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CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Draft Measure Information Template – Automated Lighting Controls and Switching Requirements in Warehouses

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team, March 2011

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Draft CASE report—

Automated Lighting Controls and Switching Requirements in Warehouses

2011 California Building Energy Efficiency Standards

Sempra Draft Report March 2011

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1. Overview

Description	<p>The proposed measure is to require the installation of occupancy sensors in warehouse aisle ways and open spaces 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 longer than 30 minutes.</p>																																
Type of Change	<p>Mandatory Measure The change would add and modify mandatory requirements for automatic lighting controls and switching.</p> <p>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 for different occupancy types, and are an option in the Power Adjustment Factor table for warehouses.</p> <p>The Standards and Manuals language would be modified in order to include the new requirements. The change would require an addition to Section 131.</p>																																
Energy Benefits	<p>The energy savings benefits of this measure are reduced power loads used in lighting end use. Because warehouses are operated during the afternoon, peak demand will also be reduced. Savings estimates are based on measured lighting and occupancy patterns. The table below shows annual savings in each occupancy type, in kWh/ft²/yr, cumulative statewide savings in GWh/yr, and cumulative statewide peak load reduction in MW/yr.</p> <p>The measure is expected to save 82 GWh/yr, and to reduce peak load by 8.2 MW. Energy benefits broken down by individual spaces are as follows:</p> <table border="1" data-bbox="529 1241 1328 1696"> <thead> <tr> <th>Space Type</th> <th>Energy savings per square foot (kWh/ft²/yr)</th> <th>Statewide energy savings (GWh/yr)</th> <th>Statewide peak load reduction (MW)</th> </tr> </thead> <tbody> <tr> <td>Aisle Freezer</td> <td>1.17</td> <td>2.2</td> <td>0.36</td> </tr> <tr> <td>Aisle Non-refrigerated</td> <td>1.50</td> <td>48.7</td> <td>5.62</td> </tr> <tr> <td>Aisle Refrigerated</td> <td>1.82</td> <td>7.0</td> <td>1.09</td> </tr> <tr> <td>Open Non-refrigerated</td> <td>1.96</td> <td>21.1</td> <td>0.86</td> </tr> <tr> <td>Open Refrigerated</td> <td>1.75</td> <td>2.2</td> <td>0.22</td> </tr> <tr> <td>Open Freezer</td> <td>1.96</td> <td>1.2</td> <td>0.05</td> </tr> <tr> <td>Total</td> <td>1.62</td> <td>82.4</td> <td>8.2</td> </tr> </tbody> </table>	Space Type	Energy savings per square foot (kWh/ft ² /yr)	Statewide energy savings (GWh/yr)	Statewide peak load reduction (MW)	Aisle Freezer	1.17	2.2	0.36	Aisle Non-refrigerated	1.50	48.7	5.62	Aisle Refrigerated	1.82	7.0	1.09	Open Non-refrigerated	1.96	21.1	0.86	Open Refrigerated	1.75	2.2	0.22	Open Freezer	1.96	1.2	0.05	Total	1.62	82.4	8.2
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Non-Energy Benefits	<p>This measure does not provide non-energy benefits, except for the intangible benefit of making building occupants more aware of energy use.</p>																																

Environmental Impact	<p>The only significant environmental impacts of the measure are those related to the energy savings.</p> <p>Material Increase, (Decrease), or No Change (NC): (All units are lbs/year)</p> <table border="1" data-bbox="427 331 1435 554"> <thead> <tr> <th></th> <th>Mercury</th> <th>Lead</th> <th>Copper</th> <th>Steel</th> <th>Plastic</th> <th>Others (Identify)</th> </tr> </thead> <tbody> <tr> <td>Per Unit Measure¹</td> <td>NC</td> <td>NC</td> <td>NC</td> <td>NC</td> <td>NC</td> <td></td> </tr> <tr> <td>Per Prototype Building²</td> <td>NC</td> <td>NC</td> <td>NC</td> <td>NC</td> <td>NC</td> <td></td> </tr> </tbody> </table> <p>Water Quantity and Quality Increase, (Decrease), or No Change (NC):</p> <table border="1" data-bbox="427 606 1435 829"> <thead> <tr> <th></th> <th>Water Savings (or Increase) (Gallons/Year)</th> <th>Mercury Content</th> <th>Other Contaminants, Specify</th> </tr> </thead> <tbody> <tr> <td>Per Unit Measure</td> <td>NC</td> <td>NC</td> <td>NC</td> </tr> <tr> <td>Per Prototype Building</td> <td>NC</td> <td>NC</td> <td>NC</td> </tr> </tbody> </table> <p>Air Quality in lbs/Year, Increase, (Decrease), or No Change (NC)³:</p> <table border="1" data-bbox="427 879 1435 1060"> <thead> <tr> <th></th> <th>NOX</th> <th>SOX</th> <th>CO</th> <th>PM10</th> <th>CO2</th> <th>VOC</th> </tr> </thead> <tbody> <tr> <td>Per Unit Measure</td> <td>0.00026</td> <td>0.0015</td> <td>0.00037</td> <td>0.00012</td> <td>0.94</td> <td>NC</td> </tr> <tr> <td>Per Prototype Building</td> <td>0.58</td> <td>3.5</td> <td>0.84</td> <td>0.27</td> <td>2110</td> <td>NC</td> </tr> </tbody> </table>		Mercury	Lead	Copper	Steel	Plastic	Others (Identify)	Per Unit Measure ¹	NC	NC	NC	NC	NC		Per Prototype Building ²	NC	NC	NC	NC	NC			Water Savings (or Increase) (Gallons/Year)	Mercury Content	Other Contaminants, Specify	Per Unit Measure	NC	NC	NC	Per Prototype Building	NC	NC	NC		NOX	SOX	CO	PM10	CO2	VOC	Per Unit Measure	0.00026	0.0015	0.00037	0.00012	0.94	NC	Per Prototype Building	0.58	3.5	0.84	0.27	2110	NC
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Technology Measures	<p>Measure Availability and Cost:</p> <p>Technology to satisfy the proposed measure is readily and widely available from multiple manufacturers. 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 92 distinct models are available to serve this measure's purpose, and the two most commonly suggested models were CMR-9 made by SensorSwitch and W-*A (where * is 500, 1000 or 2000 ft² coverage area) made by Wattstopper.</p> <p>Useful Life, Persistence and Maintenance:</p> <p>Life of ceiling mounted occupancy sensors is identified by Title 24 as 15 years (AEC & CEC, 2005). We have assumed that the energy savings associated with this technology will be sustained for the life of the product. Stakeholders confirmed that there are no maintenance costs related to this technology except for initial commissioning.</p>																																																						

Performance Verification	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.
Cost Effectiveness	The measure is cost effective with a payback period of approximately one to three years. See section 3.7.2 for details.
Analysis Tools	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.
Relationship to Other Measures	The proposed measure would eliminate the current (2008) Power Adjustment Factor of 0.2 for occupancy sensors in spaces >250sf: 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.”

Using data from a study conducted in 2005 by HMG for Pacific Gas & Electric Company (PG&E)¹, we have reduced the savings from daylighting by a factor of 8%, to take account of the fact that photocontrol systems, while effective, do not function perfectly in practice. The 2005 study found an overall 92% realization rate for photocontrol systems in warehouses.

We used this switching scheme because it represents the most savings that can cost-effectively be achieved in warehouses by using multi-level controls, and therefore produces a lower bound (conservative) estimate of the remaining savings that can be achieved by the occupancy sensors. In practice, most warehouses use only one or two levels of switching, rather than three, and are required by Title 24 to switch off only two-thirds of the electric lighting (not the 92% we have modeled).

2.3 Data on Space Geometry

Though the data set contains only warehouse spaces, we sub-categorized several types of space to achieve better granularity. Following guidance given during the first stakeholder meeting, we categorized spaces as being *freezer*, *refrigerated* or *non-refrigerated* spaces, and as: *mezzanine*, *aisles* or *open spaces*. HMG consulted with the Stakeholder Group to confirm that the distinction between these three space types is something that is understood by people in the industry. Mezzanines are nonstructural floors that are added to increase the available square footage of a warehouse. They are usually constructed from steel and come with access stairs and their own integrated electrical power and lighting. They can be used as office space, storage for small items, changing rooms, lockers, etc. In grocery warehouses they are sometimes used as an interface between the warehouse and the retail space, for the transfer of goods.

Using a 3x3 matrix, each logged space was therefore categorized as being one of nine types (see Figure 1).

Warehouse Space Type	Aisle	Open	Mezzanine
Freezer			
Non-refrigerated			
Refrigerated			

Figure 1. The nine space types used in the analysis

To assign the correct space type to each set of logged data, we used the descriptions that were written by the warehouse managers of each facility at the time the loggers were installed. Many of the locations were poorly described (e.g. “1st Floor Warehouse”) thus, HMG decided to omit any sensor that was not clearly defined as one of the space types.

Note that Title 24 2008 defines the following types of warehouse buildings/spaces:

- ♦ REFRIGERATED WAREHOUSE is a building or a space constructed for storage of products, where mechanical refrigeration is used to maintain the space temperature at 55 F or less.
- ♦ REFRIGERATED SPACE is a building or a space that is a refrigerated warehouse, walk-in cooler, or a freezer.

¹ McHugh, Pande, Ander, Melnyk. 2004. Effectiveness of Photocontrols with Skylighting. Published in the 2004 IESNA Annual Conference Proceedings Paper #13 pp. 1-18 IESNA, New York. Available online at http://www.h-m-g.com/downloads/Papers/Photocontrol_effectiveness_Paper13wcover.pdf

- ◆ STORAGE, COLD, is a storage area within a refrigerated warehouse where space temperatures are maintained at or above 32 F.
- ◆ STORAGE, FROZEN is a storage area within a refrigerated warehouse where the space temperatures are maintained below 32 F.

For the purposes of this analysis, freezer and Storage, Frozen are synonymous. Title 24 does not currently contain definitions of aisles or open areas in warehouses, so we have added proposed definitions, in Section 4.2.

2.4 Stakeholder Meetings

The purpose of the stakeholder meetings was to help create the lighting model of warehouse spaces, to confirm whether the lighting layouts, lighting controls, and warehouse operating assumptions were correct, and most importantly to confirm that the proposed measure(s) would not have a significant adverse effect on warehouse operations.

We convened a Stakeholder Group comprised of representatives from the industries affected by this proposal. These included:

- ◆ Lighting controls manufacturers
- ◆ Luminaire manufacturers
- ◆ Lighting designers
- ◆ Warehouse owners
- ◆ Grocery Store owners

See section Appendix A – Stakeholder Group Participants 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.

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 warehouse lighting
- ◆ Current code requirements and potential future changes
- ◆ Current design problems and technology limitations/opportunities
- ◆ Initial analysis of potential energy savings from warehouses, based on logged data
- ◆ Proposed lighting layouts for warehouse open spaces and aisles
- ◆ 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 provided a great deal of 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. For instance, stakeholders gave us most of the information required for the lighting models—typical dimensions for warehouse aisles, luminaire spacings, lamp types, and information about how warehouses are typically broken down into different functional areas. Most importantly, they confirmed that the use of controls in warehouses was a suitable way to save energy, and would not interfere with warehouse operations.

HMG also contacted individuals beyond those included in the Stakeholder Group in order to make use of knowledge of a particular topic. For instance, we contacted other lighting controls companies that were not on the stakeholder group to confirm the functions, price and availability of suitable occupancy sensors.

2.5 Designer/User Survey

To find out whether designers, installers or users have *already* used occupancy controls successfully in these spaces, we wanted to gather information 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 facility managers (the survey questions varied between the three professions). 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.

2.6 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 (2008) Title 24 Standards. When we had developed draft language, we reviewed this with Gary Flamm² at the California Energy Commission to check compatibility with Title 24's overall structure and specific provisions, and to work out which of several language options would be most appropriate.

Since this proposal suggests turning lights off within aisles, 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 NFPA standards and the California Building Code Section 1003.2.9.1 in order to fully understand the current standards regarding emergency lighting for the means of egress.

2.7 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 (Watts/sf) for the modeled spaces. We confirmed with the stakeholder group that the lighting layouts we had used were common lighting design

² These discussions took place between September 2008 and March 2009

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.

2.8 Emergency Lighting Models

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

2.9 Market and Pricing Survey

To find out typical market prices and availability of occupancy sensors, we contacted lighting controls distributors to ask for prices. 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, and we attempted to obtain prices for all the common types of occupancy sensor. Details of this analysis are provided in section 3.7.1.

2.10 Cost-Effectiveness Calculation

Occupancy sensors are considered to have a useful life of 15 years (AEC & CEC, 2005). 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 for the 2008 standards³. Each hour is assigned an estimated price for energy, 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 reported the benefit:cost ratio as an additional measure of cost effectiveness.

³ 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 summarizes the results of the data collection and analysis described above. It includes an analysis of the amount of statewide floorspace, occupancy sensor energy savings, designer survey results, equipment prices, and measure cost-effectiveness.

3.1 Percentage of Floorspace Devoted to Warehouse Space Types

To estimate the percentage of warehouse floorspace that is aisles versus open areas, we used the proportion of each type from the sample of logged data, which was 75%/25% (aisle space vs. open space respectively). We asked the Stakeholder Group whether this was a fair estimate of the proportions of those two space types, and they agreed that it was.

Within these two space types, we further divided the sample by the storage temperature of the space. Again, we used the proportions of each temperature type from the sample of logged data. The number of loggers and the resulting percentages of total warehouse space are shown in Figure 2. Based on stakeholder interactions, HMG defined space breakdowns as reported in Section 2.3.

Warehouse Space Type	Aisle	Open	Mezzanine ¹
Freezer	10 (2%)	0	0
Non-refrigerated	223 (65%)	73 (21%)	1
Refrigerated	28 (8%)	12 (3.5%)	15
<i>Totals</i>	<i>251 (75%)</i>	<i>85 (25%)</i>	<i>Omitted</i>

1. Please see section 2.3 for a definition of the Mezzanine space type

Figure 2 Number of data loggers installed by space type (% of total warehouse space)

Of the spaces that were categorized as mezzanine, there were no freezer spaces, only one refrigerated space, and 15 non-refrigerated spaces. Due to this small sample for Mezzanine floor space, this data was omitted from further analysis.

3.2 Review of Current Code Language Content and Context Review

We reviewed the current Title 24 requirements for warehouses 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 and IESNA illuminance recommendations, because these standards ensure that people are able to see adequately and to find their way out of buildings during an emergency. Each of these standards influenced our proposed code language to some degree, as described below.

3.2.1 Current Title 24 Standards

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 review of the current standards to ensure that our proposed language does not upset the existing structure and create contradictions or unnecessary complexity.

Structure of the Lighting Controls Requirements

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 (2008) Lighting Power Density Requirements

The 2008 Title 24 standards require that Commercial/Industrial Storage applications use the *Area Category* or *Tailored* methods for determining area Lighting Power Density (LPD). Area Category Method (Table 146F) allows an LPD of 0.6 W/sf for non-refrigerated storage and 0.7 W/sf for refrigerated storage. To ensure a conservative estimate of savings, in all of our calculations we have assumed that warehouses are lit with 0.6 W/sf of lighting (for the buildings we studied, we did not have actual LPD values).

Current (2008) Title 24 Lighting Controls Requirements

Warehouse open areas should be designated as egress routes under Section 10-103(a)(2) of Title 24, Part 1⁴, when they serve as egress routes for the aisle ways that lead off from them. Egress lighting of 0.3 W/sf is exempt from the requirement for area controls (wall switches occupancy sensors) in Section 131(a). Therefore, in theory, under Title 24 2008, warehouses should have at least one “readily-accessible” wall switch that controls the lighting in the space (except for the 0.3 W/sf that is exempted). Note that because warehouse racks are not “floor to ceiling partitions”, each aisle is *not* currently required to have separate lighting controls.

Section 131(b) requires multi-level controls in spaces that have a connected load greater than 0.8 W/sf. Because warehouses are limited to either 0.6 or 0.7 W/sf (non-refrigerated and refrigerated respectively), they are exempt from the requirement for multi-level controls. Note, however, that in practice there may already be two levels of control for open areas because 0.3 W/sf of the lighting may be on a separate circuit for egress lighting.

Section 131(d) Shut-Off Controls requires automatic shut-off controls in addition to the area controls required by Section 131(a). Section 131(d) is subject to the same exemption for egress lighting as Section 131(a). The requirement of Section 131(d) can be met with an automatic time clock control, by occupancy sensor control, or by an automatic daylighting control device. In daylit warehouses (i.e. all new-construction non-refrigerated warehouses) this requirement is met in practice by the prescriptively-required automatic daylighting control device. Each automatic shut-off control device must be equipped with a manual off-override that serves an area no larger than 5,000 sf.

As a result of these requirements, the current least-cost configuration for warehouse lighting is to have photocontrols with an off-override wall switch in non-refrigerated warehouses, and to have a timeclock control in conjunction with an off-override in refrigerated warehouses. In both cases there will be one circuit for egress lighting that is either uncontrolled (on 24/7), or controlled by

⁴ Note that Title 24 Part 1 is not part of the Energy Efficiency Code—the Energy Efficiency Code is Part 6, although it is often referred to simply as “Title 24” for convenience.

a time clock or a manual switch. In both cases there is no need for the aisles to have separate controls.

Power Adjustment Factors (PAFs)

If designers choose to install bi-level controls in warehouses they can earn a Power Adjustment Factor (PAF)⁵. Warehouses can claim PAF of 0.15 when the following condition is met: “Occupant sensor controlled multi-level switching or dimming system that reduces lighting power at least 50% when no persons are present (maximum of 2 aisles per sensor in warehouses).”

Skylights

Skylights are required in spaces greater than 8,000 sf with ceiling heights of 15 ft or higher⁶. At least one half of the floor area shall be in the daylight area served by skylights (refrigerated warehouses are exempt, see Exception 1 to 143c). Photo controls are mandatory in daylight areas greater than 2,500 sf; whereas spaces smaller than 2,500 sf can receive a compliance credit for installing controls.

3.2.2 Code Requirements for Emergency Lighting

The California Building Code Section 1003.2.9.1 states that, “The means of egress serving occupied portions shall be illuminated at an intensity of not less than 1 fc at the floor level.”

The National Fire Protection Association (NFPA) Section 7.9.2.1 code states:

“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 minimum 15-minutes duration, and the motion sensor is activated by any occupant movement in the area served by the lighting units.”

And,

“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.”⁷

3.2.3 IESNA Recommended Illuminance Levels

The IESNA Handbook (9th edition) recommends a minimum of 5-10 fc for simple orientation, short visits, and bulk storage. It recommends 15-20 fc for basic visual acuity and fine item storage (Section 10), and IESNA recommends 20-50 fc for detailed visual tasks. Stakeholders identified areas where higher light levels may be needed, such as where workers are performing detailed eye to hand type tasks (quality control, attaching small parts, etc). IESNA recommends 20-50 fc for detailed visual tasks/performance. Therefore, HMG recommends not including these spaces in this proposed code change.

⁵ California Code of Regulations, Title 24 Part 6 Table 146C

⁶ California Code of Regulations, Title 24 Part 6 Section 143 c

⁷ NFPA section 7.9.2.1

3.3 Energy and Peak Load Savings

Each logger was in place for two to four weeks, with occupancy and light level data recorded at two minute intervals, so the granularity of the logged data was sufficient for us to generate accurate estimates of savings due to different occupancy sensor time delays. A brief analysis of the effect of time delay showed that reducing the delay to less than 30 minutes resulted in almost no additional savings, unless the delay was reduced close to zero (which is not acceptable to occupants). This suggests that most of the savings accrue during long unoccupied periods, either overnight or at times when a specific aisle is not being accessed.

The occupancy patterns of each of the defined warehouse spaces 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 spaces to have a LPD of 0.6W/sf, the prescriptive 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 energy consumption (the percentage of time for which lights were on in the sample buildings) and the energy consumption with occupancy sensors installed (lights on *and unoccupied*). The technical potential for energy savings is therefore the difference between the two lines.

This calculation is based on a 30-minute occupancy sensor time delay, i.e. we used a database algorithm to search through the data for continuous periods of 30 or more minutes during which the lights were on and the space was unoccupied.

The savings potential (difference between the two lines) is roughly constant throughout the day, fluctuating between 15% and 30% (note that this difference cannot be seen during the daylight periods in Figure 3). This suggests that savings from occupancy sensors are available at all times of day, and therefore that many of the warehouses in the dataset had 24-hour operation.

Figure 3 shows that the savings that can be obtained by occupancy sensors in a daylight (non-refrigerated) warehouse drop close to zero during the middle of the day because the electric lighting has already been switched off by the photocontrol system which is prescriptively required by Title 24. Similar plots for all warehouse space types are presented in Appendix D – Energy Use Graphs.

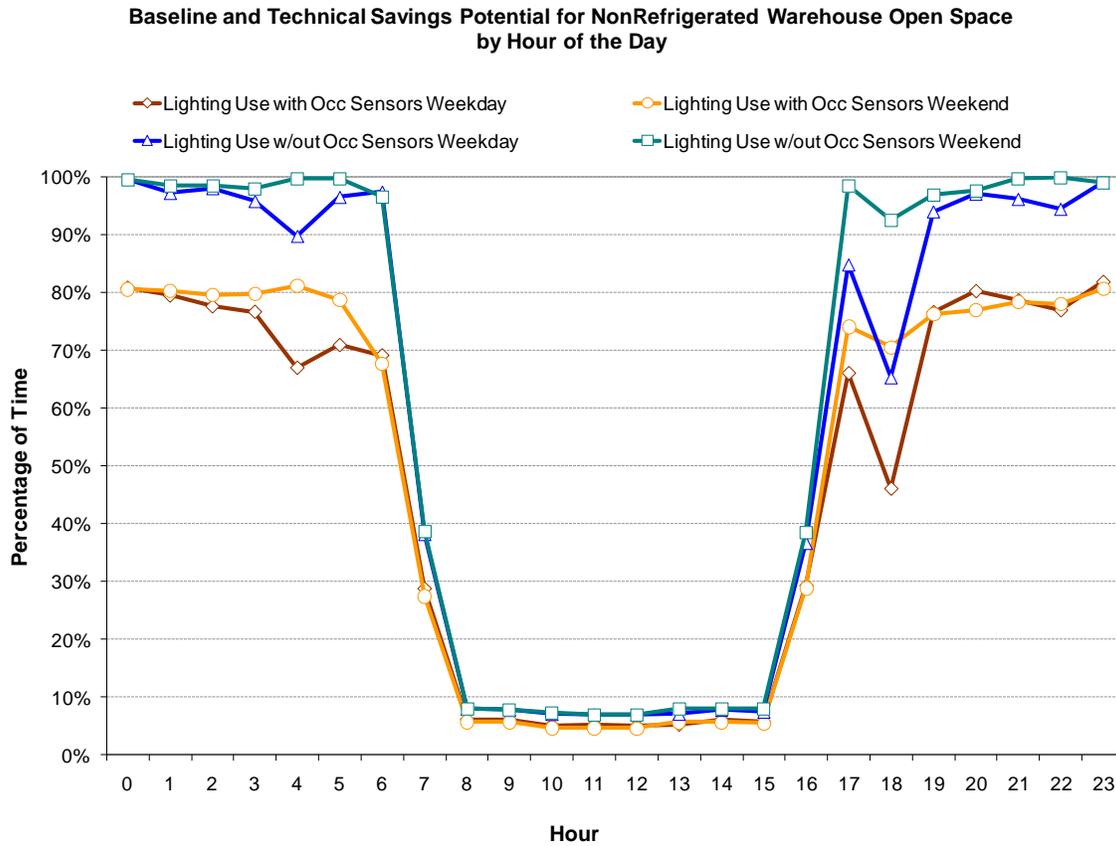


Figure 3: Baseline and Technical Savings Potential for Non-refrigerated Warehouse Open Spaces, by Hour of the Day and by Weekday/Weekend

3.3.1 Savings per Square Foot

In both aisles and open areas, the lighting was on for the majority of the time during the baseline condition (93% of the day), but the lights could be switched off (because spaces were unoccupied) for 20% of the day on average, meaning that this measure would reduce lighting load to zero for 13% of the time during the year (20%-7%). These values are a weighted average by the statewide floor area of each space type.

Assuming an installed load of 0.6W/sf, reducing this load to zero 13% of the time (8760 hours times 0.13) equals 0.08 W/sf savings on average, or 0.7 kWh/sf/yr (see Figure 4 for a breakdown of hourly savings by space type).

Note that the W/sf savings figures in Figure 4 are for weekdays only, and have been reduced somewhat, due to the savings already achieved by daylighting, in the nonrefrigerated warehouse types. The reduction in lighting use between 8 am and 3 pm is due to the daylight adjustment based on Skycalc values as explained in Section 2.2.

Also 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.

For each of the space type classifications in Figure 2, we calculated savings per square foot (W/sf) in Figure 4 based on operating hours as measured by the logging occupancy sensor data, in conjunction with an assumption that the installed load in a Title 24-compliant warehouse would be the maximum allowed 0.6 W/sf.

The savings by hour in Figure 4 due to occupancy sensors indicates that the different types of warehouse space have distinctly different daily patterns of use, reflecting the different times at which goods are loaded, unloaded and distributed around the warehouse. However, all types show significant savings from occupancy sensors, which leads us to believe that the measure should apply equally to all five of the space types shown in Figure 4.

Figure 4 shows that aisles have higher savings than open spaces, which is to be expected because the open areas are generally thoroughfares that people use to access the aisles, so open areas have higher levels of traffic and fewer unoccupied periods. Refrigerated and freezer spaces have the highest potential savings, primarily because daylighting controls don't deduct from the savings.

Hour	Aisle Freezer	Aisle Non-refrigerated	Aisle Refrigerated	Open Non-refrigerated	Open Refrigerated
0	0.40	0.29	0.24	0.11	0.37
1	0.37	0.25	0.24	0.11	0.33
2	0.41	0.23	0.24	0.12	0.31
3	0.40	0.21	0.29	0.11	0.33
4	0.46	0.22	0.41	0.14	0.37
5	0.46	0.22	0.42	0.15	0.31
6	0.42	0.30	0.30	0.17	0.32
7	0.40	0.13	0.27	0.06	0.29
8	0.43	0.03	0.33	0.01	0.29
9	0.38	0.02	0.27	0.01	0.24
10	0.34	0.02	0.27	0.01	0.20
11	0.29	0.02	0.35	0.01	0.15
12	0.25	0.02	0.31	0.01	0.20
13	0.27	0.02	0.31	0.01	0.17
14	0.21	0.02	0.43	0.01	0.20
15	0.28	0.02	0.34	0.01	0.22
16	0.27	0.10	0.26	0.04	0.25
17	0.26	0.26	0.26	0.11	0.26
18	0.27	0.26	0.26	0.12	0.26
19	0.30	0.28	0.25	0.10	0.28
20	0.42	0.30	0.24	0.10	0.36
21	0.42	0.31	0.23	0.10	0.36
22	0.39	0.30	0.25	0.10	0.36
23	0.40	0.30	0.26	0.10	0.36
<i>Average</i>	<i>0.35</i>	<i>0.17</i>	<i>0.29</i>	<i>0.08</i>	<i>0.28</i>
<i>Peak Savings⁸</i>	<i>0.28</i>	<i>0.26</i>	<i>0.43</i>	<i>0.12</i>	<i>0.26</i>

Figure 4. Weekday Lighting Energy Savings from the Use Of Auto-On Auto-Off Occupancy Sensors with a 30 Minute Time Delay(W/sf)

3.3.2 Statewide Savings

To assess statewide savings potential, we also needed to know how much floorspace within the state of California is taken up by each of the space types. We used two data sources for this estimation: NRNC and CEUS (see bibliography). We were able to obtain estimates for warehouse floor space from the NRNC. A description is provided in Section 5.3.

According to the California Nonresidential New Construction (NRNC) database, new warehouse floorspace totaled 233 million ft² from 1999 – 2005. Therefore annual warehouse

⁸ Peak savings is the greatest reduction in load during any single hour between 12:00 and 18:00 on weekdays, for each space type.

new construction was 38.8 million ft² per year during this period. The NRNC survey details not only the building type (warehouses belong to the CEC defined “C&I Storage” space) but also the specific occupancy area types within each building. It shows that 84% of the 38.8 million ft² of new warehouse construction is used for stocking and storing goods. The remaining 16% is used for various other purposes including electronic equipment, dining, lockers and changing rooms, offices, etc. Therefore we estimate that the annual square footage of warehouse new construction affected by this measure will be 32.6 million ft² (38.8 million * .84).

To calculate the square footage of lighting retrofits within *existing* buildings, we used the measure life for lighting systems assumed within Title 24 (15 years) and the approximate life of a warehouse building (30 years). Typically, therefore, each warehouse building has one lighting retrofit within its 30 year life. This means that lighting retrofits occur in 3.3% of warehouse floorspace per year.

Using the NRNC data that 84% of the floorspace would be subject to this new code requirement, and that the amount of existing warehouse floorspace in California is 650 million ft² (from CEUS), we expect that retrofits account for another $650 * 0.84 * (1/30) = 18.2$ million ft² of lighting eligible for this new requirement.

We calculate that this measure will affect a total of 50.9 million square feet of lighting, as summarized in Figure 5. In this table, the square footage for each space type is back calculated from the grand statewide total square footage, using the proportion of space types shown in Figure 2.

	Non-refrigerated	Refrigerated	Freezer
Aisle	32.4	3.8	1.9
Open	10.8	1.3	0.6
Total	43.2	5.1	2.5
Grand Total		50.9	
New Construction Subtotal		32.7	
Lighting Retrofit Subtotal		18.2	

Figure 5. Square Footage of Lighting Affected by this Measure - Million sf per Year

Figure 6 shows the projected technical savings potential from the measure. The values are calculated by multiplying the affected square footage from Figure 5 by the energy savings per square foot shown in Figure 4.

	Non-refrigerated	Refrigerated	Freezer
Aisle	48.7	7.0	2.2
Open	21.1	2.2	1.1
Total	69.8	9.2	3.3
Grand Total		82.4	
New Construction Subtotal		52.9	
Lighting Retrofit Subtotal		29.5	

Figure 6. Energy Savings Potential from this Measure – GWh 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 warehouses, 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.

We found that only one survey participant had experience using occupancy sensors in warehouse spaces. According to his answers, typical dimensions of aisle ways are 70'0" x 4'0", with fixtures 10'0" on center. Typical design illuminance for aisle ways is 15 – 20 fc. Each aisle was controlled by an occupancy sensor with one controlled circuit covering two aisles (there were 10 aisles so five circuits in total). There were seven (7) fixtures per aisle, so 14 fixtures were controlled by each sensor. Time delay was set to 10 minutes. The respondent stated that common practice is for each sensor to control two switch legs.

Additionally, he stated that lighting in the open spaces of a warehouse typically provides 15 – 20 fc. He used occupancy sensors with a 10 minute delay in the open spaces. The survey participant reported no negative feedback from occupants and that none of the occupancy sensors had ever failed for either space type.

3.5 Lighting Model and Simulations

Industry-standard radiosity-based lighting design software (Lumen Designer 2.0) was used to check illuminance levels from typical light fixtures and layouts, to verify that the required levels of illuminance could be met using the proposed LPDs, and that emergency lighting would have sufficient brightness and uniformity.

3.5.1 Warehouse Simulation

Using Lumen Designer radiosity software, we developed a warehouse model with dimensions of 276'0" x 30'0" for an aisle way (10 ft wide aisle with 10 ft wide shelving on either side) and 45'0" x 136'0" for an open space (area without permanent partitions higher than 5 ft).

Illuminance plots from the software are shown in Appendix B—Illuminance Plots for Warehouses.

The aisle way and open area were modeled side by side with no obstructing partition, therefore allowing light within each space to affect the adjacent light levels, as is typical in warehouses. Fixtures were modeled consistently throughout the entire space as 3 x 32W 4' T8 direct fixtures. Lamps had a lumen output of 2900, and fixtures were spaced at 20' on center. HMG ran simulations on the model for two scenarios:

- ◆ All lights on (simulating normal lighting state)
- ◆ 2/3 of installed lighting off (simulating unoccupied periods)

Lumen Designer results are detailed in Figure 7, and the graphical output from the software is shown in Figure 8 and Figure 9. HMG presented these results to stakeholders and they agreed that the lighting technologies, layouts, light levels and power densities in the simulation were typical of standard practice in warehouses. HMG consulted the IESNA Handbook and confirmed recommendations of 5-10 fc for simple orientation/short visits and 15-20 fc for basic visual acuity, which this proposal would allow. Stakeholders did identify areas where higher light levels may be needed. These would be areas where workers are performing detailed eye to hand type tasks (quality control, attaching small parts, etc). IESNA recommends 20-50 fc for detailed visual tasks/performance. Illuminance requirements for these tasks are almost always provided by localized task lighting, rather than by a high level of lighting throughout the space. Therefore we have not included detailed visual tasks in this study.

By modeling the aisle and open space in “emergency lighting” mode, assuming a typical number of fixtures equipped with emergency ballasts, HMG found that 1 fc could be easily maintained with an LPD as low as 0.046 W/sf.

Figure 7 shows that even if the occupancy sensors were to fail in the off mode, there would still be sufficient lighting available from the uncontrolled lamps to provide more than the 1 fc average illuminance required for egress lighting (see shaded cells).

Space Type	Lighting Conditions	Minimum illuminance (fc)	Average illuminance (fc)	Maximum illuminance (fc)	LPD (W/sf)
Aisle	All lights on (occupied state)	11	14	15	0.49
	2/3 of lights off (unoccupied state)	3.7	4.7	5	0.16
Open Area	All lights on (occupied state)	14	19	21	0.44
	2/3 of lights off (unoccupied state)	4.7	6.3	7	0.15

Figure 7. Table of Summary Data from Lumen Designer



Figure 8. Radiosity Rendering of a Warehouse Open Space in the Occupied (left) and Unoccupied (right) States

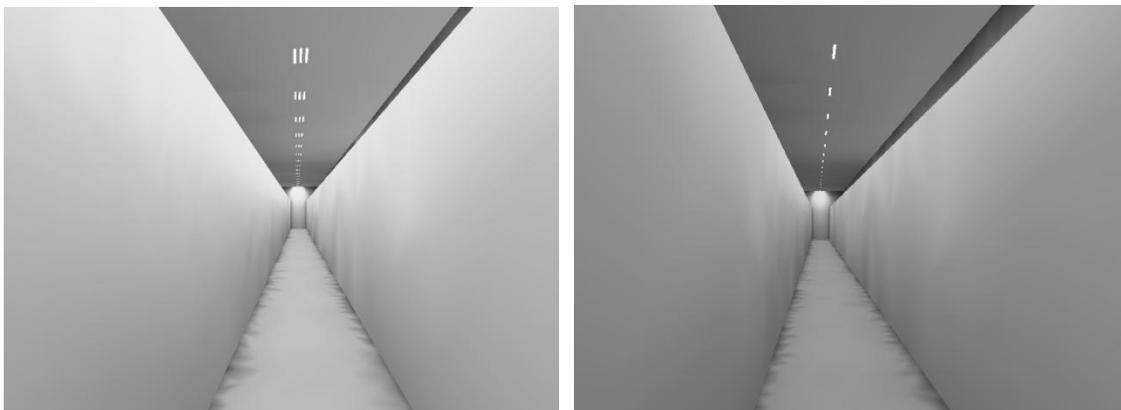


Figure 9. Radiosity Rendering of a Warehouse Aisle in the Occupied (left) and Unoccupied (right) States

3.6 Market and Pricing Survey

The market and pricing survey provides the equipment costs that form part of the basis for the life-cycle costing in section 3.7, and serves to demonstrate that the equipment proposed for this code measure is available from several different suppliers.

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 10. 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 well represented by the sales reps we surveyed. Figure 10 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 ⁹	17	88	65	132
Inland Empire ¹⁰		77	30	
Los Angeles	17	264	85	99
Sacramento	17	231	20	33
San Diego	17	110	75	33
Other	17		50	33

Figure 10. Number of Sales Reps Listed on each Manufacturers' 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 was 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 11, 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 the sensor accessories was included, and that diversity in the market was adequately captured. The technical data we collected included:

⁹ Alameda, Contra Costa, Marin, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma counties

¹⁰ Riverside and San Bernardino counties.

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

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

Figure 11. Number of Occupancy Sensors for which Prices were Obtained, by Type

Figure 12 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 12. Average Price of Ceiling-Mounted Occupancy Sensors in Pricing Survey, by Type

3.7 Cost Effectiveness

The hourly (“8760”) estimates for energy use were multiplied by the hourly values for Time Dependent Valuation (TDV \$/kBTU) to obtain hourly estimates for the value of the energy saved. TDV\$ and kWh values were summed over 8760 hours to quantify annual savings. TDV\$ are in present value dollars. Additionally, we compared the cumulative annual savings with the costs of installing and purchasing occupancy sensors to quantify Life Cycle Cost (Δ LCC).

3.7.1 Sensor Costs per Square Foot

Cost-effectiveness is determined by the price of the sensors (see 3.6) and the amount of floorspace that can be controlled by a sensor. The Stakeholder Group told us that line voltage infrared sensors are typical for warehouse applications, because user override is usually not desirable (therefore low voltage switches are not required), and because ultrasonic sensors do not work well in open areas. Based on this information we have used line voltage sensors as the basis

for the cost effectiveness calculations. From the pricing survey, the mean price of these sensors was \$49.91 (Figure 13).

For the floorspace served by each sensor, we used the 40' on-center spacing suggested by the stakeholder group (and typically quoted in manufacturers' literature), along with a conservative (low) estimate of the width of aisles, at 8' (also from the stakeholder group). This gives an average of 320 square feet served by each sensor—much less than the 1,000 square foot maximum quoted by manufacturers, and therefore well within the technical capability of commonly-available sensors. For open areas we have assumed a slightly greater coverage of 500 square feet, which is the lowest value typically quoted by manufacturers.

We used a survey conducted by Craig DiLouie for the Lighting Controls Association¹ (LCA) to estimate how often contractors are called back 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. 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 generally familiar with the installation and calibration of occupancy sensors, which leads us to believe that they would be competent to install them in warehouses 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.”*

¹ DiLouie, Craig. Study Finds Occupancy Sensors Routinely Commissioned by Satisfied Contractors, but Suffer High Callback Rate . July 2007. Accessed at http://www.aboutlightingcontrols.org/education/papers/2007_occ_sensor_study.shtml

Installed Cost (per sensor)		Notes
Dual technology line voltage sensor	\$49.91	From pricing survey
Installation and commissioning	\$100.00	1 hour (per RS Means) at \$100/hr
Callbacks	\$20.00	20% callbacks per LCA survey
Total	\$169.91	
Area Served by each sensor		
Length	40'	From manufacturers' literature,
Width	8'	Conservative estimate of typical aisle width
Area	320 ft²	(500 ft ² for open spaces)
Total Cost per Square Foot		
Total	\$0.53 /ft²	(\$0.34 / ft ² for open spaces)

Figure 13. Installed Costs for Occupancy Sensors

3.7.2 Life Cycle Cost and Benefit:Cost Ratio

The present value of the total savings over the 15 year measure life is shown in Figure 14, in the “savings” column. The second column (Δ LCC) is the difference between the savings estimate and the installed cost for occupancy sensors, shown in Figure 13. Because the Δ LCC value is positive, the measure is cost-effective over its 15 year life. Figure 14 also shows the benefit:cost ratio for each space, i.e. the number of times the cost savings outweigh the installation costs over the life of the measure.

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. Instead we have provided the final values for savings and cost, shown in Figure 14.

Space Type	Savings (TDV \$/ft ²)	Δ LCC (TDV \$/ft ²)	Benefit:Cost Ratio
Aisle Freezer	\$3.02	\$2.48	5.68
Aisle Non-refrigerated	\$3.33	\$2.74	6.26
Aisle Refrigerated	\$4.39	\$3.80	8.26
Open Non-refrigerated	\$4.29	\$3.92	12.64
Open Refrigerated	\$4.42	\$4.04	13.00
Open Freezer	\$4.29	\$3.92	12.64
Average	\$3.64	\$3.11	7.99

Figure 14. Table of Life Cycle Cost

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

We propose to change the standards to require that at least two thirds of the lighting in warehouse aisles and open spaces 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), to set out those spaces in which occupancy sensors are required.

This proposal allows an opportunity to simplify the code. We propose to remove the Power Adjustment Factor of 0.15 for “Commercial and Industrial Storage stack areas (max. 2 aisles per sensor)”, allowed when the lighting is controlled by a “Multi-level occupant sensor (see Note 21) that reduces lighting power at least 50% when no persons are present. May be a switching or dimming system.” (see Note 32) in table 146-C.

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

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 W/sf 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 two thirds of the lighting conflicts with the 0.3 W/sf threshold whenever the installed LPD is less than 0.6 W/sf (which it must be in warehouses). The lighting calculations we carried out for the warehouse space (Section 3.3) showed that sufficient emergency illuminance could be achieved in the corridor using 0.05 W/sf.

4.2 Proposed Language

We propose to add language to section 101 to describe the affected areas, and to Section 131 to define the new requirements.

SECTION 101(b)

NONRESIDENTIAL FUNCTION AREA OR TYPE OF USE

Commercial and industrial storage is a room, area, or building used for storing items.

Aisle way is a warehouse facility term describing a long, usually narrow space between storage racks. Aisles are usually lit using a single row of ceiling fixtures along the centerline of the aisle.

Open area is a warehouse facility term describing a large unobstructed area that is typically used for the handling and temporary storage of goods.

SECTION 131 – INDOOR LIGHTING CONTROLS THAT SHALL BE INSTALLED

(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.

EXCEPTION 1 to 131(d)6: In spaces in which the installed lighting power is 80% or less of the value allowed under the Area Category Method, occupant sensors may reduce power by only 60%.

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)	Total primary sidelit daylight areas less than 2,500 ft ² in an enclosed space and all secondary sidelit areas. (see Note 4)	Effective Aperture				
		General Lighting Power Density (W/ft ²)	>10% and $\leq 20\%$	>20% and $\leq 35\%$	>35% and $\leq 65\%$	> 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/ft ²)	$0.6\% \leq EA < 1\%$	$1\% \leq EA < 1.4\%$	$1.4\% \leq EA < 1.8\%$	$1.8\% \leq EA$
		LPD < 0.7	0.24	0.30	0.32	0.34
		$0.7 \leq LPD < 1.0$	0.18	0.26	0.30	0.32
		$1.0 \leq LPD < 1.4$	0.12	0.22	0.26	0.28
		$1.4 \leq LPD$	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.						

4.3 NOTES FOR TABLE 146-C:

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

To qualify for the PAF the multi-level occupant sensor shall comply with the applicable requirements of Section 119

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.

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.

4.4 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 California Energy 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

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5.2 Personal Communications

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

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

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

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

Teresa Clarke. 2008. Developer with Affordable Housing Alliance. Regarding her experience with controls in AHA's multifamily buildings. September 2008.

5.3 Other

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Heschong Mahone Group. 2002. *Photocontrol System Field Study*, report submitted to Southern California Edison. Retrieved from www.h-m-g.com.

6. Appendices

Appendix A – 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 hotel and multifamily buildings.

- ◆ 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

Appendix B—Illuminance Plots for Warehouses

This sections shows floor-level illuminance plots for a warehouse aisle (top of image) and open space (bottom of image) generated by Lumen Designer using standard radiosity calculations on a regular grid.

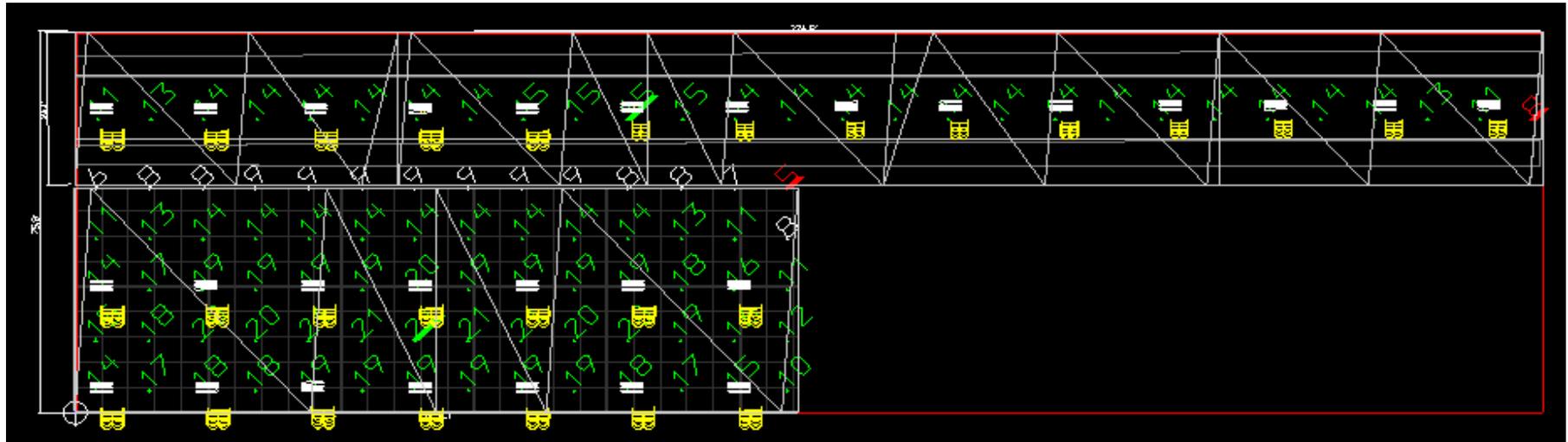


Figure 15. Illuminance Plot for Occupied State (all lighting on)

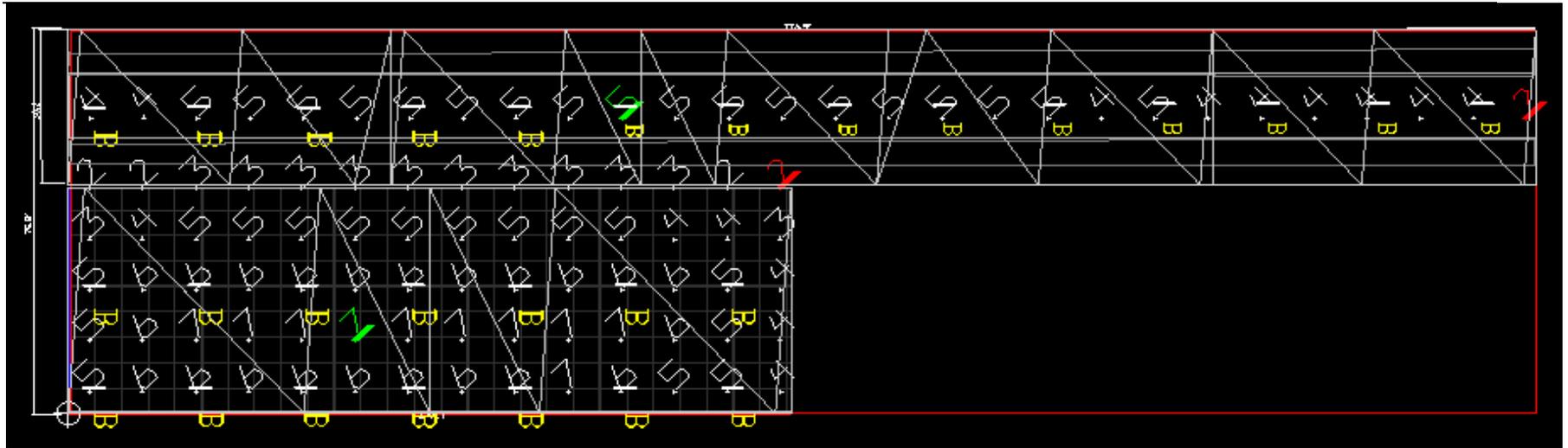


Figure 16. Illuminance Plot for Unoccupied State (2/3 of lamps off)

Appendix C—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

Region	Manufacturer Name	Unit Price	Req Aux Equipment Price	Low voltage model?	Line Voltage Model?	Infrared Model?	Ultrasonic Model?	Dual Tech Model?
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 17. Results of Market and Pricing Survey

Appendix D –Energy Use Graphs

The following graphs show the energy use before occupancy sensors are installed (blue and gray lines) and the energy use after installation (yellow and red lines). The difference between the lines is the amount of savings realized for each space type. Each data point is the percentage of time that lights are on for a given hour of the day. This data is first presented in section 3.3.

