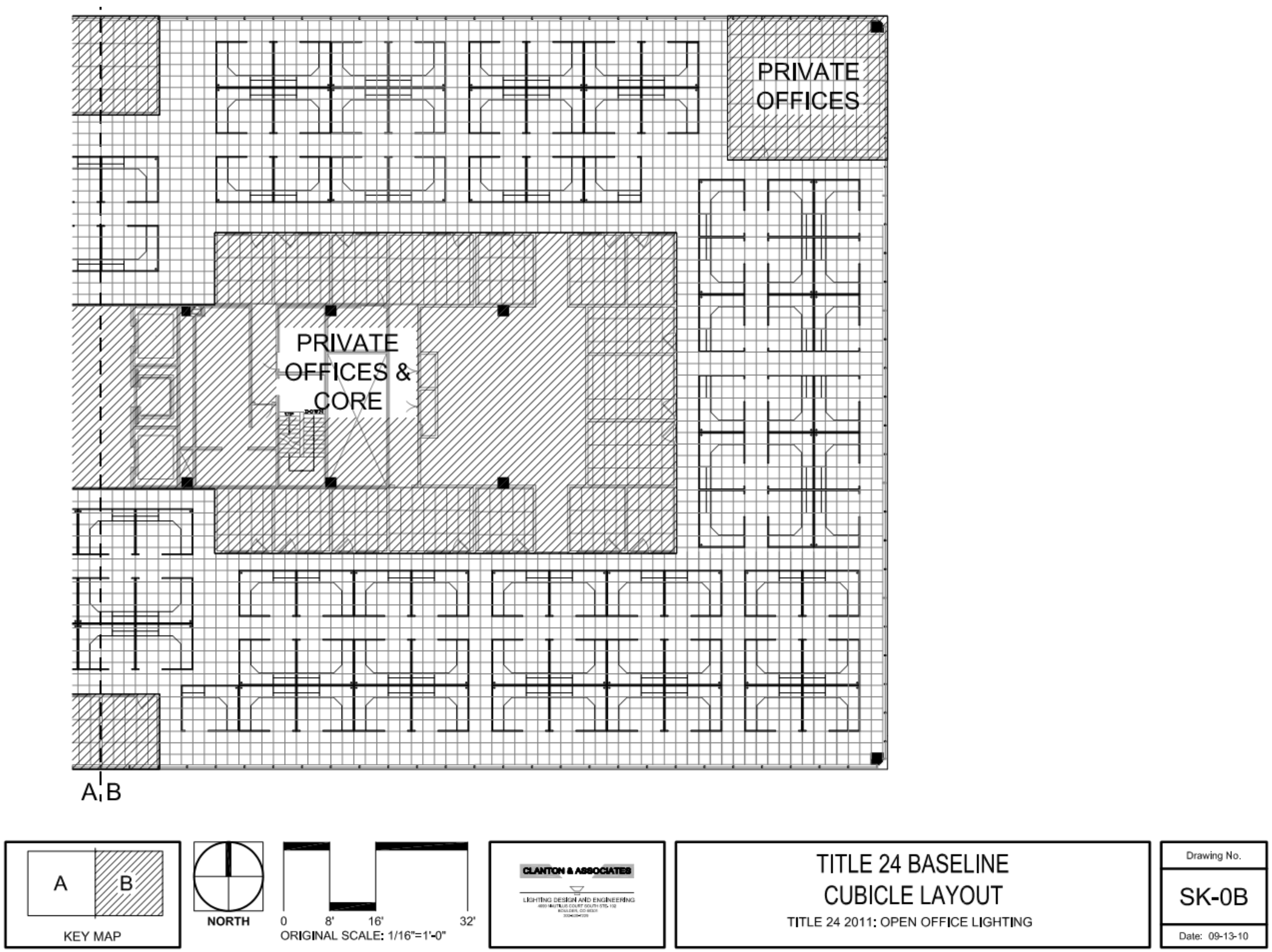


Figure 53 East Wing of Large Office Prototype Floor Plan

7. Appendix B--Sensitivity analysis results for egress lighting assumption

The following figure shows the sensitivity analysis for assuming a value of 10% for egress lighting, as part of the cost savings analysis.

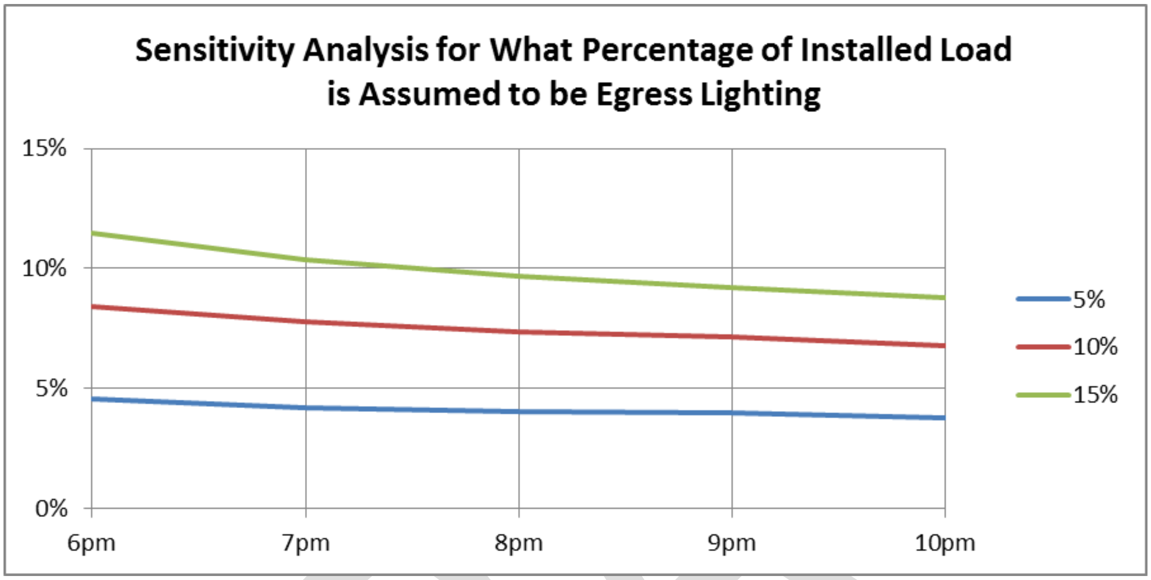


Figure 54 Results of sensitivity analysis for assumption that egress lighting comprises 10% of total lighting

8. Appendix C--Lighting Retrofit Market Literature Review

Findings from Lighting Retrofit Market Literature Review

8.1 Types of Alteration Project

Changes to lighting systems can come in many forms, from the most basic maintenance, replacing components, to comprehensive tenant improvements, replacing entire lighting systems. This section summarizes and categorizes the broad range of lighting alteration projects.

The table below gives a summary of the types of project, from the most simple (at the top) to the most extensive. It shows how they are commonly categorized in the market, and in the Nonresidential Remodeling and Renovation Study prepared by ADM and TecMRKT Work for the California Energy Commission (the "NRRR study"3). It also shows how they are categorized in Title 24, and which Title 24 sections are triggered by each.

3 Nonresidential Remodeling and Renovation Study. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Final volumes published March 2002.

Activity	Common Description of Type of Construction	NRRR Study Classification	2008 Title 24 category	2008 Title 24 sections triggered
Maintenance –lamp replacement, cleaning and burnout replacement	Lighting maintenance	Emergency replacement / Planned maintenance	Repair	None
Replacement of ballast and lamp	Lighting upgrade	Retrofit	Repair	None
Luminaire replacement	Lighting upgrade	Retrofit	Alteration	ss130 and ss146 if >50%
Luminaire relocation	Tenant improvement	Remodeling	Alteration	ss130 and ss146 if >50%
Additional luminaires added	Tenant improvement	Remodeling	Alteration	ss130 and ss146 if the connected load is increased
Installing new lighting + wiring in a space that had <0.5 W/sf	Tenant improvement	Remodeling	Alteration	ss119, ss130, ss131, ss134, ss143(c), ss146
Installing any lighting in an existing but previously unlit space	New construction	Renovation	Alteration	ss119, ss130, ss131,ss132, ss134, 143(c), ss146, ss147
Installing lighting during new construction	New construction	New construction	Addition	All

Figure 55 Classifications of Lighting Retrofit Project Types

8.1.1 Lighting Maintenance Projects

These are the least complicated lighting projects. Lighting equipment requires regular basic maintenance such as cleaning, replacement of burned out lamps, and replacement of failed ballasts. All of these are regular aspects of luminaire maintenance, and are not considered to be alterations within Title 24:

- Section 149(b)1 Note: "Replacement of parts of an existing luminaire, including installing a new ballast or new lamps, without replacing the entire luminaire is not an alteration subject to the requirements of Section 149(b)1."

It should be noted that while there is a cultural preference for keeping lamps and ballasts within a given lighting system as consistent as possible, in the Title 24 definition there is not a requirement for like-to-like replacement, so the exact type and corresponding energy use of lamps or ballasts may change.

Similarly, "repairs" are defined in code as follows:

- Section 149(c): "Repairs. Repairs shall not increase the preexisting energy consumption of the repaired component, system, or equipment."

8.1.2 Lighting Upgrade Projects

These projects can include either ballast-and-lamp replacements or whole luminaire replacements across a given lighting system. The first of these does not trigger Title 24 2008 compliance, whereas the second does if more than 50% of the luminaires are replaced.

Most utility-sponsored lighting efficiency programs have focused primarily on lamp-replacement programs, as suggested by a market assessment report in Oregon4, as well as a recent California program evaluation report.5

Lighting upgrades are commonly incentivized by the utilities as "retrofit" projects, and are often eligible for large incentives because they do not trigger Title 24 compliance and therefore the incentives are paid on projected savings relative to the existing lighting power density (LPD) , which is usually higher than the applicable Title 24 LPDs.

8.1.3 Tenant Improvements, Remodels and Renovations

These projects are the more extensive and are usually part of a larger set of improvements triggered by tenant improvements or renovations, due to a change in tenancy or other simultaneous upgrades to the space, such as new furniture layouts, new surfaces and/or HVAC equipment.

These projects typically involve replacement, relocation and/or addition of luminaires and controls to meet the changing needs of a space, and to upgrade to new voluntary standards or Title 24 requirements.

Tenant improvements and remodels are commonly incentivized by the utilities as "retrofit" projects, although in the case of these projects Title 24 is usually triggered. Thus, the incentive payments are based on savings relative to the current Title 24 baseline, not relative to the existing installed load, and are therefore likely considerably less than for "lighting upgrade" projects.

8.2 Typical Factors Influencing Alteration Projects

Since "alterations" are required to comply with Title 24 (whereas "repair" projects are not), this sections describes the typical factors influencing alteration projects.

8.2.1 Incentive Programs and Program Participation

A study of high bay lighting in IOU territories between 2006 and 2008 found that while 57% of high bay lighting purchasers received some program incentives, only 22% of purchased high bay fixtures during that time period were rebated through the incentive programs. This implies that the incentive program was reaching a broad range of market actors rather than focusing only on the largest or

4 Oregon Lighting Market Assessment. Prepared by HMG for the Energy Trust of Oregon. Published December 2009.

5 2006-2008 Energy Efficiency Evaluation Report. Prepared by the CPUC. Published July 2010.

repeat customers. However, the study also found indications that contractors were having equal success selling higher efficiency T5HO high bay lighting to their customers with and without incentives, i.e. that many of the participants may have been free riders. The study concluded that this was because the contractors and customers found T5HO systems to have benefits beyond just energy efficiency to justify the higher initial cost of the technology.6

The NRRR study found that rates of participation in the Savings by Design program in 2000 averaged around 2% of remodel and renovation projects. A breakdown of participation by building type is shown in Figure 56.

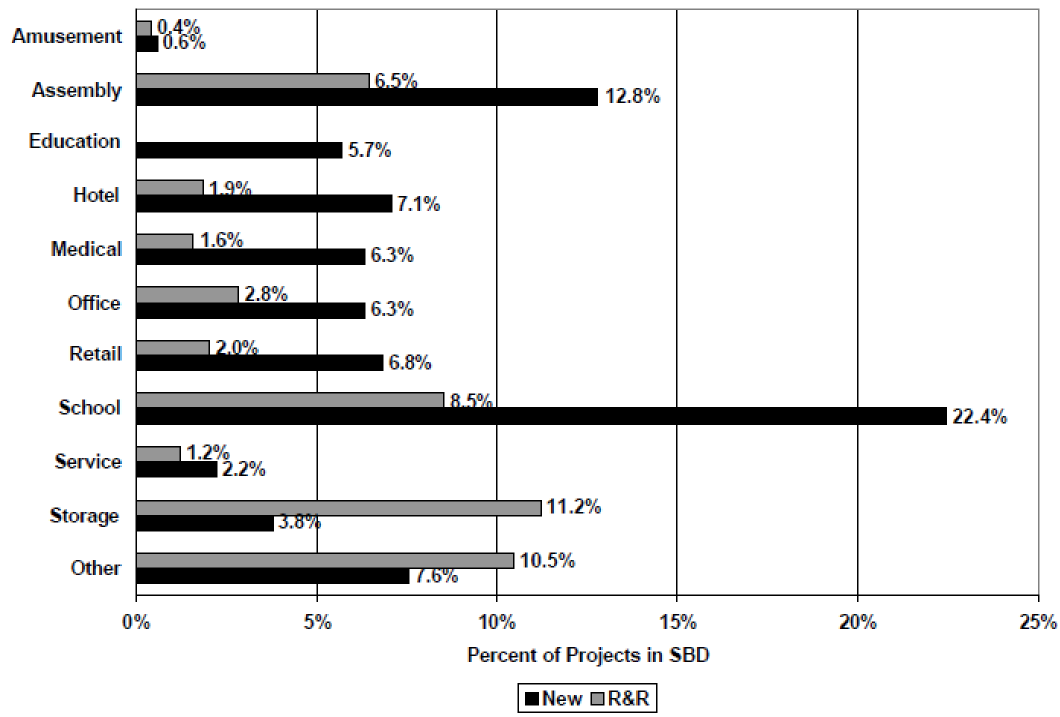


Figure 56 Percentages of New Construction and Retrofit and Remodel Projects that Participated in Savings by Design in 2000 (R&R = retrofit and renovation)

6 High Bay Lighting Market Effects Study. Prepared by Kema, Inc for the CPUC. (program years 2006-2008)

An evaluation of Ecology Action's RightLights program found that a majority of program participants would not have installed higher efficiency lighting without the program, as indicated in Figure 57, below. Only 14% of participants were either somewhat or very likely to install higher efficiency lighting without the program.7

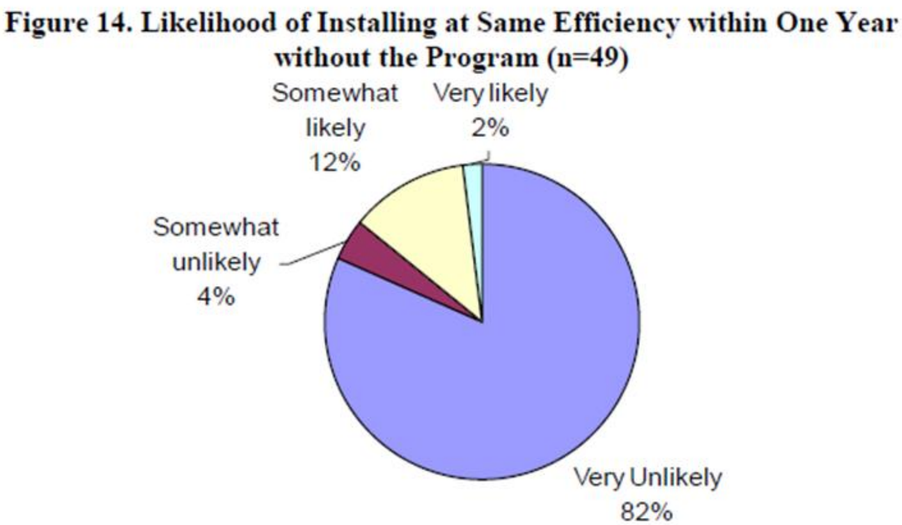


Figure 57 Likelihood that Program Participants would have Installed the same Equipment without the Program (NRRR report Vol. 3, figure 14)

7 Evaluation of the 2004-2005 RightLights Program. Prepared by Quantec, LLC for PG&E.

8.2.2 Decision Makers

According to the NRRR study, the opportunity to influence decision makers to adopt energy efficient lighting measures depends on the role of the decision maker. For instance the potential to influence owners in owner-occupied buildings is quite high. The opportunity to influence commercial developers who buy/renovate/sell is low while the opportunity to influence commercial real estate firms that buy/renovate/hold is low moderate. It is very difficult to encourage energy efficiency among triple net lease operators. Because the ground lease segment is similar to the owner segment in many ways, it is possible to influence this segment to undertake energy efficiency projects when they renovate. The opportunity to encourage efficiency in the replacement market is generally low.8

Essentially, as would be expected, the opportunity to influence decision-makers depends on how easy it is for that decision-maker to act autonomously, and how much ongoing financial interest they have in the efficiency (or leasability) of the building.

The same study included a breakdown of typical decision makers in renovation and remodeling projects, as shown below in Figure 58.9

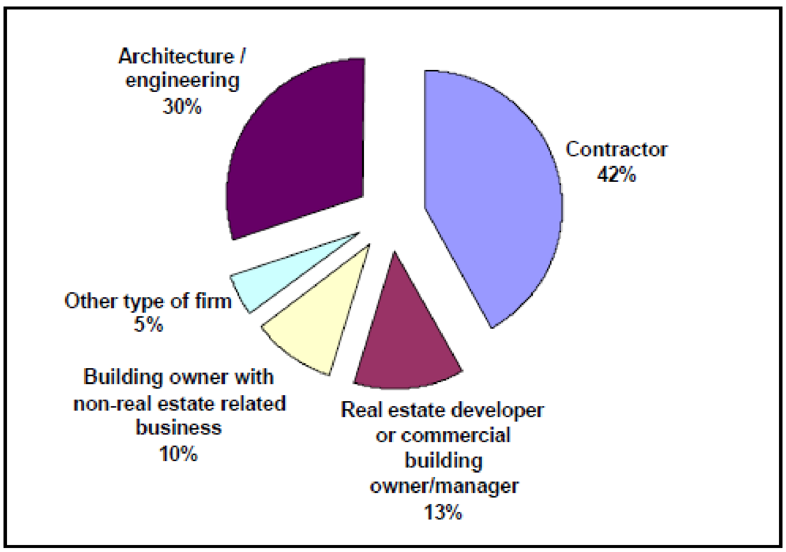
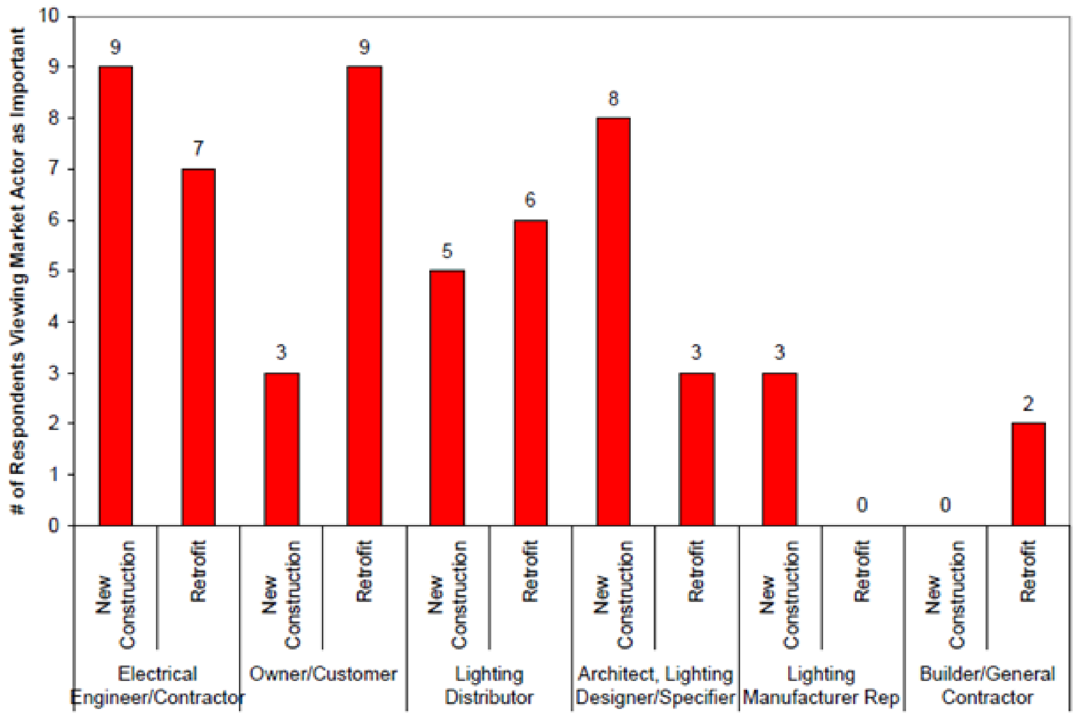


Figure 58 Relative Frequency of Different Types of Firms among Decision Makers for Remodeling and Renovation Projects

8 Nonresidential Remodeling and Renovation Study, Volume I. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published July 2001.

9 Nonresidential Remodeling and Renovation Study, Volume III. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published March 2002.

A study that included an overview of commercial lighting retrofit programs in 200x for PG&E found that owners/customers were significantly more important in the specification process for retrofit/remodeling projects than they are on new construction, and conversely that design professionals such as engineers and architects are more influential in new construction than in retrofits. Figure 59, below, describes the relative importance of various actors in lighting specification for new construction and for retrofit/remodeling projects.10



Note: n = 19 for new construction and 23 for retrofit/retrofit remodeling. The total numbers of "important" market actors are greater than 19/23 because some respondents cited multiple important market actors.

Figure 59 Most Important Market Actors in the Lighting Specifications Process

A report from ACEEE11 looked at a range of studies and was able to identify some broad correlations between project size or client type and decision making process:11

10 Process Evaluation of 2006-2008 PG&E Mass Markets Program Portfolio and CFL, Swimming Pool Market Characterizations. Prepared by Kema, Inc for PG&E.

11 Commercial Lighting Retrofits: A Briefing Report for Program Implementers. Jennifer Amann and Steve Nadel, ACEEE. Published April 1, 2003.

- Large building owners and developers often work with professional lighting designers, architect, and engineers to design lighting systems for new or retrofit projects.
- Smaller building owners are more likely to work with electrical contractors and lighting suppliers when developing or retrofitting their lighting design.

8.2.3 Funding for Retrofit Projects

For projects completed in leased space, the "project [is] completed for the lessee in nearly 90 percent of cases"12. This means that lighting alterations are usually funded by the tenant, and therefore that decisions about the economic viability of a project as a whole, or elements of a project, are made according to the tenant's expectations and criteria for cost-effectiveness.

Figure 60 shows that the majority of office space in PG&E and SCE's territories is owner-occupied, whereas the majority of retail is leased space.

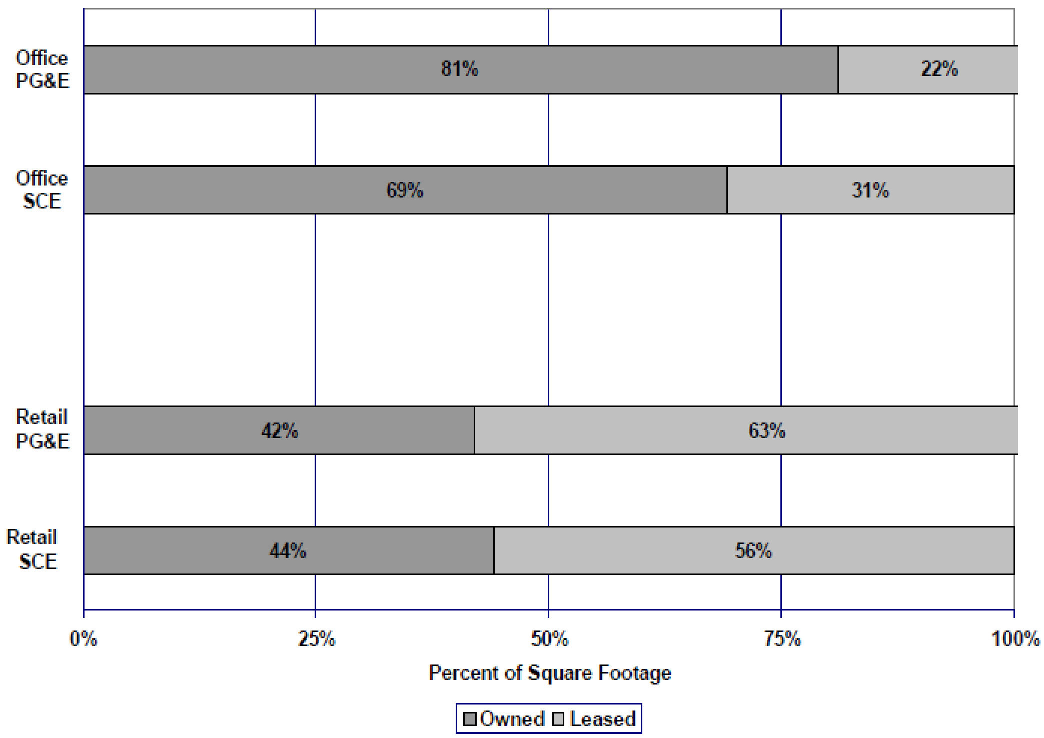


Figure 60 Comparison of Owned vs. Leased Floor Space in PG&E and SCE Service Areas

12 Nonresidential Remodeling and Renovation Study, Volume III. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published March 2002. P.4-1

8.2.4 Criteria for Project-Level Decision Making

The NRRR study surveyed decision makers who had made substantial changes to lighting systems to determine the importance of a variety of selection criteria. Figure 61, below, indicates that the primary factor in the decision making process was “Title 24 requirements,” followed by “Improved lighting quality” and “Energy efficiency of item.” These finding suggest that decision makers in these scenarios are aware of the necessity to meet energy code requirements, but that they are also motivated by light quality and energy efficiency.13

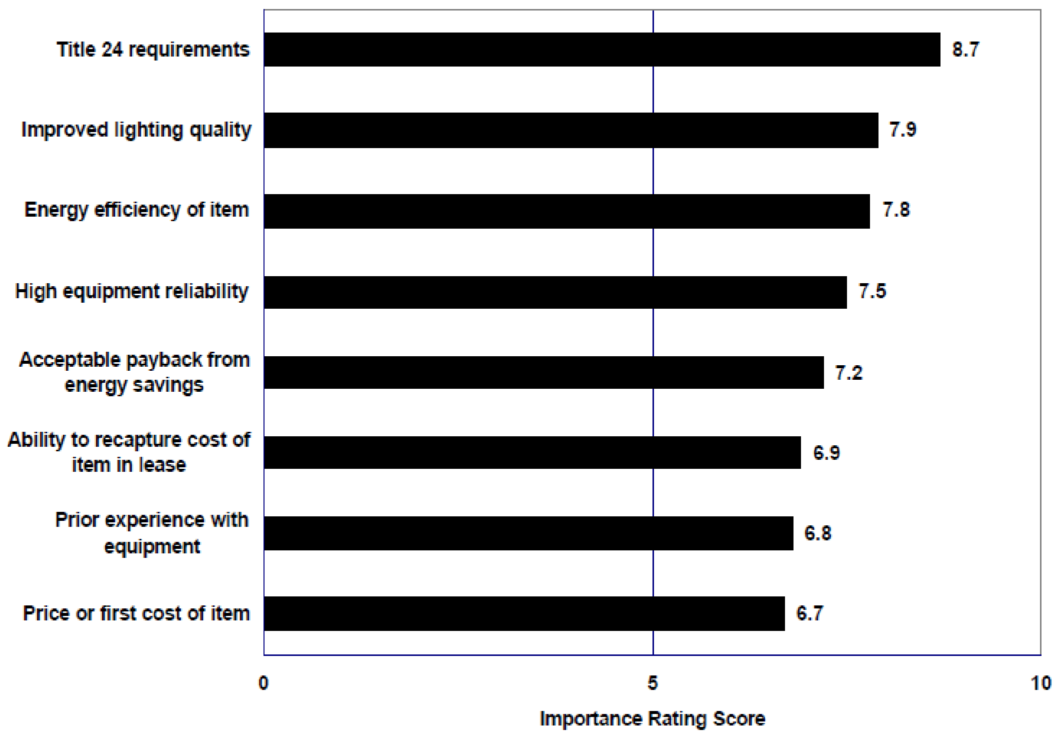


Figure 61 Importance of Various Criteria when Making Changes to Lighting Systems

13 Nonresidential Remodeling and Renovation Study, Volume III. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published March 2002.

The same study also looked at factors that influenced decision makers that did not make substantial changes to lighting systems. As shown in Figure 61, below, the main reason for not making changes to lighting systems as part of a renovation was that the system was already efficient. The next three highest ranked criteria are all related to costs of efficiency improvements, suggesting that these decision makers may not directly benefit from the energy savings of lighting improvements. This may also suggest that different decision makers have different priorities in the renovation process (designers and engineers may be more concerned with code and light quality, while landlords and developers are most concerned with payback), and that the role of the decision maker may impact whether or not substantial changes are made to lighting systems.14

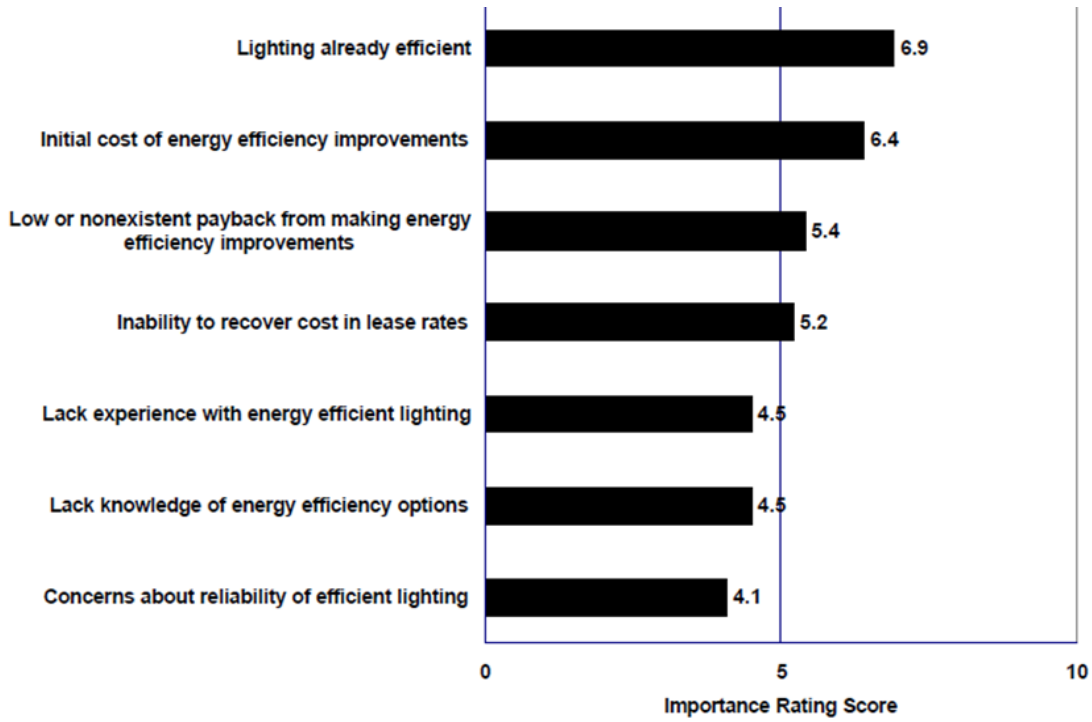


Figure 62 Average Importance Ratings for Reasons Preventing Lighting-Related Energy Efficiency Improvements

14 Nonresidential Remodeling and Renovation Study, Volume III. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published March 2002.

A study conducted for PG&E identified lighting specification criteria for retrofit/remodeling projects as identified by contractors who offer retrofit services. As shown in Figure 62 below, energy efficiency was mentioned most frequently, followed by cost.15

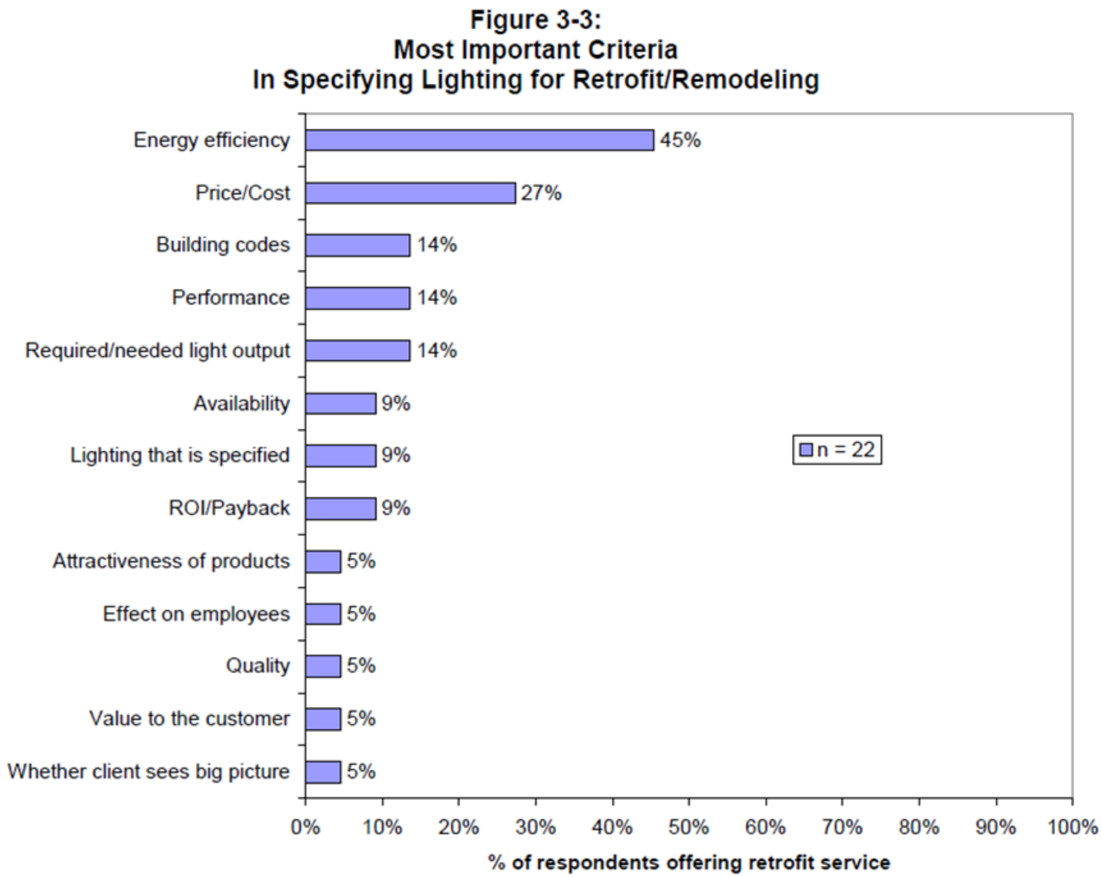


Figure 63 Most Important Criteria in Specifying Lighting for Retrofit/Remodeling

15 Process Evaluation of 2006-2008 PG&E Mass Markets Program Portfolio and CFL, Swimming Pool Market Characterizations. Prepared by Kema, Inc for PG&E.

In contrast, a study evaluating Ecology Action's RightLights program for PG&E identified reasons that businesses chose not to participate in the program. As shown in Figure 63 below, cost was the most common deterrent. Also of note are responses of "Already installed efficient lighting" (8%) and "Did have or will have it installed" (3%), indicating that 11% of non-participants had already retrofitted or installed higher efficiency lighting.16

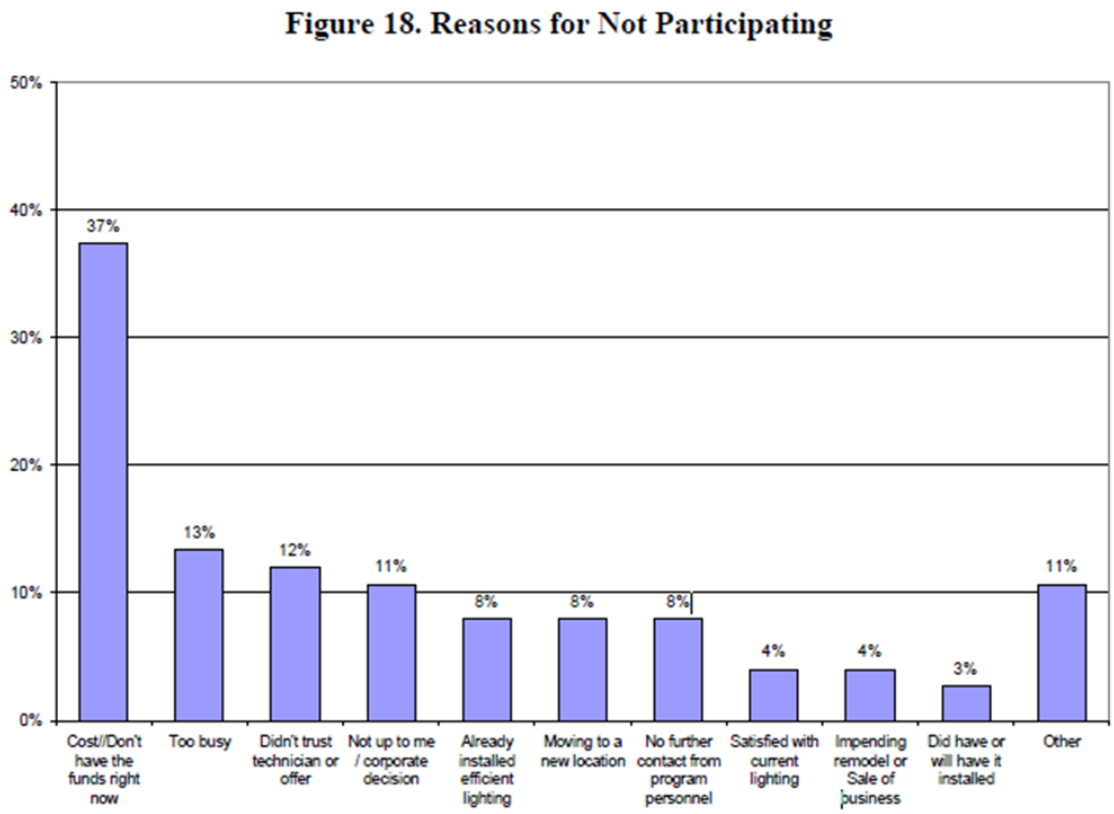


Figure 64 Reasons for Not Participating in Lighting Retrofit Projects

8.3 Typical Project Characteristics

Since "alterations" are required to comply with Title 24, whereas "repair" projects are not, this section describes the typical characteristics of alteration projects.

16 Evaluation of the 2004-2005 RightLights Program. Prepared by Quatec, LLC for PG&E.

8.3.1 Frequency of Retrofit Projects

The NRRR study found that turnover and changes in commercial buildings are frequent:17

- Renovation and retrofit projects occur approximately once every ten years in office buildings (more frequently in leased space than in owned space), every fifteen years in retail space, and every eight years in schools and other institutional spaces.
- Tenant turnover is highest in small office, retail and restaurant sectors.
- Lighting equipment may or may not be changed depending on the vintage of the equipment and its condition. If the remodel is fairly extensive, lighting equipment is likely to be changed, especially if the lighting is of an older and less efficient type. Lighting is likely to be changed if the building is undergoing a change in its use, for example, from a warehouse to office space.

Figure 65 shows the likelihood of various types of construction projects (not just lighting) occurring each year in a given building, depending on the building type. The "new construction/remodeling" category includes both entirely new construction and buildings that are demolished and rebuilt, or extensively remodeled. Note that in office space, retrofits are more likely in leased space whereas renovations are more likely in owned space.

Market Segment	New Construction/ Remodeling	Renovation	Retrofit	Percentage of All Space
Office/owner	1.9%	5.3%	1.4%	8.5%
Office/leased	0.5%	3.8%	6.5%	10.7%
Retail/sole	2.2%	0.9%	1.1%	4.2%
Retail/multisite	3.3%	2.1%	1.8%	7.3%
Institutional	0.2%	6.8%	5.1%	12.1%
Other	1.5%	1.8%	0.7%	4.0%

Figure 65 Likelihood of Various Types of Construction Project Occurring Each Year, by Building Type

17 Nonresidential Remodeling and Renovation Study, Volume I. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published July 2001.

8.3.2 Frequency of Lighting and Other Alterations

As shown in Figure 66, a survey of tenants conducted for the NRRR study found that lighting was "changed" in 76 percent of retrofit projects, and thus was the most common element to be changed in a retrofit It also found that "lighting changes were likely to be accompanied by changes in the HVAC distribution system 85 percent of the time and by changes in interior layout 69 percent of the time." Retrofit projects that include all three elements were also common: "Changes to lighting that were combined with changes to the HVAC distribution system occur with changes in layout about 64 percent of the time."

This information suggests that the majority of retrofit projects are total rehabilitations, involving two or three of the main elements of the space. Because these projects likely involve significant work inside the ceiling and other parts of the building structure, changes to lighting control systems may be cost-effective in many cases.

Building Component Changed	*Percent of Cases*
Interior Components Changed:	
Lighting	76
HVAC distribution system	72
Interior partitions	60
HVAC components	46
Power distribution system and components	37
Exterior Components Changed:	
External windows, skylights and doors	19
Roof system	10
Shell structure, ornamentation and façade elements	9
Total cases (N)	341

Figure 66 Building Components Substantially Changed during Remodeling or Renovation (NRRR study, Vol. 2, Table 8-4)

8.3.3 Lighting Relocations vs. Replacements

According to other surveys conducted for the NRRR, of the respondents who made changes to lighting systems, only 22% of projects reused existing fixtures, while the remainder said they replaced fixtures. When asked if the systems were more efficient after they were replaced, 98% of those who replaced lighting fixtures and 83% of those who reused fixtures said that the systems were more energy efficient after the remodeling and renovation.18

18 Nonresidential Remodeling and Renovation Study, Volume II. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published February 2002.

8.3.4 Project Value and Square Footage

The Nonresidential Renovation and Remodeling (NRRR) study also provided a breakdown of renovation square footage by building type in California for 2000, as shown below in Figure 67. Office buildings make up the largest segment, approximately 34% of square footage. However, it is important to note that not all of these projects include lighting changes.19

CEC Building Type	*Estimate of Annual SF for R&R*	*CEC Estimate of Annual SF Additions*
Office	89.0	42.5
Retail	24.1	22.6
Restaurant	4.0	3.6
Grocery	6.3	5.7
Refrigerated Warehouse	1.4	1.2
Warehouse	24.7	25.5
School	31.7	10.5
College	18.7	4.3
Hospital	19.3	5.8
Hotel/motel	9.0	7.7
Miscellaneous	33.0	23.7
Totals	261.2	153.1

Figure 67 Annual Square Footage Undergoing Remodeling or Renovation in California in 2000, by building type (NRRR report, Table 6-4).

As shown in Figure 68, the dollar value of permits (in year 2000 dollars) for alteration and addition projects has increased steadily over time. This may or may not represent an increase in the square footage of those projects, because the value of those projects per square foot may have increased over time, and NRRR report does not give annual square footage data. A simple linear extrapolation gives an average value of $9bn per year (in 2000 year dollars) during the next code cycle (2014 to 2017). Assuming that the ratio of permit value to floor space ($/sf) in 2000 remains constant, this suggests that the annual square footage of alteration and addition projects in the next code cycle will be approximately 327 million square feet.

19 Nonresidential Remodeling and Renovation Study, Volume III. Prepared by ADM Associates, Inc. and TecMRKT Work LLC for the California Energy Commission. Published March 2002.

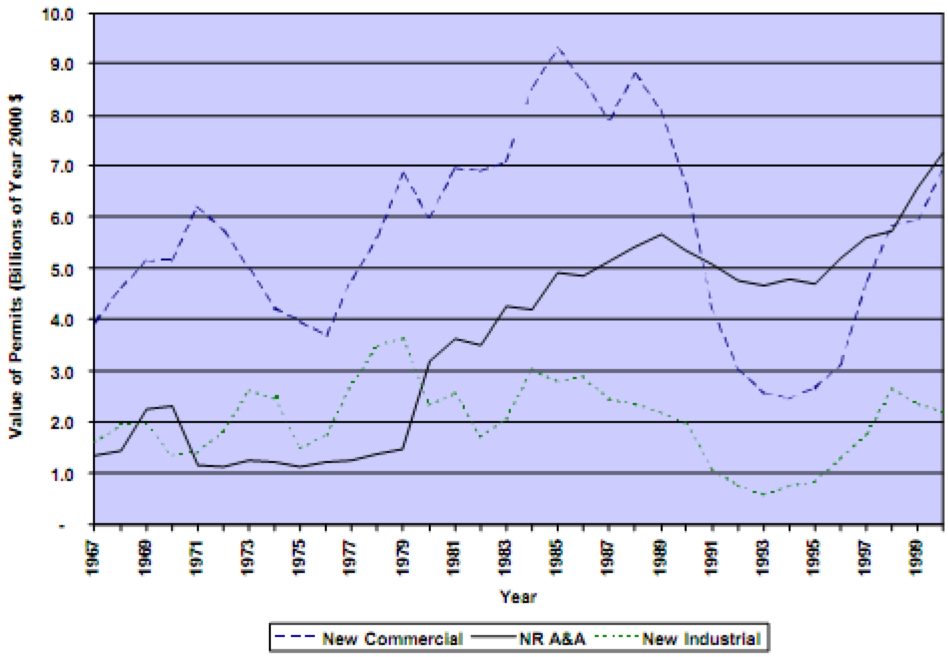


Figure 68 Statewide Annual Permitting Activity for Nonresidential Alterations and Additions (from NRRR Report, Figure 3-1).

Trend line shows a linear extrapolation from 2014 to 2030 (16 year measure life).

9. Appendix D--Online Survey

9.1 Retrofit Lighting Survey

March 18, 2011

Introduction

We're contacting you on behalf of the California Investor Owned Utilities (IOU) Statewide Codes and Standards Team. This team is working on a number of proposed changes to Title 24, and more information can be found at www.calcodes.com.

We are conducting research for a proposed change to the requirements of the Title 24 energy code, in regard to luminaire retrofit projects. Briefly, the proposed changes are as follows:

A reduction in the threshold for energy code compliance, from 50% of luminaires being moved or replaced (in a given space), down to 20% or 10% of luminaires being replaced.
A requirement for retrofit projects to install the same controls that are required in new construction projects, i.e.

Area controls (wall switches or vacancy sensors)

Multi-level (bi-level) switching

Photocontrols

Automatic shut off controls (e.g. night sweep)

The purpose of this survey is to inform the assumptions and methods we are using to calculate the costs and statewide savings from the proposed changes.

We want to use your experience in lighting retrofit projects to improve our analysis. If there are any questions that you do not feel able to answer, please just click "Do not know".

The link below provides access to a memo that summarizes the propose code changes. You do not need to read the memo to answer the questions in this survey, but it provides background information that you may wish to review.

This survey contains ten specific questions, and three follow up options.

Q1--Project Characteristics—Building types

What percentage of your luminaire retrofit projects take place in each of the following building types (must sum to 100%)

Large office buildings (>20,000 sf) ___%
Small office buildings (<20,000 sf)_ ___%
Warehouses ___%
Retail ___%
Schools ___%
Other what types?_____Percentage:___%

Q2--Project Characteristics—Percentage of luminaires replaced PER PROJECT

Thinking in terms of the whole project (e.g. the client's building, or the leased space):

What percentage of your luminaire retrofit projects fall into each of the following categories (must sum to 100%) >50% of luminaires are moved or replaced, and the contractor pulls a permit
>50% of luminaires are moved or replaced, and the contractor DOES NOT pull a permit
Between 40% and 50% of the luminaires are moved or replaced
Between 30% and 40% of the luminaires are moved or replaced
Between 20% and 30% of the luminaires are moved or replaced
Between 10% and 20% of the luminaires are moved or replaced
Less than 10% of the luminaires are moved or replaced (e.g. a ballast-only changeout)

Q2--Project Characteristics—Percentage of luminaires replaced PER SPACE

Thinking in terms of each enclosed space in the project (e.g. an office space, a classroom, a warehouse):

What percentage of your luminaire retrofit projects fall into each of the following categories (must sum to 100%)

>50% of luminaires are moved or replaced, and the contractor pulls a permit
>50% of luminaires are moved or replaced, and the contractor DOES NOT pull a permit
Between 40% and 50% of the luminaires are moved or replaced
Between 30% and 40% of the luminaires are moved or replaced
Between 20% and 30% of the luminaires are moved or replaced
Between 10% and 20% of the luminaires are moved or replaced
Less than 10% of the luminaires are moved or replaced (e.g. a ballast-only changeout)

Q3--Project Characteristics—Lighting Power Density of Existing Lighting

In what percentage of your luminaire retrofit projects does the EXISTING lighting have the following power densities? (Should sum to 100%) What is the% breakdown of the lighting power density of the EXISTING lighting systems?

	Building type				
Lighting power density	Open offices	Private offices	Warehouses	Retail	Other (describe)
<0.7 W/sf	o	o	o	o	o
0.7-1.0 W/sf	o	o	o	o	o
1.0-1.5 W/sf	o	o	o	o	o
1.5-2.0 W/sf	o	o	o	o	o
>2.0 W/sf	o	o	o	o	o

Q4.5 Project Characteristics—Changes to Lighting Circuits

In your projects, what *percentage of the luminaires* undergo the following changes in circuiting?

	0-5%	5-10%	10-25%	25-50%	>50%
New or moved wiring is being installed to serve added or moved luminaires					
Conductor wiring from the panel or from a light switch to the luminaires is being replaced					
A lighting panel is installed or relocated					

Comments:

Q4--Project Characteristics—Are lighting Controls added?

How common are each of the following control types, in your retrofit projects? Please enter the percentage of projects that have each of the following controls installed as part of the retrofit.

Area controls (wall switches or vacancy sensors)
Multi-level (bi-level) switching
Photocontrols
Automatic shut off controls (e.g. night sweep)

Q5--Project Characteristics—Existing controls in offices

In what percentage of your OFFICE retrofit projects does the existing building have NO area controls, (i.e., there are no wall switches or occupancy sensors within sight of the luminaires they control).

0%
1%-10%
10%-20%
20%-30%
30%-40%
40%-50%
50%-60%
60%-70%
70%-80%
80%-90%
90%-100%

Q6—Project Characteristics—Retrofit controls in offices

In existing OFFICE buildings that do NOT have area controls, how commonly are each of the following controls retrofitted?

No controls (the space remains non-compliant with the Title 24 2008 "area controls" requirement)
"Annunciated switches" are added to a central switch panel, i.e. switches that are labeled and have an indicator light
Additional wall switches are added in various locations throughout the space, within sight of the luminaires they control
Additional occupancy sensors are installed throughout the space

Q6--Project characteristics—Effect of costs for OFFICE retrofit projects

The research conducted for the attached memo suggests that lighting alteration projects happen mostly as part of a tenant improvement (TI). TI's are often carried out when a new tenant moves in, and often include other elements such as HVAC, partitions, ceiling systems and furniture.

From your experience, what would be the effect of adding additional costs (for lighting controls) to office retrofit projects? Please indicate on the table below what you think the likely effect would be, for the ranges of cost indicated. Note that "cancelled" means that the lighting would not be retrofitted (not that the entire project would be cancelled).

Cost for office lighting controls	No effect	A few projects would be cancelled	Most projects would be cancelled	Almost all projects would be cancelled
$0.10 per square foot	o	o	o	o
$0.25 per square foot	o	o	o	o
$0.50 per square foot	o	o	o	o
$0.75 per square foot	o	o	o	o

Q7--Analysis—Basis for costing of the proposed measure

We are using two typical retrofit control system types as the basis for costing the "automatic shut off controls" (i.e. time sweep controls) element of this proposed measure. These systems are described below. Please let us know if you have any comments about using either of these systems, and if there are technical difficulties that could add to the cost of installing them.

A timeclock-based "sentry switch" shut-off system that mechanically actuates manual wall switches to the off position (and therefore gives users the ability to manually switch the lights back on). This system also provides a "blink" warning prior to shutoff.

In what percentage of your retrofit projects is a system like this installed?

(Percentage of projects) __________________

General comments ____
____

Potential installation difficulties_________________________________
____

A timeclock-based wireless shut-off system that uses wireless switches to convey user overrides to the lighting control system. This system also provides a "blink" warning prior to shutoff.

In what percentage of your retrofit projects is a system like this installed?
(Percentage of projects) __________________General comments ________________
____

Potential installation difficulties_________________________________
____

Q8--Analysis—Low voltage wiring

In calculating costs, we are assuming that low voltage wiring (for dimming or step switching control) can be installed during a tenant improvement project at a cost that is not significantly different from a new construction project. This is because low voltage wiring can easily be routed through suspended ceilings or exposed ceilings, without needing to be attached to the structure. Do you think this is a reasonable assumption? If not, please explain why.

Yes ____
No (explain) ____

Q9--Miscellaneous—Egress controls

In a separate code change proposal, the Investor Owned Utilities are proposing that egress lighting should mostly be switched off when the building is unoccupied. We are proposing to waive that requirement for retrofit projects, due to the potentially high cost of changing regular ballasts for emergency ballasts, installing dual power transfer switches, or making changes to circuits..

Do you agree that the requirement to shut off egress lighting should be waived for retrofit projects? If not, please explain why.

Yes (additional comments)__________________
No (explain) ____

Q10--Miscellaneous—Ballast-only changeouts

The current language of Title 24 (2008) makes an exception for ballast-only changeouts, making them exempt from having to meet energy code requirements. This is different from the ASHRAE/IES 90.1 code, which *does* require ballast-only changeouts to meet energy requirements.

Ballast-only projects are not required to pull a building permit (in California), and therefore these projects are unlikely to be inspected for compliance with the energy code.

Do you think that ballast-only projects should be subject to the lighting requirements of Title 24 (sections 146 and 131)?

Yes (comments) ____
No (comments) ____

Q11—Other Issues

Is there anything else you'd like the Statewide IOU Codes and Standards Team to consider regarding the proposed code changes?

Yes
No
Please explain your answer in more detail:____
____
____

Q12—Further Contacts

Do you have suggestions for other people we should contact for information or experience on these issues?

Name____Organization____Contact Information____

Name____Organization____Contact Information____

Q13—Thank you for your time.

Would you like to be added to our Cal Codes update email list for lighting code changes?

This email list provides notification of upcoming meetings, access to white papers and other background information for the code changes process. It also allows you to comment on the proposed code changes prior to adoption of the 2013 Title 24 code language.

Additional information is available from the Cal Codes website, www.calcodes.com.

You can also stay updated through the California Energy Commission's website at www.energy.ca.gov/title24.