CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Lighting in Multifamily and Hotel Corridors

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team October 2011

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1. Overview

Complete the following table, providing a brief sentence or two for each category of information.

<table>
<tr><td>a. Measure Title</td><td>Automated lighting controls and switching requirements for hotels and multifamily building corridors.</td></tr>
<tr><td>b. Description</td><td>The proposed measure is to require the installation of occupancy sensors in corridors and stairwells in lodging and multifamily buildings throughout California. The occupancy sensors are to be configured to switch off at least one-half of the installed lighting wattage, and to be in accordance with Section 119 the occupancy sensor time delay should be no more than 30 minutes.</td></tr>
<tr><td>c. Type of Change</td><td> Mandatory Measure. This change would both add and modify mandatory measures. This change would not significantly change the scope or direction of the current Standards. This change would not require implementation of systems or equipment that are not already readily available on the market and for use in the proposed applications. These systems are already regulated and included in the current Standards. The Standards and Manuals language would be modified in order to include the new requirements. The change would require an addition to Section 131, and addition to Section 150(k), and removal of one line from table 146-C. </td></tr>
<tr><td>d. Energy Benefits</td><td> This measure is expected to save 1.89 kWh/sf/yr, which is 36% of lighting energy use, assuming an installed load of 0.6W/sf, 0.22 W/sf on average. During the 12pm-6pm peak period, the average savings is 31%, or 0.19 W/sf. We calculate that this measure will affect 1.8 million square feet of hotels and 10.7 million square feet of multifamily buildings per year, for a total of 12.5 million square feet of building area. The measure is expected to reduce statewide peak load by 2.6 MW per year, and to reduce statewide energy use by 26 million kWh/yr.
<table>
<tr><th></th><th>Electricity Savings (kWh/sf/yr)</th><th>Demand Savings (W/sf)</th><th>Natural Gas Savings (Therms/sf/yr)</th><th>TDV Electricity Savings ($/sf)</th><th>TDV Gas Savings ($/sf)</th></tr>
<tr><td>Savings per square foot</td><td>1.89</td><td>0.19</td><td>NC</td><td>$2.18</td><td>NC</td></tr>
</table>
<table>
<tr><th>Total Electric Energy Savings (GWh)</th><th>Total Gas Energy Savings (MMtherms)</th><th>Total TDV Savings ($)</th><th>Total TDV Energy (kBTU)</th></tr>
<tr><td>23.6</td><td>0</td><td>38,900,000</td><td>437,000,000</td></tr>
</table>
</td></tr>
<tr><td>e. Non-Energy Benefits</td><td>This measure does not provide non-energy benefits, except for the intangible benefit of making building occupants more aware of energy use.</td></tr>
</table>

f. Environmental Impact	The proposed change has small negative impacts associated with added wiring and additional occupancy sensors, and a very large positive environmental impact associated with reduced energy consumption. There are no water impacts from this measure outside the reduced water usage associated with reduced energy consumption. For details of the materials impact calculations, see Section 3.8.

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

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
Statewide impact	27(I)	27(I)	52083(I)	5482(I)	13706(I)	NC

Water Quantity and Quality Increase, (Decrease), or No Change (NC):

	Water Savings (or Increase) (Gallons/Year)	**Mercury Content**	**Other Contaminants, Specify**
Per Unit Measure[1]	NC	NC	NC
Per Prototype Building[2]	NC	NC	NC

Air Quality in lbs/Year, Increase, (Decrease), or No Change (NC)[3]:

	NOX	**SOX**	**CO**	**PM10**	**CO2**	**NOX**
Per Unit Measure	0.00030	0.0018	0.00043	0.00014	1.1	0.00030
Per Prototype Building	6.5	39	9.4	3.0	23635	6.5

<table>
<tr><td>g. Technology Measures</td><td>

Measure Availability and Cost:

Technology to satisfy the proposed measure is readily and widely available from multiple manufacturers, and sufficient competition exists to ensure that pricing is competitive. Occupancy controls have been on the market for a substantial period of time. Acceptance and success of this technology is widely acknowledged. The principal manufacturers are: Cooper Controls Greengate, Hubbell, Leviton, Lightolier, Lutron, SensorSwitch, Square D and Wattstopper. These manufacturers supply distributors throughout the state who coordinate with electricians and contractors. The market is available to supply adequate equipment to meet the requirements of this measure; of the nearly three (3) dozen distributors contacted, all were prepared to fill orders next day. A thorough market survey effort discovered that at least eight (8) distinct models are available to serve this measure's purpose.

Useful Life, Persistence and Maintenance:

The life of lighting control technology is identified by T24 as 15 years (AEC & CEC, 2005). In practice, ceiling-mounted occupancy controls are likely to last much longer. Energy savings associated with this technology will be sustained for the life of the product. Stakeholders, and a survey of contractors conducted by the Lighting Controls Association and referenced later in this report confirm that there are no added maintenance or commissioning costs related to this technology.
</td></tr>
<tr><td>h. Performance Verification of the Proposed Measure</td><td>The proposed update would require commissioning during initial installation of the system by an electrician. According to the survey of contractors conducted by Lighting Controls Association and referenced in this report, commissioning of occupancy sensors is already standard practice and is well understood by contractors.</td></tr>
<tr><td>i. Cost Effectiveness</td><td>
<table>
<tr><th>Measure Name</th><th>Additional Cost Per Unit (Relative to Basecase) ($/sf)</th><th>Additional Maintenance Costs (Relative to Basecase) ($/sf)</th><th>Measure Life (Years)</th><th>LCC Per Prototype Building ($/sf)</th></tr>
<tr><td>Auto Lighting Controls</td><td>0.93</td><td>0.05</td><td>15</td><td>2.18</td></tr>
</table>
</td></tr>
<tr><td>j. Analysis Tools</td><td>The benefits from this measure can be quantified using the current reference methods. The installation and operation of this measure, along with impacts on energy consumption can be modeled in the current reference methods and analysis tools. However since this measure is proposed as mandatory, analysis tools are not relevant since the measure is not subject to whole building performance trade-offs.</td></tr>
</table>

k. Relationship to Other Measures	The proposed measure would eliminate the current (2008) Power Adjustment Factor of 0.2 for occupancy sensors in corridors and similar spaces: PAF of 0.2 for “Multi-level occupant sensor combined with multi-level circuitry and switching in accordance with Section 146(a)(2)(D)”, in “Any space >250 square feet enclosed by floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room.”

2. Methodology

This section summarizes the methods used to collect data for this CASE report. We gathered data from a wide variety of sources and conducted several different kinds of analyses, so this section sets out our broad methodology and describes how those methods contributed to the overall recommendations.

2.1 Data on Lighting Energy Use

In order to assess the savings potential from this measure, HMG needed to know how much lighting energy is currently being used in corridors and stairwells. We reviewed available literature and found one study by LBNL on lighting use in stairwells, but no existing data on energy use in corridors. We knew from previous studies that two occupancy sensor manufacturers (SensorSwitch and Wattstopper) have recorded data on occupancy and lighting use. Both these companies have a practice of providing loggers to potential clients, so those clients can accurately calculate potential savings by recording occupancy and lighting use within their own buildings.

SensorSwitch was able to provide HMG with recorded data from loggers installed in 10 different corridors within three hotel buildings. Their loggers record both occupancy and lighting status (on/off) at two minute intervals. This interval is acceptable statistically because it is much shorter than the time delay used in commercial occupancy sensors. Wattstopper also possesses a database of occupancy data from real buildings (at one minute intervals), but their database did not include any data for hotel or multifamily corridors.

By identifying periods when the logger recorded the space as "unoccupied" and "lights on", we were able to determine the overall savings potential for the space both as a percentage of total lighting energy use and as a percentage of absolute time. Having data at short intervals meant that we could calculate the effect of various occupancy sensor time delays on the resulting savings.

2.2 Data on Space Geometry

To assess savings potential, we also needed to know how much floorspace within the state of California is taken up by corridors and stairwells. We were able to obtain a stratified sample of multifamily building plans from plan checks conducted by HMG for the California Multifamily New Homes Program, and from those plans we were able to calculate what percentage of floorspace is taken up by corridors and stairwells. We were not able to obtain building plans for a sample of hotels, and could not find secondary data on the amount of floorspace given to corridors and stairwells in hotels, therefore we have used the multifamily building data for calculations in hotels. We believe it is reasonable to assume that the corridors in hotels and multifamily buildings are the same width, because they serve the same functional purpose, and because hotel rooms are typically much smaller than multifamily homes, we believe that hotels would have *more* square footage of corridor for a given total building area. The estimates of total statewide savings are therefore conservative.

2.3 Stakeholder Meetings

We convened a Stakeholder Group comprised of representatives from the industries affected by this proposal. The purpose of the Stakeholder Group was to give initial direction to the project team in terms of what are typical lighting layouts, lamp and fixtures types for each application, and what the implications of the code change options would be, in terms of added cost and maintenance, and potential effect on the businesses subject to code. As well as this initial input, later in the process we returned to the Stakeholder Group to confirm that our final lighting layouts, controls assumptions and cost figures were reasonable. At each stakeholder meeting we presented the latest version of the code change proposal/language, and invited comments on the language. The stakeholder group included:

- Lighting controls manufacturers
- Luminaire manufacturers
- Lighting designers
- Hotel owners
- Multifamily developers
- CEC Staff

See section 6.1 for a list of Stakeholder Group participants. We attempted to ensure that all these groups were well represented in the final stakeholder group. In addition to the final participant list, we contacted the following people who were unable to join the group: one (1) lighting designer, one (1) controls manufacturer, one (1) researcher, two (2) hotel end-users, and four (4) multifamily building owners.

We conducted three meetings with stakeholders in Oakland to discuss the study's progress. Meetings were held on Tuesday, December 2nd, 2008, Tuesday, March 3rd, 2009, and Tuesday, April 28th, 2009. The following items were discussed in the meetings:

- Current standard practice and best practice for hotel corridor lighting.
- Current code requirements and potential future changes.
- Current design problems and technology limitations/opportunities.
- Initial analysis of potential energy savings from hotel corridors, based on logged data.
- Proposed lighting layouts for corridors
- Results of a survey of designers and end-users, asking about typical lighting configurations and controls options
- Proposed code language and discussion of how people will comply in practice
- Cost/Benefit analysis for proposed measures

Stakeholders were active in providing support and feedback on the proposals, as well as, providing insight into the potential industry/technology barriers surrounding the proposals. Additionally, stakeholders were able to clarify common practice, design, and methods within these particular spaces types.

HMG also contacted individuals beyond those included in the Stakeholder Group in order to make use of knowledge of a particular topic. For instance, at the request of Gary Flamm of the

California Energy Commission, we contacted Naomi Miller of Naomi Miller Lighting to ask about the implications of this proposal for older occupants of hotels and multifamily buildings, whose vision may be impaired.

2.4 Designer/User Survey

To find out whether designers or installers have *already* used occupancy controls successfully in these spaces, we wanted to gather experiences from people who had designed, installed or maintained occupancy sensor controlled lighting. We therefore developed a web-based survey intended for architects, lighting designers, and hotel/multifamily facility managers (the questions varied, depending on how the respondent identified themselves at the beginning of the survey). Survey participants were asked a variety of questions about projects on which they had used occupancy controls, including what lighting equipment and controls were installed, the dimensions of the space, whether savings were achieved, and any maintenance or user response issues.

2.5 Review of Current Standards

To understand the existing context in which this proposal may be established, and how it may affect other code measures, we conducted a detailed review of sections 119, 131, and 146 of the current Title 24 Standards. As we developed the draft language, we reviewed this with Gary Flamm at the California Energy Commission to check for compatibility with Title 24's overall structure, specific provisions, and to work out which of several language options would be most appropriate.

Since this proposal suggests turning lights off within corridors and stairwells, which are often paths of egress, it was very important to be cognizant of the capacity for affecting lighting regulations in these areas. We therefore reviewed Section 7.9.2.1 of the Life Safety Code within the National Fire Protection Association (NFPA 101) standard, and the California Building Code Section 1003 in order to fully understand the current standards regarding emergency lighting for the means of egress.

2.6 Lighting Models

We used industry-standard radiosity software (Lumen Designer) to model light distributions in typical spaces under both a base case and proposed scenario. We calculated light levels (footcandles) and lighting power densities for the modeled spaces. We confirmed with the Stakeholder Group that the lighting layouts we had used were common lighting design practice for these spaces. The lighting models were extremely helpful as a basis for discussing the proposed measures, because they focused the thoughts of the Stakeholder Group on the specific challenges that might occur in real installations.

2.7 Emergency Lighting Models

We ran additional simulations, in order to ensure that the necessary emergency light levels (1 fc along the centerline of egress (see NFPA and CA Fire Code)) could be maintained by the lighting equipment and layouts we had used in the lighting models.

2.8 Market and Pricing Survey

We contacted lighting distributors to request prices of commonly installed occupancy sensors. Because many different models of occupancy sensor were available from each distributor, we asked them which model(s) they would recommend for various typical applications, and asked them to price those models. We stratified the sample by region to obtain a range of prices from different cities in California.

2.9 Cost-Effectiveness Calculation

Occupancy sensors are considered to have a useful life of 15 years (CEC 2005). Therefore we calculated estimates for annual energy savings over 15 years, adjusting for net present value due. Therefore we calculated estimates for annual energy savings and the resulting value of savings over 15 years, expressed as a net present value. Although the savings returned due to occupancy sensors are realized over 15 year life, costs are fixed and must be paid at the time of installation. By subtracting the costs from the net present value of the cumulative savings, we calculated the net financial benefit of the measure.

We conducted the life cycle cost calculation using the California Energy Commission Time Dependent Valuation (TDV) methodology. Each hour is assigned an estimated price for energy[1], and the sum of these prices over the life of the measure yields the present dollar value of savings. Life cycle cost is the difference between the TDV $ value for 15 year energy savings and the initial occupancy sensor costs. Cost effectiveness is proved when this difference is positive; in addition, we have also reported the benefit:cost ratio as an additional indicator of cost effectiveness.

2.10 Statewide Savings Estimates

The statewide energy savings associated with the proposed measures will be calculated by multiplying the energy savings per square foot with the statewide estimate of new construction in 2014. Details on the method and data source of the nonresidential construction forecast are in Section 6.5.

[1] See the California Energy Commission's guidance on Time Dependent Valuation: http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/tdv/index.html

3. Analysis and Results

This section describes seven distinct pieces of analysis that we conducted, in support of the cost-effectiveness and statewide savings calculations, and to study the adoptability of the measure. The seven pieces of analysis are:

- Percentage of floorspace devoted to corridors and stairwells
- Energy and peak load savings
- Results of design/user study
- Review of current code language content and context review
- Lighting model and simulations
- Cost effectiveness
- Market and pricing survey

3.1 Percentage of Floorspace Devoted to Corridors and Stairwells

To calculate the statewide energy impact of the proposed measure we needed to know how much floorspace would be affected. We could not find existing data on how much floorspace is typically devoted to corridors and stairwells in hotels and multifamily buildings, so we used building plans from multifamily buildings enrolled in the California utilities' incentive programs to calculate these percentages.

We did not review hotel plans because hotel rooms tend to be smaller than apartments. Therefore, the percentage of corridors and stairwells in hotels can be expected to be at least as high as in multifamily buildings. Therefore we believe that the percentages calculated for multifamily are a conservative estimate of the percentage of floorspace that would be affected by the measure. Note that, for comparison, the CASE study for bi-level controls for the 2008 code based its calculations on a simple assumption that corridors make up 20% of hotel floorspace, which is a much higher estimate than we have used.

3.1.1 Sample of Multifamily Buildings

To construct a balanced sample of multifamily buildings, we used buildings enrolled in PG&E and SCE's 2006-2008 multifamily new construction programs. Using this population allowed us to select buildings from a variety of climate zones, and building of a variety of types. We used a target of 1,500 dwelling units to create the sample, based on the time it took to review plans, and the available budget for this task.

In Figure 1 the first two columns show the total number of dwelling units enrolled in the programs (which gives a good idea of which climate zones are experiencing the greatest amount of new construction). The third and fourth columns show how many units should be included in our "ideal sample" of 1,500 units to create a representative sample by climate zone and high rise/low rise buildings[2]. The final columns show how many were included in our actual sample. We have stratified the sample by climate zone because in many cases building designs vary across the state, not necessarily directly because of climate but due to architectural styles and

[2] Under Title 24, multifamily buildings higher than three stories are classed as high-rise.

practices. Stratifying by climate zone is an attempt to accommodate this variation. We have stratified the sample by high rise and low rise buildings for the same reason, and because Title 24 treats high rise and low rise buildings as separate categories.

The final sample represents 15 separate buildings, for which we reviewed the plans in detail to extract floor areas and corridor widths.

	Program Population, units (all PG&E and SCE new construction multifamily programs 2006-2008)		**Ideal Sample for 1500 units**		**Actual Sample (#units)**		**Actual Sample (#projects)**	
Climate Zone	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise
1	0	266	0	11	0	4	0	1
2	275	1229	12	52	125	16	1	1
3	7946	3528	335	149	116	51	1	1
4	6274	2397	264	101	0	36	0	1
5	0	289	0	12	0	9	0	1
6	746	231	31	10	0	0	0	0
7	0	0	0	0	0	0	0	0
8	1197	302	50	13	481	0	1	0
9	2013	639	85	27	0	0	0	0
10	0	369	0	16	0	75	0	1
11	0	427	0	18	0	15	0	1
12	831	3913	35	165	275	52	1	1
13	240	2127	10	90	0	35	0	1
14	0	190	0	8	0	80	0	1
15	0	200	0	8	0	129	0	1
16	0	0	0	0	0	0	0	0
Total	**19,522**	**16,107**	**822**	**678**	**997**	**502**	**4**	11

Figure 1. Sample of Multifamily Units used to Calculate Corridor and Stairwell Area

This sample of multifamily buildings includes some attached townhomes and condominiums that do not have shared internal corridors that would be suitable for occupancy sensor controls. Nevertheless we have included these buildings in our sample to make the sample as representative of statewide conditions as possible.

3.1.2 Floorspace Percentages

We measured corridor and stairwell area as a percentage of total building area, and we recorded the typical dimensions of corridors and stairwells in terms of width, length and height, because these affect the number of sensors that would be required to control the lighting.

Figure 2 shows the percentage of the sample buildings' floor area that is devoted to corridors and stairwells. On average, 6.2% of the building floorspace was corridors, and 2.9% was stairwells. These averages include the buildings that had no corridors and/or no stairwells. Ten (10) of the buildings, representing 43% of the floor area had no internal corridors, and two (2) buildings representing 9% of the floor area had no stairwells.

By adding the 6.2% devoted to corridors and the 2.9% devoted to stairwells, we estimate that the total statewide floor area that would be affected by the requirement for occupancy sensor controls (bi-level lighting) is 9% of all multifamily new construction floor area (see section 3.3.2 for statewide floor area).

For cost-effectiveness calculations, we needed to know how much floorspace would be served by a typical sensor, and for that we needed to know the typical width of the corridors. We calculated the floor area that would typically be served by multiplying the average width of corridors by the maximum sensing distance of the sensor (thereby assuming that most sensors would be installed in a corridor that was at least as long as the maximum sensing distance). For those buildings that had corridors, the average width of the corridor was 5.7 feet.

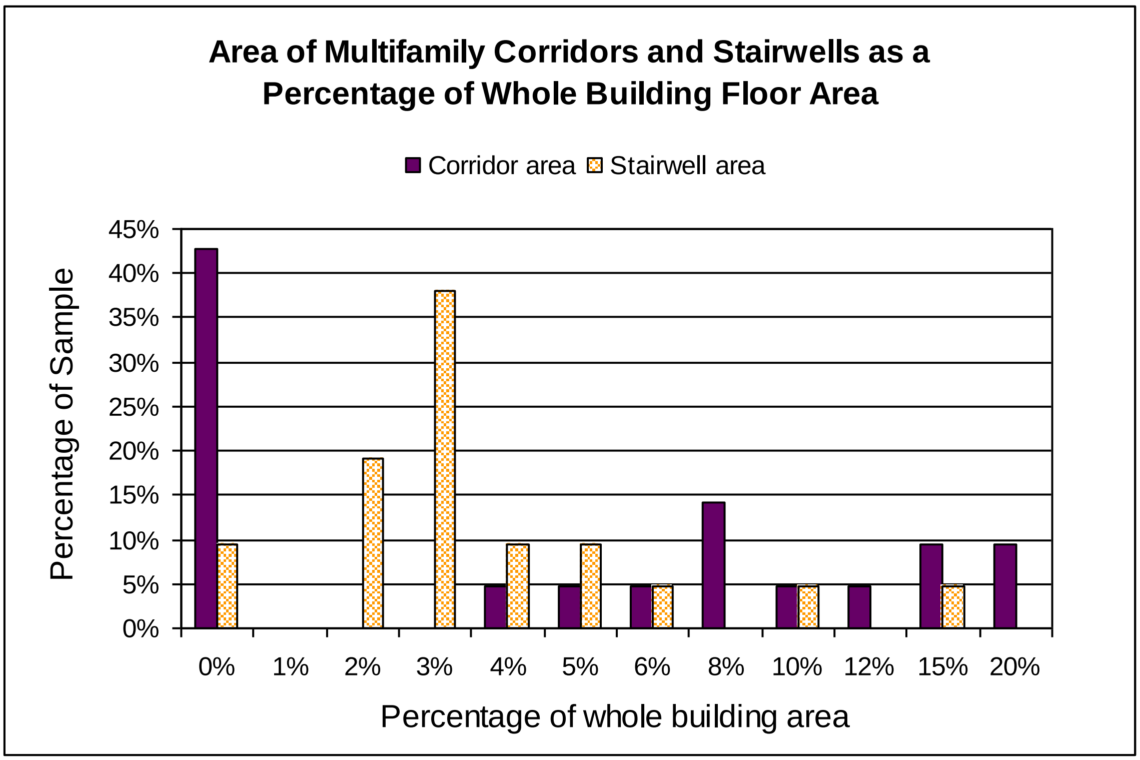

Figure 2: Histograms of the Percentage of Multifamily Floorspace Devoted to Corridors and Stairwells in the Sample Buildings

3.1.3 Use of Occupancy Sensors in the Sample Buildings

While we were reviewing the plans, we determined that none of the sample buildings had occupancy sensors in corridors and/or stairwells.

We also determined eleven (11) of the 21 buildings (three of which were high rise) had occupancy sensors *somewhere* in the building. These sensors were usually in the public bathrooms, changing rooms, laundry and other shared spaces.

3.2 Review of Current Code Language Content and Context Review

We reviewed the current requirements for corridors and stairwells in Title 24, to understand how the new requirements could most easily be incorporated into the existing code. We also reviewed other relevant standards including the fire codes, IESNA illuminance recommendations, and guidance on lighting for the aging eye, because standards must ensure that people will common vision loss due to aging are able to see adequately. Each of these standards influenced our proposed code language to some degree, as described below.

3.2.1 Current T24 Standards

Structure of the Lighting Controls Requirements

In discussion with Gary Flamm at the California Energy Commission we developed the following understanding of how lighting controls requirements are structured within Title 24. We conducted this analysis of the current standards to ensure that our proposed language does not upset the existing structure and create contradictions or unnecessary complexity.

Title 24 has a hierarchy of lighting controls, divided into three tiers. The first, simplest tier is "area controls" (section 131(a)); this requires that each space divided by ceiling-height partitions have a control capable of switching off all the lighting in the space. A simple wall switch is sufficient to meet this requirement. The second tier is "multi-level controls" (section 131(b)), which requires circuitry or dimming capability to allow some of the lighting to be switched off while the rest is left on (or vice-versa). The third is "shut-off controls" that shut off some or all of the lighting in response to a signal such as occupancy or daylighting.

Current Lighting Power Density Requirements

The current standards require that hotel/motel corridors use the Area Category or Tailored method for determining LPD. The Area Category Method (Table 146F) allows an LPD of 0.6 W/sf in hotel/motel corridors.

Current (2008) Title 24 Lighting Controls Requirements

Corridors and stairwells are usually designated egress routes under Section 10-103(a)(2) of Title 24, Part 1, which means that they are exempt from the requirement for area controls (wall switches) in Section 130(a). Switches for these spaces are typically not accessible to the public or to tenants.

Corridors are currently excluded from the requirement for multi-level controls, and the requirement is unlikely to be triggered in either corridors or stairwells because it only applies to spaces with a lighting power density greater than 0.8 W/sf, whereas "Corridors, restrooms, stairs, and support areas" are limited to 0.6 W/sf under the Area Category Method.

There are no shut-off controls requirements for corridors and stairwells. Therefore, lighting controls for corridors and stairwells in hotels and multifamily buildings currently have effectively no lighting controls, and are on 24/7, as shown in the section above (3.1.3).

Power Adjustment Factors (PAFs)

If designers choose to install multi-level controls in corridors they can earn one of two Power Adjustment Factors (PAFs)[3].

[3] California Code of Regulations Title 24 Part 6 (Energy Efficiency) Table 146C

- A PAF of 0.25 is allowed in hallways in hotels, multifamily, dormitories and senior housing for a "Multi-level occupant sensor that reduces lighting power at least 50% when no persons are present,." This means that an additional 0.2 W/sf is allowed because of the installation of controls.
- A PAF of 0.2 is allowed in any space <250sf, or any corridor controlled by a multi-level occupancy sensor

Stairwells are not specifically mentioned in regard to PAFs, but it would be reasonable to claim a PAF of 0.2 or 0.25 by classifying stairwells as corridors, or by counting each controlled area as being in the "<250sf" category.

Unfortunately, however, the requirements for multi-level occupancy sensors in section 119 require that the sensor be able to shut off *all* the lighting in the space, which is not generally acceptable for corridors. Therefore we believe it's highly unlikely that building owners would want to use these PAFs

3.2.2 Code Requirements for Emergency Lighting

The California Fire Code[4] requires that "The means of egress, including the exit discharge, shall be illuminated at all times the building space served by the means of egress is occupied." It requires the illumination level[5] to be "not be less than 1 foot-candle (11 lux) at the walking surface.", and that the minimum level should not be less than "0.1 foot-candle (1 lux) measured along the path of egress at floor level", and that "A maximum-to-minimum illumination uniformity ratio of 40 to 1 shall not be exceeded."

Emergency lighting guidelines are also offered by the National Fire Protection Association (NFPA), although these guidelines are not law in California. Section 7.9.2.1 of the NFPA code states that, "Automatic motion sensor-type lighting switches shall be permitted within the means of egress, provided that the switch controllers are equipped for fail-safe operation, the illumination timers are set for a minimum 15-minutes duration, and the motion sensor is activated by any occupant movement in the area served by the lighting units."

During "conditions of stair use" (i.e. when the stairwell is occupied), NFPA requires that the average illuminance must be at least 10 fc[6]. Note that this is at odds with the IESNA recommendation that stairwells be lit to 5fc. NFPA does not explain how the illuminance should be calculated or measured, but based on the requirement of section 7.9.2.1 (below) it would be reasonable to calculate an average along the path of egress, i.e. a line of calculation points along the center of the treads, or, as one member of the stakeholder group recommended, the average across a 3' wide egress path.

NFPA section 7.9.2.1 requires that "*Emergency lighting facilities shall be arranged to provide initial illumination that is not less than an average of 1 ft-candle (10.8 lux) and, at any point, not less than 0.1 ft-candle (1.1 lux), measured along the path of egress at floor level….A maximum-to-minimum illumination uniformity ratio of 40 to 1 shall not be exceeded*."

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[4] California Code of Regulations Title 24 Part 9 (Fire Code) Section 1006 Means Of Egress Illumination: 1006.1 Illumination Required.

[5] California Code of Regulations Title 24 Part 9 (Fire Code) Section 1006 Means Of Egress Illumination: 1006.2 Illumination level

[6] NFPA Section 7.8.1.3(1)

3.2.3 IESNA Recommended Illuminance Levels

The IESNA Handbook (9th edition) recommends a minimum of 5fc for hotel corridors, elevators and stairs. It also recommends 5fc for stairwells in general (Section 10). Note that these values are lower than the NFPA value or stairwells. The stakeholder group said that it was typical to provide 5-10fc in hotel corridors, but we did not ask them specifically about stairwells. Note that stairwells are typically a less challenging environment to light than corridors, because stairwells typically have more reflective surfaces than corridors, which create more inter-reflections and therefore higher illuminance levels.

3.2.4 Lighting for the Aging Eye

We contacted Naomi Miller of Naomi Miller Lighting, a recognized expert on lighting for the aging eye, to ask about the implications of this proposed code change for older occupants of hotels and multifamily buildings, whose vision may be impaired. She responded "*There are no implications for the aging eye if the detection of the occupancy sensors is reliable…".* She also cautioned *" In narrow corridors, it's difficult to produce reasonable uniformity and sufficient wall lighting to enable folks to see room numbers and nameplates and minimal amounts of art in hotel corridors*."

Changes in floor level can create a trip hazard for people with impaired vision, and standard practice for lighting of corridors and stairwells calls for any change in level to be well illuminated so the shadow cast by the change in level can be perceived. In most buildings, changes in level are avoided due to cost, or are smoothed out with ramps. But where changes in level exist they are usually clearly marked to avoid liability to the building owner. Because this proposed code change does not influence the illumination provided or the positioning of luminaires, it will have no effect on the quality of illumination for people with impaired vision.

The IESNA Recommended Practices guide "Lighting and the Visual Environment for Senior Living" recommends increased illumination levels for exit stairwells and landings (30 fc), hallways (active hours 30 fc, and sleeping hours 10 fc). Because these high light levels are required during the day time we believe they can easily be provided by daylight in most cases, and additional electric lighting should not be required. 10 fc in corridors is sufficient even for seniors with impaired vision, according to the IES guide. However, we recognize that reductions in light levels may be a concern for people who operate assisted living facilities, so it may be possible to allow an exception for these buildings in the code language.

3.3 Energy and Peak Load Savings

SensorSwitch provided HMG with a data set from their logging occupancy sensors. This included 20 corridor spaces in three hotels. Each logger was in place for a few weeks, with occupancy and light level data recorded at two minute intervals.

Data on the occupancy patterns of hotel corridors were analyzed to reveal savings potential by hour of the day, and by weekday/weekend. Savings potential is defined as the amount of time for which the space is lit and unoccupied, multiplied by the lighting power density (LPD) of the space. Because we are calculating savings from a new construction measure, we set all the corridors to have a LPD of 0.6W/sf, the limit set by Title 24 2008 (Tables 146-E and 146-F).

The data set shows a distinction in pattern of use between weekend and weekdays. Figure 3 shows the distinction between baseline (lights on) and potential energy savings (lights on and unoccupied), based on a 30-minute occupancy sensor time delay. The technical potential for energy savings is therefore the difference between the two lines.

As expected the baseline consumption is generally close to 100% lights on because hotel corridor lighting is typically on 24/7. The other line also follows the expected pattern of use, i.e., the corridors are more likely to be unoccupied during the night and very early morning.

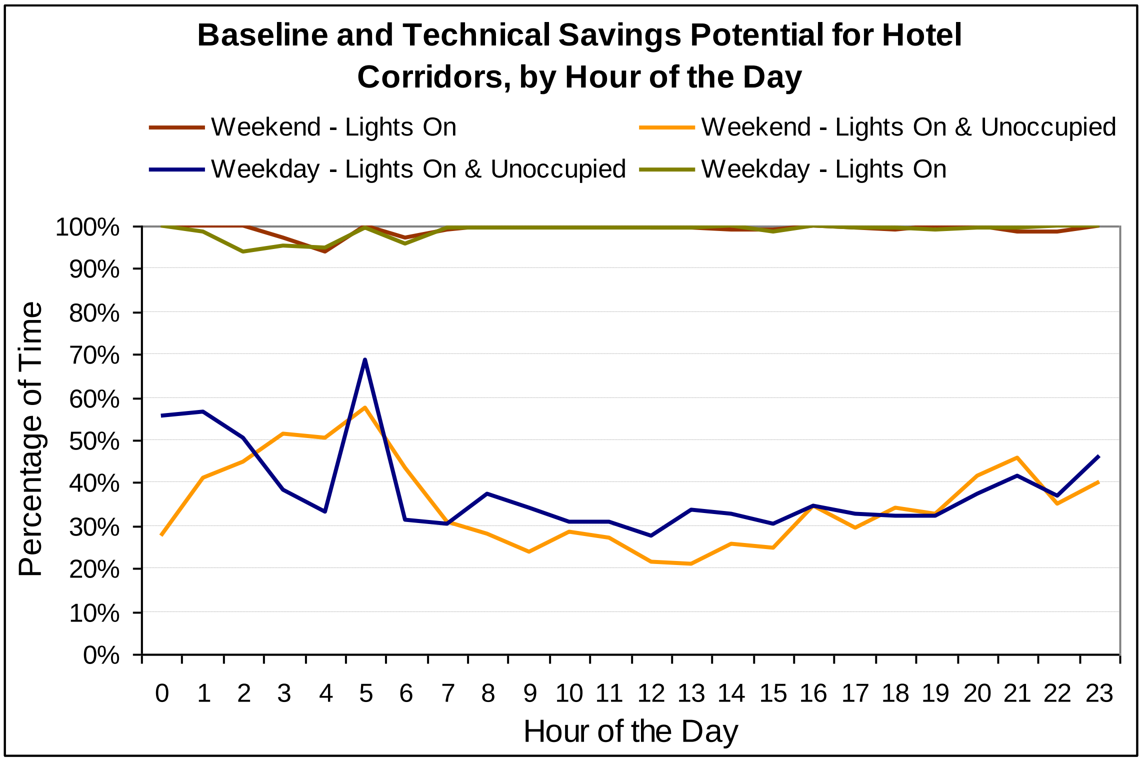

Figure 3: Baseline and Technical Savings Potential for Hotel Corridors, by Hour of the Day

3.3.1 Savings per Square Foot

The lighting was on for 99% of the time (off 1% of the time) during the baseline condition, but the lights could be switched off (because corridors were unoccupied) for 37% of the time on average, meaning that this measure would reduce lighting load to zero for 36% of the time (37%-1%) in these corridors, or, assuming an installed load of 0.6W/sf, reducing this load to zero for 36% of the time would save 0.22 W/sf on average (1.89 kWh/sf/yr).

During the 12pm-6pm peak period, the average savings is 31%, or 0.19 W/sf.

Note that these savings are calculated from the occupancy patterns of real buildings in the data set, so are not based on notional assumptions about operating hours as is sometimes the case with savings estimates.

3.3.2 Statewide Savings

We calculate that this measure will affect a total of 12.5 million square feet of lighting, as summarized in Figure 4, and described below. Assuming 1.89 kWh/sf/yr energy use reduction the measure is expected to save 23.6 million kWh/yr. Using the value of 0.19 W/sf for peak load reduction, the measure is expected to reduce statewide peak load by 2.4 MW per year.

	Hotels	Multifamily	Total
New construction	0.8	5.3	6.1
Retrofit	1.0	5.5	6.5
Total	1.8	10.7	12.5

Figure 4. Square Footage of Lighting Affected by this Measure (Million Square Feet per Year)

Hotels

The CEC construction forecast for 2014 estimates that new hotel construction will be 9.1 million square feet. This is in line with national data--according to CBECS[7] 2003, the average amount of new hotel construction averages 88 million square feet per year nationally. Apportioning this by population, California would have 11 million square feet of new hotels constructed per year. CBECS new construction data is averaged over ten year periods, so the recent downturn in the economy is likely to mean that new construction will be much less than this figure over the next few years, but since this code change is unlikely to be enforced until 2014, the downturn may not affect savings from this measure.

The CEC construction forecast also estimates that California will have 331 million square feet of existing hotel floorspace in 2014. This is somewhat different from an estimate derived from CBECS. Apportioning the 5.1 billion square feet of existing hotels in the U.S. by population[8], California would have approximately 630 million square feet of existing hotel floorspace.

Using the CEC construction forecast, and assuming that the lighting in these hotels is replaced once every 15 years (the measure life used in Title 24), and that half of the new lighting will be code compliant (a conservative assumption, because in many cases lighting replacement will not trigger code compliance, or may be carried out without permits), 11 million square feet can expect to be retrofitted each year.

Applying the 9% of floorspace that is corridors and stairwells (section 3.1), we calculate the total square footage of hotel lighting that will be affected by this requirement as 9% of 9.1 million, or 0.82 million new floor area and 9% of 11 million, or 1.0 million, retrofitted existing floor area for a total of 1.8 million square feet.

Multifamily Buildings

According to the Construction Industry Research Board (CIRB) California Construction Review May 2009, an average of 67,000 units of multifamily construction are started in California each year. According to the Energy Information Administration's 2001 Residential Energy Consumption Survey (RECS)[9], multifamily units in buildings with five (5) or more units

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[7] Commercial Buildings Energy Consumption Survey. 2003 www.eia.doe.gov/emeu/cbecs/

[8] Population figures also from CBECS, Ibid.

[9] http://www.eia.doe.gov/emeu/recs/sqft-measure.html

averaged 847 $ft^{2.}$ This gives a conservative estimate of 58 million square feet of multifamily new construction each year (the estimate is conservative because it includes only the floorspace of the units, not the common areas, so the actual total is greater).

Also according to RECS[10] there is 14.6 billion square feet of existing multifamily housing with five (5) or more units in the U.S. Apportioning by population, California can be expected to have 1.8 billion square feet. Assuming that the lighting in the common area of these buildings is replaced every 15 years (the measure life used in Title 24), and that half of the new lighting will be code compliant, 60 million square feet can expect to be retrofitted each year.

Applying the 9% of floorspace that is corridors and stairwells (section 3.1), we calculate the total square footage of multifamily lighting that will be affected by this requirement as 9% of 58 million, or 5.3 million new floor area and 9% of 60 million, or 1.9 million existing floor area , for a total of 10.7 million square feet per year.

3.4 Results of Designer/User Survey

The main purpose of the survey was to find people who had used occupancy sensors in stairwells and corridors of hotels and multifamily buildings, and to ask about their experiences with those installations. We sent out a web survey during January and February 2009. To reach as many qualified people as possible, we sent the survey to the IESNA Controls Committee to publicize the survey via their email list, and to the IESNA Motherlode Chapter (Sacramento) to publicize the survey via their newsletter. We also sent it to all members of the Stakeholder Group with a request to forward to their professional contacts, and to architects and developers involved in the California Multifamily New Homes program.

The results of the web survey revealed that only two respondents had experience with occupancy sensors in multifamily and hotel corridors and stairwells[11], and only one was able to provide detailed information on using occupancy sensors in a specific building.   The small number of corridor projects provided by SensorSwitch[12] compared to the thousands of other projects that had used their logging occupancy sensors corroborates the finding of our survey, i.e. that occupancy sensors are very rarely considered for these spaces by designers.

One survey participant who had experience using occupancy sensors in hotel spaces gave a lot of detail about one specific project (the web survey allowed open-ended responses). He said that lighting in the corridors was provided by wall sconces and recessed cans. Emergency lights were powered by a generator. The typical dimensions of the corridor were 250'0" x 6'0" with fixtures 12 ft on center. The target light level design for corridors was 5fc – 10 fc. The occupancy sensors were set with a delay of 12 minutes. The survey participant reported that none of the sensors had ever failed and that they have not experienced any difficulty with the controls.

[10] http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html

[11] Responses are shown in the Appendix, section 6.2

[12] Note that, at Sensorswitch's request, we did not attempt to contact the SensorSwitch sites directly, because the data had been obtained on the understanding that Sensorswitch would not pass contact information on to third parties.

3.5 Lighting Model and Simulations

We created models of typical spaces using lighting software. The models were used to check illuminance levels from typical light fixtures and layouts, to verify that the required levels of illuminance could actually be met using the proposed LPDs, and that emergency lighting would have sufficient brightness and uniformity.

3.5.1 Hotel Corridor Simulation

Using Lumen Designer radiosity software, we developed a corridor model with dimensions of 8'0" by 26'0". Illuminance plots from the software are shown in section 6.3

These dimensions were chosen because the stakeholder group and the analysis of multifamily buildings found that corridors are typically 6 ft wide, but we wanted to model a conservative case with more challenging levels of non-uniformity of illuminance. The model included a 90 degree turn in the corridors to check that illuminance and uniformity requirements could still be met. The lighting layout included both wall fixtures and ceiling fixtures, a common configuration according to the stakeholder group, and is a conservative case because uplights give fewer footcandles per watt than downlights.

One 13W wall sconce (lumen output was 1150) was modeled at the guest room door to provide task light for entering individual rooms to represent common practice. We used this proposed design for two other reasons: first, to address Naomi Miller's concern about the visibility of room numbers, and second because doorways are sometimes placed in recessed bays in the corridor, and we wanted to account for lighting designers' desire to provide ambient light in these recesses to enhance the perception of safety. 18W CFL downlights (lumen output was 1200) were modeled at 8'0" on center the entire length of the corridor to provide necessary egress lighting. This gave an LPD of 0.6 W/sf, which is the LPD allowed by Title 24 2008.

We ran radiosity simulations on the model for two scenarios (shown in Figure 6):

- all lights on - simulating the normal occupied lighting state
- down lights off (approximately ½ of installed LPD) – simulating unoccupied periods

Stakeholders recommended and HMG agreed that turning off the down lights during unoccupied periods is the most feasible option. A summary of the results of the lighting calculations is shown in Figure 5. The lighting calculations were conducted using the most common method used by lighting designers (a flux transfer or "radiosity" algorithm), but with a finer calculation grid than is typical for everyday lighting design work, to ensure that the calculated levels are accurate It shows that the lighting system meets the IESNA recommended average level of 5fc even with the controlled lighting switched off, and easily exceeds it with under normal (occupied) conditions[13]. This means that designers and building owners have some latitude to use lower reflectance surfaces and less efficient luminaires, and still be compliant with standards.

[13] We used a calculation grid that ended 1' from the walls. This is standard practice because the areas of the floor immediately next to the walls are not used for walking.

	Minimum illuminance (fc)	Average illuminance (fc)	Maximum illuminance (fc)	Lighting Power Density (W/sf)
All lights on (occupied state)	5	12	14	0.6
Downlights off except in elevator lobby (unoccupied state)	3	6	7	0.3

Figure 5. Summary of Lighting Calculations for Hotel Corridors

We presented these results to the Stakeholder Group and they agreed that the calculations and assumptions were reasonable. Stakeholders requested that elevator entries and lobbies not be included in the treated space, because they didn't want people exiting elevators to be faced with a darkened space. Therefore, we provided additional lighting at the entrance to the elevators (2 x 13W wall sconces) and left these switched on in the model, even when unoccupied.

Figure 6. Radiosity Rendering of a Hotel Corridor in the Occupied (left) and Unoccupied (right) States

3.5.2 Emergency Lighting Simulation

We modeled a corridor in "emergency lighting" mode, and found that 1 fc and adequate uniformity could be maintained with an LPD of 0.11 W/sf (achieved with 3 x 18W can lights left on). Therefore, the results of this analysis suggest that the requirement for emergency lighting can easily be met with less than the 0.3W/sf that are exempt from controls requirements under section 131. This corridor is a challenging (conservative) case because it is a small space with little "borrowed light" from other luminaires, because it contains a 90 degree angle and because it is illuminated by recessed can luminaires that have a low efficacy.

3.6 Market and Pricing Survey

To contact lighting distributors for the survey, we started by using the lists of sales reps on the websites of the following major occupancy sensor manufacturers. Between them, we believe that these manufacturers account for the overwhelming majority of occupancy sensor sales in the state. Manufacturers are listed in alphabetical order:

- Cooper Controls
- Greengate
- Hubbell
- Leviton
- Lightolier
- Lutron

- SensorSwitch
- Square D
- Wattstopper

From the websites of these manufacturers we generated a list of sales reps that includes 156 businesses throughout California and is geographically segmented as shown in Figure 7. Because the first four manufacturers we surveyed provided such a large number of sales rep contacts, we did not pursue sales rep contacts for the remaining five manufacturers. However, because there is so much overlap (i.e. each of the sales reps carries multiple manufacturers' sensors), all eight manufacturers are actually well represented by the sales reps we surveyed. Figure 7 gives an indication of the relative market saturation based on the larger manufacturer's sales rep locations. The table shows that occupancy sensors are available throughout the state, and that in each area of the state there are several manufacturers represented. This provides evidence that the market for occupancy sensors is well established and competitive, and able to handle the increase in orders that would result from this code change.

Region	Leviton	Lutron	SensorSwitch	WattStopper
SF Bay Area[14]	17	88	65	132
Inland Empire[15]		77	30	
Los Angeles	17	264	85	99
Sacramento	17	231	20	33
San Diego	17	110	75	33
Other	17		50	33

Figure 7. Number of Sales Reps Listed on each Manufacturer's Web Site, by Region

Seven sales reps from each region were randomly selected and called. We asked them for occupancy sensor prices, but not all reps responded with prices, the main reason being that in order to generate a bid query, the rep required project information (location, size, contractor name) which we did not have. Of those willing to assist in the survey, we asked each sales rep:

- Which manufacturer's products do you most commonly sell?
- What model(s) would you recommend?
- What would be the labor cost for a certified electrician to complete the installation?
- Can you please provide your thoughts on the relative quality of the sensors you carry and any additional insights you have about occupancy sensors?

This survey was intended to be relatively informal and open-ended, and focused on gleaning as much information as possible from the anecdotal responses given by lighting equipment reps throughout the state.

As shown in Figure 8, we obtained prices on 41 ceiling-mounted occupancy sensors. We also collected technical data on these sensors. This data was necessary to ensure that the full cost of

[14] Alameda, Contra Costa, Marin, Napa, San Benito, San Francisco, San Mateo, Santa Clara , Santa Cruz, Solano, Sonoma counties

[15] Riverside and San Bernardino counties.

the sensor accessories was included, and that diversity in the market was adequately captured. The technical data we collected included:

- Area served
- Time delay programming
- Power pack requirement
- Sensor technology (dual, ultrasonic or infrared)
- Voltage input (line or low)
- Field of view

.

	Line voltage	Low Voltage	Total
Infrared	6	3	9
Ultrasonic	19	1	20
Dual technology	2	10	12
Total	27	14	41

Figure 8. Number of Occupancy Sensors for which Prices were Obtained, by Type

Figure 9 shows the mean price for the six major types of occupancy sensor in the survey. We have not shown the range of prices obtained from different sales rep for each sensor type, but the range of prices was low compared to the difference between the sensor types.

As expected, line voltage sensors are cheaper than low voltage sensors. This is because low voltage sensors are designed to allow manual-on operation, and therefore must include circuitry for input from a low voltage switch, along with a transformer. Both these accessories add cost.

	Line Voltage	Low Voltage
Infrared	$49.91	$62.20
Ultrasonic	$99.21	$137.19
Dual technology	$91.75	$108.89

Note that price includes the price of all associated power packs, lenses etc.

Figure 9. Average Price of Ceiling-Mounted Occupancy Sensors in Pricing Survey, by Type

3.7 Cost Effectiveness

The hourly estimates for energy use were multiplied by the hourly values for Time Dependent Valuation[16] (TDV $) to obtain hourly estimates for the cost of energy. TDV $ and kWh values were summed over 8,760 hours in a year to quantify annual savings. TDV $ are in present value dollars, and the estimated annual savings were compared to costs of installing and purchasing occupancy sensors to quantify Life Cycle Cost (ΔLCC).

The present value of the total savings over the 15 year measure life is TDV $3.11/sf. Subtracting the total installed cost of $0.93/sf (see Figure 10), the ΔLCC is TDV $2.18/sf. Because this value is positive, the measure is cost-effective over its 15 year life.

The benefit:cost ratio of 3.34 is obtained by dividing the benefits of implementing this measure ($3.11/sf) by the cost of the purchasing and installing sensors ($0.93/sf). This ratio represents the cost effectiveness of mandatory occupancy sensor installation in hotel corridors; 3.34 indicates that the present value of the estimated energy savings over the life of the measure is roughly three times the one-time cost for purchasing and installation.

[16] See the California Energy Commission's guidance on Time Dependent Valuation: http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/tdv/index.html

The TDV calculation of the value of energy savings over the life of the measure is too complicated to reproduce in this report, because it requires the summing of hourly values over the course of several years, adjusted for net present value. However, the cost calculation is more straightforward and is shown in Figure 10, along with notes on the sources of the values used in the calculations. To calculate the cost per square foot, we calculated the equipment plus labor cost per sensor, and then divided by the amount of floorspace that sensor can be expected to serve (based on the data from plans of multifamily corridors in section 3.1).

Feedback from the Stakeholder Group showed that the most relevant type of sensor to use for costing purposes would be a dual technology line voltage sensor. Dual technology (ultrasonic plus infra-red) is appropriate for corridors because ultrasonic sensing works well in enclosed spaces, and is good at sensing the opening of doors. From the pricing survey (section 2.8) dual technology is actually cheaper, or at least no more expensive, than ultrasonic alone. The stakeholders said that user override would not be desirable, so a line voltage (rather than low voltage) sensor is appropriate.

Installed Cost (per sensor)		**Notes**
Dual technology line voltage sensor	$91.75	From pricing survey
Installation and commissioning	$100.00	1 hour (per RS Means) at $100/hr
Callbacks	$20.00	20% callbacks per LCA survey (described below)
Total	**$211.75**	
Area Served by each sensor		
Length	40’	From manufacturers’ literature,
Width	5.7’	Average width of corridors from survey of multifamily plans
Area	**228 ft^2**	
Total Cost per Square Foot		
Total	**$0.93 /ft^2**	

Figure 10. Installed Costs for Occupancy Sensors

We used a survey conducted by Craig DiLouie for the Lighting Controls Association (LCA 2007) to estimate how often contractors are called back to site to fix problems with occupancy sensors (we did not use this survey to calculate other costs). The survey found that contractors are called back to 20% of jobs to change occupancy sensor sensitivity or time delay. Because time delays in corridors and stairwells would most likely, in practice, be set to the maximum 30 minutes, and because the likelihood of nuisance switching or insufficient sensitivity is low, we anticipate that callbacks for these spaces would be less frequent, so 20% would be a conservative assumption. In our cost calculations we have included the cost for a one-hour contractor call-back in 20% of cases.

The LCA survey also found that contractors are general familiar with the installation and calibration of occupancy sensors, which leads us to believe that they would be competent to install them in corridor and stairwell spaces for this code measure: "*electrical contractors routinely calibrate motion sensitivity and time delay settings in occupancy sensor installations; recommend occupancy sensors in a majority of lighting retrofit projects; select time delay settings that on average support optimal energy savings and lamp life; and are satisfied with occupancy sensor performance, ease of installation and commissioning, and customer/occupant acceptance.*"

3.8 Materials Impacts

This proposed measure will result in the use of more occupancy sensors in multifamily and hotel corridors, and this section quantifies the impact of those sensors in terms of the materials used in their manufacture.

The materials impact calculations below use the same assumptions as are shown in the calculations of cost-effectiveness and statewide savings in the preceding sections.

The materials impacts *per component* are shown in Appendix 6.6. Note that the values for mercury and lead content of components (except for lamps) are calculated by using the maximum percent-by-weight values allowed under California law, and so represent a conservative overestimate of the mercury and lead content.

		Number of square feet per component	
Component	**Basis for calculation**	Hotels	Multifamily
Occupancy sensors in corridors	One occupancy sensor per 40' length of corridor, which is 5.7' wide (see Section 3.7)	40' length of corridor multiplied by 5.7' width = 228 sf	40' length of corridor multiplied by 5.7' width = 228 sf
Additional power wiring for luminaires	#12 power wiring equal in length to the total length of corridor affected by the measure (i.e., tandem wiring of fixtures)	100' of #!2 wire serves 100x5.7 = 570 sf of corridor	100' of #!2 wire serves 100x5.7 = 570 sf of corridor

Figure 11. Basis for Calculation of Materials Impacts

Component	**square feet per component**	**Materials impact (lbs/year)**					
		Mercury	**Lead**	**Copper**	**Steel**	**Plastic**	**Others (Identify)**
Hotels			1.8	Million square feet of corridor per year			
Occupancy sensors in corridors	228	4	4	1184	789	1974	0
Additional power wiring for luminaires	570	0	0	6316	0	0	0
Multifamily buildings			10.7	Million square feet of corridor per year			
Occupancy sensors in corridors	228	23	23	7039	4693	11732	0
Additional power wiring for luminaires	570	0	0	37544	0	0	0
Statewide total		**27**	**27**	**52083**	**5482**	**13706**	**0**

Figure 12. Statewide Materials Impact

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

This section describes the specific recommended language and contains enough detail to develop the draft standard in the next phase of work. We have used the language from the 2008 standard, and have used underlining to indicate new language and strikethroughs to show deleted language.

4.1 Summary of Proposed Changes

This section summarizes the code language initially recommended by the IOU team.

We propose to change the standards to require at least half the lighting in corridors and stairwells in hotels and multifamily buildings to be controlled by an occupancy sensor that switches the lighting off at unoccupied times. The occupancy sensor would have to meet the requirements for occupancy sensors in section 119(d), with the caveat that it need not switch off *all* the lighting in the space.

We propose to add a new section 131(h) and add to the requirements of 150(k)16, to set out those spaces in which occupant sensors are required. Note that an alternative approach to amending the code would be to modify the exceptions to 131(d) to require corridors and stairwells to have a "time switch or other control capable of automatically shutting off the lighting". However, we believe that time switches are inappropriate for corridors and stairwells, and would be overridden if installed. Our proposed approach also simplifies the code as much as possible by adding requirements rather than adding exceptions.

This proposal allows two opportunities to simplify the code. First, we propose to remove the exception to 131(b) that exempts corridors from the requirement for multi-level switching. This exception is now redundant. Second, we propose to remove the Power Adjustment Factor of 0.25 for "Hallways of hotels/motels , multi-family, dormitory, and senior housing" in table 146-C. All these buildings are classified as "hotels" or "multifamily" under the code, so they can all be removed without creating follow-on effects. The PAF of 0.2 for "any size corridor" will not apply unless the corridor is controlled by a *multi-level* occupant sensor, which would create more savings than a single-stage sensor, and therefore should still qualify for a PAF even under the revised code. Because multi-level occupant sensors must have manual-on functionality, they are unlikely to be used in corridors or stairwells anyway.

We also propose to revise section 131(b) by lowering the threshold for multi-level controls from 0.8 W/sf to 0.5 W/sf. We were advised by the Energy Commission that we should recommend a reduction in this threshold, but not until the stakeholder process had already concluded, so we did not have an opportunity to discuss this change with stakeholders. The threshold for multi-level controls has not been lowered for several code cycles, during which LPDs have been reduced significantly in many space types, so this change is required to maintain the "hierarchy" of controls (basic switch/multi-level switching/automatic controls). Lowering this requirement for bi-level controls would affect the following spaces:

- Electrical, mechanical, telephone rooms 0.7 W/sf
- Locker/dressing room 0.8 W/sf

- Commercial and industrial storage (refrigerated) 0.7 W/sf (these spaces are already going to be affected by the proposal for automated lighting controls in warehouses, being prepared for SDG&E by HMG)

All other spaces are not affected by the drop from 0.8 W/sf to 0.5 W/sf. They are either higher than 0.8 and therefore already required to install bi-level or they are below 0.5 W/sf. Therefore, a change in this threshold would not negatively affect many spaces, but would allow us to keep the hierarchy of the code intact.

Finally, we propose to lower the exemption for emergency lighting from 0.3 W/sf to 0.2 W/sf, because the requirement to switch off at least 50% of the lighting conflicts with the 0.3 W/sf threshold whenever the installed LPD is less than 0.6 W/sf (which it usually is, in the case of corridors and stairwells). The lighting calculations we carried out for the corridor space (section 3.5) showed that sufficient emergency illuminance could be achieved in the corridor using 0.11 W/sf.

4.2 Code Language Recommended by the Investor-Owned Utilities Codes and Standards Team

This is the language that was originally proposed to the CEC by the IOU Codes and Standards team as a result of the stakeholder meetings and analysis described in this report, and as a result of initial discussions with the CEC. This language was presented in the Draft CASE report.

SECTION 131 – INDOOR LIGHTING CONTROLS THAT SHALL BE INSTALLED

(b) Multi-Level Lighting Controls

The general lighting of any enclosed space 100 square feet or larger, and has a in which the connected lighting load that exceeds 0.8 watts per square foot, and that has more than one light source (luminaire), shall have multi-level lighting controls. A multi-level lighting control is a lighting control that reduces lighting power by either continuous dimming, stepped dimming, or stepped switching while maintaining a reasonably uniform level of illuminance throughout the area controlled. Multi-level controls shall have at least one control step that is between 30% percent and 70% percent of design lighting power and allow the power of all lights to be manually turned off, and at least one step of minimum light output operating at less than 35% of full rated lighting system power (this control step could be completely off, creating a bi-level control). A reasonably uniform level of illuminance in an area shall be achieved by any of the following:

1. Continuous or stepped Dimming of all lamps or luminaires; or

2. Switching alternate lamps in luminaires, alternate luminaires, and alternate rows of luminaires.

EXCEPTIONS to Section 131(b):

~~1. Lights in corridors.~~

2. A space that has only one luminaire with no more than two lamps.

(d) Shut-off Controls

6. Occupant sensors that reduce lighting power in the space by at least 50% and are compliant with Section 119 shall be installed in the following spaces:

1. Corridors

2. Stairwells

3. Aisle ways in warehouses

4. Open spaces in warehouses

Each luminaire must be controlled by no more than two occupant sensors.

SECTION 146(c)—CALCULATION OF ALLOWED INDOOR LIGHTING POWER DENSITY

TABLE 146-C LIGHTING POWER ADJUSTMENT FACTORS

TYPE OF CONTROL		TYPE OF SPACE	FACTOR
Multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D		Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, ~~corridor~~, conference or waiting room.	0.20
~~Multi-level occupant sensor (see Note 2) that reduces lighting power at least 50% when no persons are present. May be a switching or dimming (see Note 3) system.~~		~~Hallways of hotels/motels , multi-family, dormitory, and senior housing~~	~~0.25~~
		~~Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)~~	~~0.15~~
		~~Library Stacks (maximum 2 aisles per sensor)~~	~~0.15~~
Dimming system	Manual	Hotels/motels, restaurants, auditoriums, theaters	0.10
	Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters	0.20
Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal. (See Note 1)		All building types	0.05
Manual dimming of dimmable electronic ballasts. (see Note 3)		All building types	0.10
Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal when used in combination with manual dimming of dimmable electronic ballasts (see Note 1 and 3).		All building types	0.15
Combined controls	Multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D combined with automatic multi-level daylighting controls	Any space ≤ 250 square feet within a daylit area and enclosed by floor-to-ceiling partitions, any size classroom, ~~corridor~~, conference or waiting room. The PAF may be added to the daylighting control credit	0.10
	Manual dimming of dimmable electronic ballasts (see Note 3) when used in combination with a multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D.	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, ~~corridor~~, conference or waiting room	0.25

Automatic multi-level daylighting controls (See Note 1)			Effective Aperture			
	Total primary sidelit daylight areas less than 2,500 ft² in an enclosed space and all secondary sidelit areas. (see Note 4)	General Lighting Power Density (W/ft²)	>10% and ≤20%	>20% and ≤35%	>35% and ≤65%	> 65%
		All	0.12	0.20	0.25	0.30
			Effective Aperture			
	Total skylit daylight areas in an enclosed space less than 2,500 square feet, and where glazing material or diffuser has ASTM D1003 haze measurement greater than 90%	General Lighting Power Density (W/ft²)	0.6% ≤ EA < 1%	1% ≤ EA < 1.4%	1.4% ≤ EA < 1.8%	1.8% ≤ EA
		LPD < 0.7	0.24	0.30	0.32	0.34
		0.7 ≤ LPD< 1.0	0.18	0.26	0.30	0.32
		1.0 ≤ LPD < 1.4	0.12	0.22	0.26	0.28
		1.4 ≤ LPD	0.08	0.20	0.24	0.28

NOTES FOR TABLE 146-C:

1. PAFs shall not be available for lighting controls required by Title 24, Part 6.

2. To qualify for the PAF the multi-level occupant sensor shall comply with the applicable requirements of Section 119
3. To qualify for the PAF all dimming ballasts for T5 and T8 linear fluorescent lamps shall be electronic and shall be certified to the Commission with a minimum RSE in accordance with Table 146-D.
4. If the primary sidelit daylight area and the secondary sidelit daylight area are controlled together, the PAF is determined based on the secondary sidelit effective aperture for both the primary sidelit daylight area and the secondary sidelit daylight area.

SECTION 150(k)

16. Common Areas of Low-rise Residential Buildings. Permanently installed lighting in the enclosed, non-dwelling spaces of low-rise residential buildings with four or more dwelling units shall be high efficacy luminaires. Occupant sensors that reduce the lighting power in the space by at least 50% and are compliant with Section 119 shall be installed in corridors and stairwells. Each luminaire must be controlled by no more than two occupant sensors.

~~**EXCEPTION to Section 150(k)16:** Permanently installed luminaires that are not high efficacy shall be allowed provided that they are controlled by an occupant sensor(s) certified to comply with the applicable requirements of Section 119(j).~~

4.3 Code Language Proposed by the California Energy Commission

This is the text of the code language proposed by the California Energy Commission for sections 131, 146(c), and 150(k). This language was sent by the CEC to the California investor-owned utilities Codes and Standards Team on August 17, 2011.

Note that this language may be different than the language originally proposed by the IOU team, and shown in Section 4.2.

SECTION 131 – INDOOR LIGHTING CONTROLS THAT SHALL BE INSTALLED

(b) Multi-Level Lighting Controls…

…

~~EXCEPTIONS to Section 131(b):~~

~~1. Lights in corridors.~~

EXCEPTION 1 to Section 131(b): Classrooms with a connected general lighting load of 0.7 watts per square feet and less shall have at least on step between 30-70 percent of full rated power.

EXCEPTION 2 **to Section 131(b).:** A**n** ~~space~~ **area enclosed by ceiling height partitions** that has only one luminaire with no more than two lamps

…

(c) Shut-off Controls

7. Areas where partial ON/OFF occupant sensors are required instead of complying with Section 131(c)1.

A. Lighting in common area corridors which provide access to guestrooms and dwelling units of high-rise residential buildings and hotel/motels shall be controlled

with occupant sensor(s) that automatically reduce lighting power by at least 50 percent.

B. **In parking garages, parking areas and loading and unloading areas, general lighting shall be controlled by occupant sensors having at least one control step between 20 percent and 50 percent of design lighting power. No more than 500 watts of rated lighting power shall be controlled by a single occupant sensor. A reasonably uniform level of illuminance shall be achieved in accordance with the applicable requirements in Table 131-A**

Note: Interior areas of parking garages are classified as indoor lighting for compliance with Section 131(c)5C. Parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provision in Section 132.

SECTION 146(c) – CALCULATION OF ALLOWED INDOOR LIGHTING POWER DENSITY

TABLE 146-A LIGHTING POWER ADJUSTMENT FACTORS

TYPE OF CONTROL		TYPE OF SPACE	FACTOR
To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section 146(a)2			
Multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D		Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, ~~corridor~~, conference or waiting room.	0.20
~~Multi-level occupant sensor (see Note 2) that reduces lighting power at least 50% when no persons are present. May be a switching or dimming (see Note 3) system.~~		~~Hallways of hotels/motels , multi-family, dormitory, and senior housing~~	~~0.25~~
		~~Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)~~	~~0.15~~
		~~Library Stacks (maximum 2 aisles per sensor)~~	~~0.15~~
Dimming system	Manual	Hotels/motels, restaurants, auditoriums, theaters	0.10
	Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters	0.20
Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal. (See Note 1)		All building types	0.05
Manual dimming of dimmable electronic ballasts. (see Note 3)		All building types	0.10
Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal when used in combination with manual dimming of dimmable electronic ballasts (see Note 1 and 3).		All building types	0.15
Combined controls	Multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D combined with automatic multi-level daylighting controls	Any space ≤ 250 square feet within a daylit area and enclosed by floor-to-ceiling partitions, any size classroom, ~~corridor~~, conference or waiting room. The PAF may be added to the daylighting control credit	0.10
	Manual dimming of dimmable electronic ballasts (see Note 3) when used in combination with a multi-level occupant sensor (see Note 2) combined with multi-level circuitry and switching in accordance with Section 146(a)2D.	Any space ≤ 250 square feet enclosed by floor-to-ceiling partitions; any size classroom, ~~corridor~~, conference or waiting room	0.25

			Effective Aperture			
Automatic multi-level daylighting controls (See Note 1)	Total primary sidelit daylight areas less than 2,500 ft² in an enclosed space and all secondary sidelit areas. (see Note 4)	General Lighting Power Density (W/ft²)	>10% and ≤20%	>20% and ≤35%	>35% and ≤65%	> 65%
		All	0.12	0.20	0.25	0.30
	Total skylit daylight areas in an enclosed space less than 2,500 square feet, and where glazing material or diffuser has ASTM D1003 haze measurement greater than 90%		Effective Aperture			
		General Lighting Power Density (W/ft²)	0.6% ≤ EA < 1%	1% ≤ EA < 1.4%	1.4% ≤ EA < 1.8%	1.8% ≤ EA
		LPD < 0.7	0.24	0.30	0.32	0.34
		0.7 ≤ LPD< 1.0	0.18	0.26	0.30	0.32
		1.0 ≤ LPD < 1.4	0.12	0.22	0.26	0.28
		1.4 ≤ LPD	0.08	0.20	0.24	0.28

~~NOTES FOR TABLE 146-C:~~

1. ~~PAFs shall not be available for lighting controls required by Title 24, Part 6.~~
2. ~~To qualify for the PAF the multi-level occupant sensor shall comply with the applicable requirements of Section 119~~
3. ~~To qualify for the PAF all dimming ballasts for T5 and T8 linear fluorescent lamps shall be electronic and shall be certified to the Commission with a minimum RSE in accordance with Table 146-D.~~
4. ~~If the primary sidelit daylight area and the secondary sidelit daylight area are controlled together, the PAF is determined based on the secondary sidelit effective aperture for both the primary sidelit daylight area and the secondary sidelit daylight area.~~

SECTION 150(k)

~~16~~**12. Interior C**ommon Areas of Low-rise **Multi-Family** Residential Buildings. ~~Permanently installed lighting in the enclosed, non-dwelling spaces of low-rise residential buildings with four or more dwelling units shall be high efficacy luminaires.~~

~~EXCEPTION to Section 150(k)16: Permanently installed low efficacy luminaires shall be allowed provided that they are controlled by an occupant sensor(s) certified to comply with the applicable requirements of Section 119.~~

A. **In a low-rise multi-family residential building where the total interior common area in a single building equals 20 percent or less of the floor area, permanently installed lighting for the interior common areas in that building shall be high efficacy luminaires or controlled by an occupant sensor.**

B. **In a low-rise multi-family residential building where the total interior common area in a single building equals more than 20 percent of the floor area, permanently installed lighting in that building shall:**

   i. **Shall comply with the applicable requirements in Sections119, 130, 131, 146, and 149; and**

   ii. **Lighting installed in corridors and stairwells shall be controlled by occupant sensors that reduce the lighting power in each space by at least 50 percent. The occupant sensors shall be capable of turning the light fully on from all designed paths of egress**

4.4 Differences between the Recommended and Proposed Language

This section highlights the key differences between the language recommended by the IOU tea m (Section 4.2) and the language proposed by the CEC (Section 4.3).CEC language revised text in Exceptions to 131(b) (Multi-Level Lighting)

Exception 2 was reworded to read, "An area enclosed by ceiling height partitions that has only one luminaire with no more than two lamps." This change is simply to clarify the language, and does not affect the code requirement.

CEC language relocates shut-off controls to section 131(c)

Shut-off controls requirements have moved from 131(d) to 131(c). This change is to simplify the code and does affect the code requirement.

CEC language revised Lighting Power Adjustment Factor Table

The Lighting Power Adjustment Factor table is now Table 146-A to reflect changes made elsewhere, and the notes in the table are consolidated into one note at the top of the table which reads, "To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section 146(a)2." This change is simply to clarify the language, and does not affect the code requirement.

CEC language revised text in 150(k) for Common Areas in Low-Rise Residential Buildings

The CEC language creates a distinction in lighting control requirements based on the proportion of the building devoted to common areas. This is consistent with other requirements of the code, which require separate Title 24 compliance for the dwellings vs. the common areas, when the common area exceeds 20% of the building floor area.

The CEC language also allows for "high efficacy luminaires or occupant sensor," rather than both high efficacy luminaires and occupant sensors as described in the proposed language. We believe that this language creates an unnecessary inconsistency with section 131, and recommend that common areas that comprise less than 20% of the floor area should have both high efficacy and occupant sensors.

4.5 Material for Compliance Manuals

We will develop material for the compliance manuals in the final CASE report once the proposed code language has been approved by the Commission.

In this section, we will provide information that will be needed to develop the Residential and/or Nonresidential Compliance Manuals, including:

- Possible new compliance forms or changes to existing compliance forms.
- Examples of how the proposed Standards change applies to both common and outlying situations. Use the question and answer format used in the 2005 Residential and Nonresidential Compliance Manuals.
- Any explanatory text that should be included in the Manual.
- Any data tables needed to implement the measure.

5. Bibliography and Other Research

5.1 Codes and Standards

California Code of Regulations (CCR), Title 24. Known as the California Building Standards Code. Regarding standards for emergency egress lighting. http://www.bsc.ca.gov/title_24/default.htm

Life Safety Code of the National Fire Protection Association (NFPA). Regarding standards for emergency egress lighting. http://www.nfpa.org/categoryList.asp?categoryID=124&URL=Codes%20&%20Standards

Illuminating Engineering Society of North America. Lighting Handbook, 9th Edition. Regarding recommended light levels for space. IESNA 2000. www.iesna.org.

California Energy Commission (CEC).2005. Life Cycle Cost Methodology – 2008 California Building Energy Efficiency Standards. Prepared by Architectural Energy Corporation (AEC).

5.2 Personal Communications

Linda Murphy and Keith Sage. Program staff for California Multifamily New Homes Program. Regarding plans for multifamily buildings. February 2009.

Mara Blitzer. Senior Project Manager with Tenderloin Neighborhood Development Corp. Regarding use of occupancy sensors in multifamily corridors. October 2008.

Jay Wratten. Designer with Flack & Kurtz. Regarding use of occupancy sensors in multifamily corridors. November 2008.

Gary Flamm. Lighting Lead at California Energy Commission. Regarding hierarchy of code and appropriate code language for proposed measure. September 2008-March 2009.

Miguel Castellanos. Engineer with ECOM Engineering. Regarding installation and reliability of occupancy sensors. September 2008.

Teresa Clarke. Developer with Affordable Housing Alliance. Regarding her experience with controls in AHA’s multifamily buildings.

Naomi Miller. Lighting designer with Naomi Miller Lighting Design. Now working at Pacific Northwest National Laboratory. Regarding the visual needs of aging occupants. September 2008.

5.3 Other

SensorSwitch, Inc. Logged data from occupancy sensors. Not published. 2008.

Construction Industry Research Board (CIRB), California Construction Review, May 2009. http://www.cirbdata.com/reports/index.html

WattStopper, Inc. Nightlights Fuel Energy Savings and Guest Satisfaction. Case study conducted by Lawrence Berkeley Laboratory. www.wattstopper.com.

California Commercial End Use Survey (CEUS). Regarding energy use intensities for lighting. http://www.energy.ca.gov/ceus/

Lighting Contractors Association (LCA).2007. *Study Finds Occupancy Sensors Routinely Commissioned by Satisfied Contractors, but Suffer High Callback Rate* . Prepared by DiLouie, Craig . July 2007. Accessed at http://www.aboutlightingcontrols.org/education/papers/2007_occ_sensor_study.shtml

6. Appendices

6.1 Stakeholder Group Participants

The Stakeholders Group includes those who attended one of the three meetings, and a few people who we contacted separately to make use of specific expertise. Note that the Stakeholder Group for this proposed measure was combined with the Stakeholder Group for a measure on occupancy sensors in warehouses.

- George Loisos, Architect/Lighting Designer, Loisos + Ubbelohde Architects
- Lisa Bornemann, Lighting Designer, H. E. Banks + Associates
- Christ Surunis, Sr. Account Supervisor - Hospitality, Lutron Electronics Company, Inc.
- Teresa Clarke, Senior Project Manager, Affordable Housing Associates
- Jeff Fox, Director of Projects and Product Development, Hilton Garden Inn Brand Management
- Ben Hahn, Marketing Manager, SensorSwitch
- Jim Abrams, President (Now Retired), California Hotel and Lodging Association
- Bobbie Singh-Allen, VP of Government Relations, California Hotel and Lodging Association
- Charles Knuffke, Panel Manager, The Watt Stopper
- Gregor Stewart, Associated Lighting Representatives, Inc.
- Nick Bleeker, Director of Business Development, Day-Brite Capri Omega
- Gary Flamm – California Energy Commission
- Jeff Fox - Hilton Hotels, Hilton Garden Brand
- Rick Lawton – Safeway
- Eric Richman – PNNL
- Lynn Mohrfield – California Hotel and Lodging Association
- Mike Crockett - Safeway

6.2 Responses to Designer/Installer Survey

We estimate that the survey was sent out to at least 200 designers and engineers through the channels described in section 3.4, though we cannot know the exact number. Only two respondents had considered using occupancy sensors in corridors or stairwells. Text from their survey responses is provided below:

6.2.1 Response #1

"We decided to put half of the hallway fixtures on sensor and half not. Since the fixtures are energy efficient, it takes a few seconds for the lights to go on. If all of the hallway lights are on sensors, one can exit the elevator into darkness, waiting for the lights to brighten up. So as not to scare people, we will have half of the lights on at all times and half on sensors. This is an attempt to try and meet the request of our Asset Management staff to avoid over-lighting hallways while keeping our tenants feeling good about the space.

Regarding stairwells, I think the sensors present the same issue raised above with the hallways as far as the issue of walking into a dark space. We want to encourage our tenants to take the stairs when they can - walking into a dark space isn't very encouraging, but on the other hand most of the time the stairs aren't used so conceptually they are a space where we could save a lot of energy.

6.2.2 Response #2

I know we have proposed such an approach in both corridors and stairwells for multi-family buildings, but I'm not aware of any projects that have been completed.

Typically, we have seen resistance to an approach where all of the lights would be turned on/off by an occupancy sensor in a public space. There is the perception that users would be nervous about walking into a completely dark space. We have proposed several approaches where, for example, a colored LED light would be kept on at night in stairwells to create an effect when viewed from outside the building and to provide a low initial level of light when users first step into the space. Circulation lights then come on/off via occupancy sensors.

Owners, however, have been willing to incorporate a reduced lighting level state during off-peak hours for corridors using a time clock to turn lights off. When I was at HLB, I worked on a project called 200 Second in Oakland where this approach was applied in the corridors".

6.3 Illuminance Plots for Hotel Corridor

This sections shows floor-level illuminance plots for a hotel corridor generated by Lumen Designer using standard radiosity calculations on a regular grid.

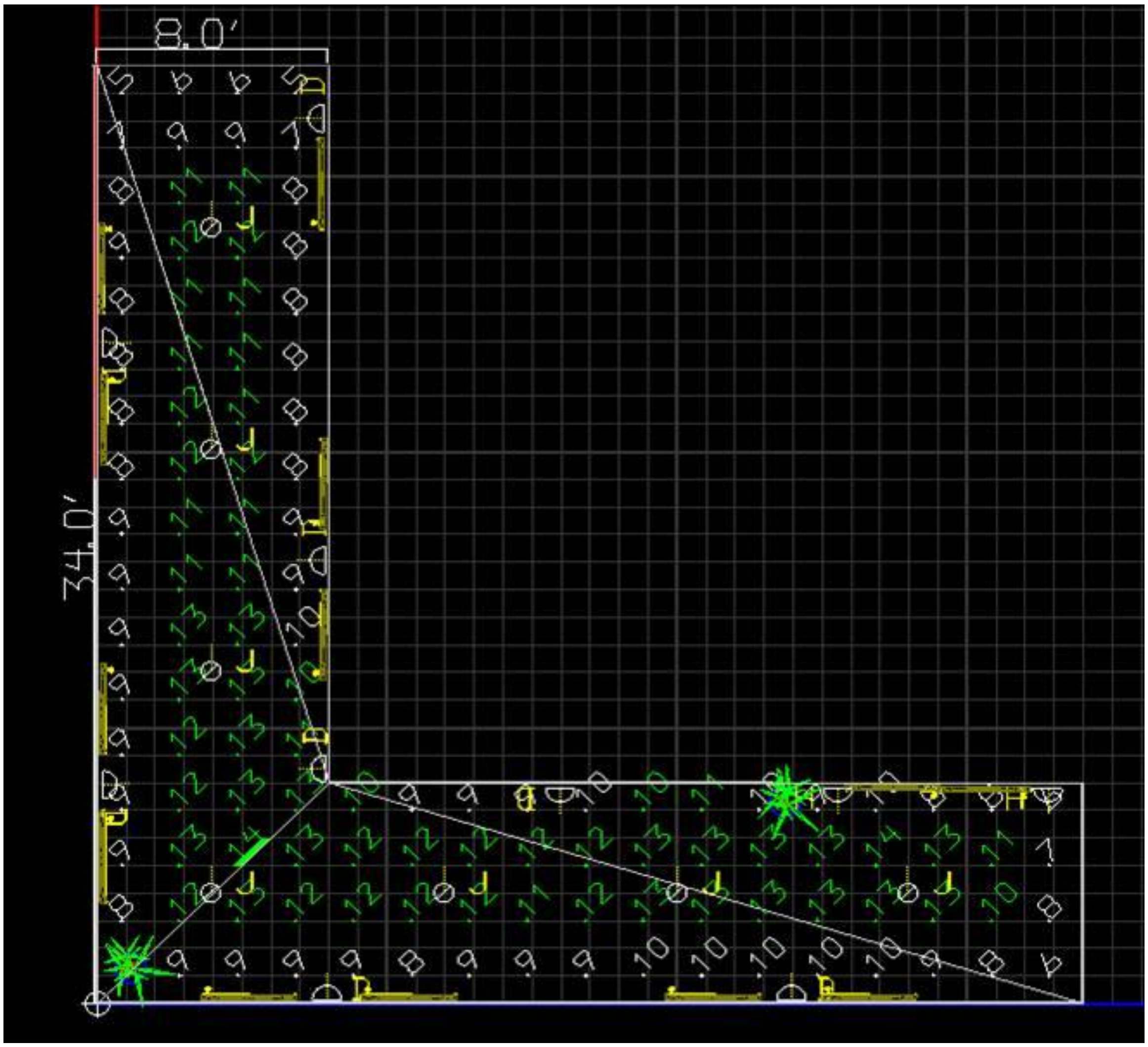

Figure 13. Illuminance Plot for Occupied State (sconces and downlights on)

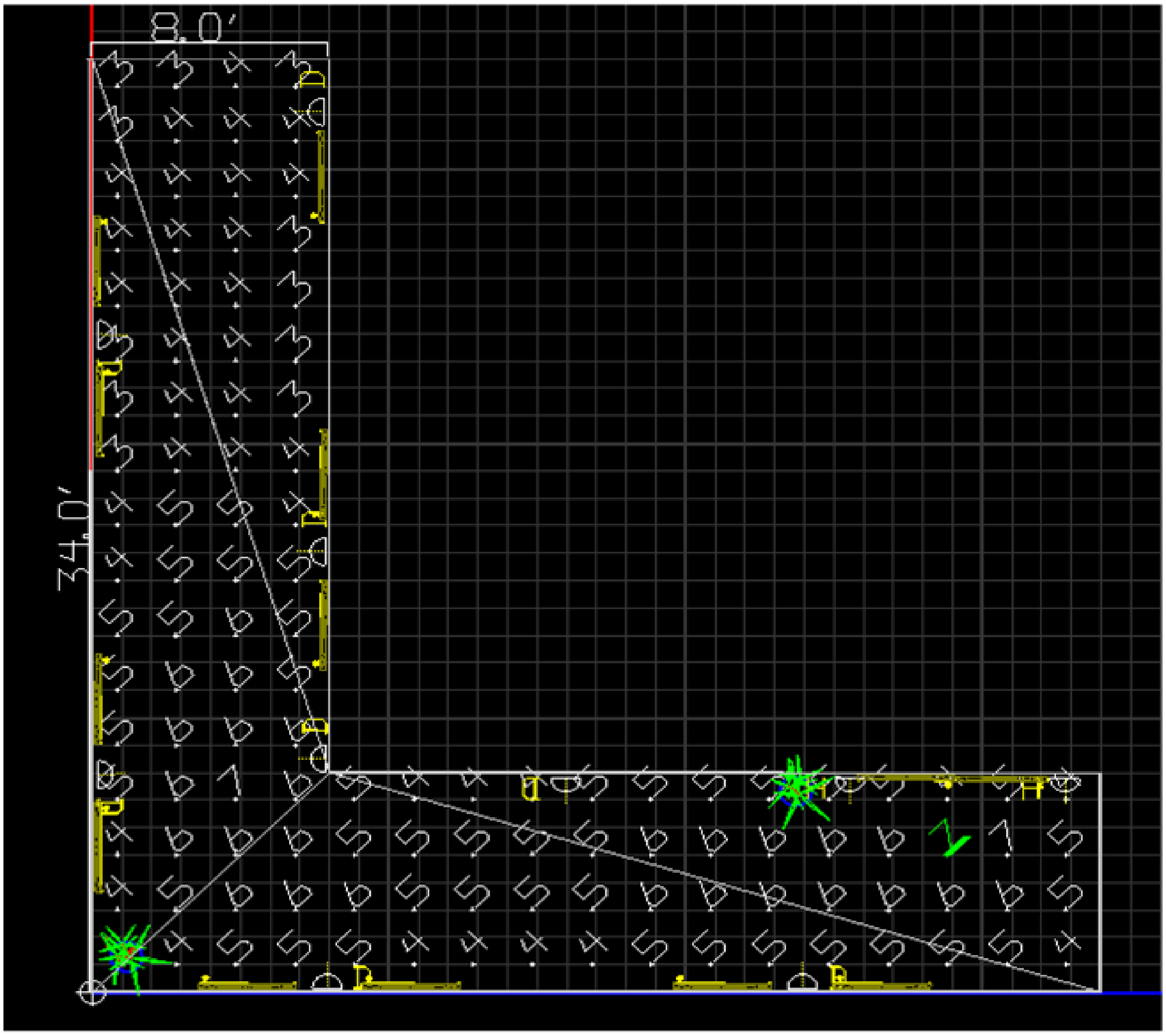

Figure 14. Illuminance Plot for Occupied State (sconces on, downlights off)

6.4 Results of Market and Pricing Survey

This appendix shows the results of the market and pricing survey. The survey was conducted in November and December 2008. The column showing "Required auxiliary equipment price" refers to power supplies and lenses that had to be included to make the equipment functional.

Region	Manufacturer Name	Unit Price	Req Aux Equipment Price	Low voltage model?	Line Voltage Model?	Infrared Model?	Ultrasonic Model?	Dual Tech Model?
BA	Leviton	$129.00	$31.00	TRUE	FALSE	FALSE	FALSE	TRUE
IE	Leviton	$125.00	$35.70	TRUE	FALSE	FALSE	FALSE	TRUE
IE	Leviton	$107.60	$35.70	TRUE	FALSE	FALSE	FALSE	TRUE
IE	WattStopper	$90.44	$23.41	TRUE	FALSE	FALSE	TRUE	FALSE
IE	WattStopper	$74.81	$23.41	TRUE	FALSE	FALSE	TRUE	FALSE
IE	WattStopper	$86.00	$35.00	TRUE	FALSE	TRUE	FALSE	FALSE
IE	WattStopper	$100.00	$35.00	TRUE	FALSE	FALSE	TRUE	FALSE
IE	WattStopper	$162.00	$35.00	TRUE	FALSE	FALSE	FALSE	TRUE
IE	WattStopper	$43.00		FALSE	TRUE	TRUE	FALSE	FALSE
LA	Leviton	$137.19		TRUE	FALSE	FALSE	TRUE	FALSE
LA	Leviton	$91.46		TRUE	FALSE	FALSE	FALSE	TRUE
LA	Leviton	$157.13		TRUE	FALSE	FALSE	FALSE	TRUE
SD	SensorSwitch	$67.50		FALSE	TRUE	FALSE	FALSE	FALSE
SD	SensorSwitch	$43.50		FALSE	TRUE	FALSE	FALSE	TRUE
SD	WattStopper	$90.00	$30.00	TRUE	FALSE	FALSE	TRUE	FALSE
SD	WattStopper	$110.00	$30.00	TRUE	FALSE	FALSE	TRUE	FALSE
Sac	SensorSwitch	$49.95		FALSE	TRUE	FALSE	FALSE	FALSE
Sac	SensorSwitch	$93.75		TRUE	FALSE	FALSE	FALSE	TRUE

Sac	SensorSwitch	$95.00		TRUE	FALSE	FALSE	FALSE	TRUE
Sac	WattStopper	$105.63	$25.02	TRUE	FALSE	FALSE	TRUE	FALSE
Sac	WattStopper	$123.38	$25.02	TRUE	FALSE	FALSE	TRUE	FALSE
LA	WattStopper	$92.67	$20.67	TRUE	FALSE	FALSE	TRUE	FALSE
LA	WattStopper	$40.00		FALSE	TRUE	TRUE	FALSE	FALSE
LA	Leviton	$140.00	$34.00	FALSE	FALSE	FALSE	FALSE	TRUE
BA	SensorSwitch	$49.00		FALSE	TRUE	FALSE	FALSE	FALSE
BA	SensorSwitch	$75.60	$37.32	TRUE	FALSE	FALSE	FALSE	FALSE
BA	SensorSwitch	$63.00		TRUE	FALSE	FALSE	FALSE	TRUE
BA	WattStopper	$109.00		TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$95.00		TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$120.00	$30.00	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$100.00	$30.00	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$80.00	$30.00	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$88.20	$24.80	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$107.10	$24.80	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$125.10	$24.80	TRUE	FALSE	FALSE	TRUE	FALSE
BA	SensorSwitch	$50.00		FALSE	TRUE	FALSE	FALSE	FALSE
BA	SensorSwitch	$65.00		TRUE	FALSE	FALSE	FALSE	TRUE
BA	WattStopper	$107.00	$27.30	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$91.63	$27.30	TRUE	FALSE	FALSE	TRUE	FALSE
BA	WattStopper	$75.00	$27.30	TRUE	FALSE	FALSE	TRUE	FALSE
BA	Leviton	$25.00	$31.00	TRUE	FALSE	TRUE	FALSE	FALSE

Figure 15. Results of Market and Pricing Survey

6.5 Non-Residential Construction Forecast details

6.5.1 Summary

The Non-Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from Dodge construction database, the demand forecast office future generation facility planning data, and building permit office data.

All CASE reports should use the statewide construction forecast for 2014. The TDV savings analysis is calculated on a 15 or 30 year net present value, so it is correct to use the 2014 construction forecast as the basis for CASE savings.

6.5.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ) as well as building type (based on NAICS codes). The 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and additional construction. Total construction is the sum of all existing floor space in a given category (Small office, large office, restaurant, etc.). Additional construction is floor space area constructed in a given year (new construction); this data is derived from the sources mentioned above (Dodge, Demand forecast office, building permits).

Additional construction is an independent dataset from total construction. The difference between two consecutive years of total construction is not necessarily the additional construction for the year because this difference does not take into consideration floor space that was renovated, or repurposed.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has provided CASE authors with the ability to aggregate across multiple building types. This tool is useful for measures that apply to a portion of various building types' floor space (e.g. skylight requirements might apply to 20% of offices, 50% of warehouses and 25% of college floor space).

The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022 (or 10-12 years in the future), and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure). The CEC non-residential construction forecast is the best publicly available data to estimate statewide energy savings.

6.5.3 Citation

"NonRes Construction Forecast by BCZ v7"; Developed by Heschong Mahone Group with data sourced August, 2010 from Abrishami, Moshen at the California Energy Commission (CEC)

6.6 Data for Materials Impacts

This section sets out the raw data used to calculate the materials impacts of the proposed measure (see Overview: Section F), and the underlying data and assumptions.

Component	Weight per component (lbs)					
	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
3-lamp magnetic ballast for linear fluorescent, steel case	0.0035	0.0035	0.20	3.30	0	0
3-lamp electronic ballast for linear fluorescent, steel case	0.0025	0.0025	0.15	2.35	0	0
3-lamp electronic ballast linear fluorescent, plastic case	0.0005	0.0005	0.15	0.1	0.25	0
occupancy sensor	0.0005	0.0005	0.15	0.1	0.25	0
#12 power wiring, 100'	0	0	2	0	0	0
Cat 5 control wire, 100'	0	0	0.94	0	0	0
Linear fluorescent or compact fluorescent lamp	0.00001	0	0	0	0	0
35W PAR30 CMH lamp	0.0055	0	0	0	0	0
70W PAR30 CMH lamp	0.022	0	0	0	0	0
150W T6 CMH lamp	0.031	0	0	0	0	0

Figure 16. Materials Content of Typical Lighting Components, by Weight

Note that in Figure 16 the materials weights for an occupancy sensor are the same as those for an electronic ballast with a plastic case. We made this assumption because these two components are very close to the same size, and both contain electronics that control electrical power, within an insulated plastic case.

Mercury and Lead

The figures for mercury and lead were calculated in one of two ways. For electrical components (ballasts and occupancy sensors) they were calculated by using the maximum allowed percentages, by weight, under the European RoHS[17] requirements, which were incorporated into California state law effective January 1, 2010. The California Lighting Efficiency and Toxics Reduction Act applies RoHS to general purpose lights, i.e. "lamps, bulbs, tubes, or other electric devices that provide functional illumination for indoor residential, indoor commercial, and outdoor use." RoHS allows a maximum of 0.1% by total product weight for both mercury and lead. In practice the actual percentage of mercury and lead in these components may be very much *less* than these values, so the values in the table are conservative overestimates. Values for the total weight of these components (from which the lead and mercury values are calculated) were obtained from the online retailer www.ballastshop.com, and corroborated by the Lighting Research Center's Specifier Report on electronic ballasts[18].

For lamps, the mercury content of the lamp is almost always given by the lamp manufacturer in product cut sheets. The figures in the table are all based on high-volume products from the online catalog for Philips lighting. The amount of lead in a lamp is assumed to be negligible; no information on the presence of these substances in lamps could be found either from product manufacturers or from online sources.

Copper, Steel and Plastics

For ballasts, the amount of copper and steel was estimated by comparing the weight of the electronic plastic-cased ballast with the electronic steel-cased ballast, and assuming that the difference in weight was due to the steel case (i.e., that the electronics inside the two ballasts were the same). For the plastic ballast, a little more than half the weight of the component was assumed to come from the case, with the remaining weight being made up by copper and steel. For the magnetic ballast, the weights for copper and steel were scaled up from the electronic ballast, in proportion to the increase in total component weight (from 2.5lbs up to 8lbs).

For wiring, the weight of copper was calculated using the cross-sectional area of the conductor wires, and multiplying this by the nominal length (100') and by the density of copper (8.94 g/cm^3). The area of the conductor wires was obtained from online sources[19].

For lamps, the amount of copper, steel and plastic in a lamp is assumed to be negligible; no information on the presence of these substances in lamps could be found either from product manufacturers or from online sources.

[17] http://ec.europa.eu/environment/waste/weee/index_en.htm

[18] http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SREB2.pdf

[19] http://en.wikipedia.org/wiki/American_wire_gauge, and http://en.wikipedia.org/wiki/Cat_5