Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Nonresidential Indoor Lighting Alterations – Results Report

Measure Number**:** 2019-NR-LIGHT6-F

Nonresidential Indoor Lighting

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Authors:	Rachel Levine and Stefaniya Becking (Energy Solutions)
Project Management:	California Utilities Statewide Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, SoCalGas®, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District

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1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison, and SoCalGas® – and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission evaluates proposals submitted by the Statewide CASE Team and other stakeholders and may revise or reject proposals.

In August 2017, the Statewide CASE Team submitted the CASE Report that is presented in Attachment 1 to recommend code changes related to nonresidential indoor lighting alterations. This document explains the revisions that occurred to the proposed code changes between the submittal of the Final CASE Report to the Energy Commission and the Energy Commission's adoption of the 2019 Title 24, Part 6 Standards on May 9, 2018. The document begins with a concise description of the adopted code language, followed by the estimated energy savings of the adopted requirements, with the remainder of the document outlining the evolution of the code changes and the final adopted language.

2. MEASURE DESCRIPTION

The Statewide CASE Team's Final CASE Report on nonresidential lighting alterations recommended four main revisions to the existing requirements on nonresidential lighting alterations. Three of the proposed revisions were adopted as code or partially accepted as summarized below.

1. The recommendation to reduce the number of luminaires from two to one per enclosed space in the existing exception to the lighting alteration code was adopted. As a result, private offices that often have two luminaires installed will no longer be exempt from the lighting alteration code.
2. The proposed requirement to have partial OFF occupant sensing controls in stairwells under Option 3 while continuing to exempt corridors from partial OFF occupant sensing controls under Option 3 was partially accepted. Both stairwells and corridors are no longer exempt from the requirement to install occupant sensing controls under Option 3.
3. The proposed requirement to reduce the *total* existing lighting wattage of altered luminaires by a universal wattage reduction percentage of 50 percent of the rated wattage under Option 3 (rather than 50 percent for office, retail, and hotel and 35 percent for all other occupancies) was partially accepted. The Energy Commission adopted a universal wattage reduction of 40 percent and allowed to reduce the *total* existing lighting wattage of altered luminaires.

Additionally, the Energy Commission adopted significant code changes that were not proposed in the Statewide CASE Team's Final CASE Report. The Statewide CASE Team commented on these code changes throughout the language adoption process. Specifically, the Energy Commission adopted:

- A simplified lighting alteration project classification by removing subtypes, i.e., entire luminaire, component modification, and lighting wiring project subtypes;

- An overarching code trigger of ten percent of luminaires being affected per enclosed space;
- The revised exception threshold from the lighting alteration code by reducing the threshold from 70 to 50 luminaires;
- The revised threshold of 80 percent of the Lighting Power Allowance (LPA) for Option 1 and 2;
- A building size threshold limiting Option 3 to one-for-one luminaire alterations in buildings or tenant spaces of 5,000 ft² or less; and
- The matching lighting control requirements between Option 2 and 3, including no longer requiring multi-level lighting controls under Option 2 and not providing any exceptions from occupant sensing controls under Option 3.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Sections of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document(s)
Nonresidential Indoor Lighting Alterations	Prescriptive	141.0(b)2I, 141.0(b)2J, 141.0(b)2K	N/A	No	NRCC-LTI-06-E

3. STATEWIDE ENERGY IMPACTS OF ADOPTED REQUIREMENTS

Table 2 shows the estimated energy savings of the adopted requirements over the first twelve months that are in effect. The first-year savings have changed since submitting the Final CASE Report.

Table 2: Estimated Statewide First Year[a] Energy and Water Savings

Measure	First Year Electricity Savings (GWh/yr)	First Year Peak Electrical Demand Reduction (MW)	First Year Water Savings (million gallons/yr)	First Year Natural Gas Savings (million therms/yr)
New Construction	N/A	N/A	N/A	N/A
Additions	N/A	N/A	N/A	N/A
Alterations	21.0	2.8	N/A	N/A
Total	21.0	2.8	N/A	N/A

a. First year savings from all buildings completed statewide in 2020.

The Statewide CASE Team developed a spreadsheet-based model as a tool for the Energy Commission to perform a transparent analysis of the energy impacts from potential changes to the nonresidential lighting alteration requirements.

The lighting alteration model assessed the relative energy savings resulting from each of the three prescriptive pathways to comply with Title 24, Part 6 nonresidential lighting alteration requirements (using the existing building stock as a baseline). Specifically, the model quantified the effects of lower 2019 lighting power density (LPD) levels, and consequently lower LPA, on energy savings from nonresidential lighting alterations. The lighting alteration model could be used in future Title 24, Part 6 code cycles to assess relevant code change proposals.

Also, the lighting alteration model was adopted to calculate the expected per-unit and statewide energy and demand savings resulting from the Statewide CASE Team's proposed code language in the Final CASE Report.

The Statewide CASE Team updated some of the model inputs to calculate energy and demand savings from the adopted code language. Table 3 summarizes the updates to the model inputs for the base and standards cases that were originally used in the Final CASE Report. The updates reflect changes to some LPD values and control requirements in the adopted code language. For the standards case, the updates also reflect changes to the LPA threshold for Option 2, the wattage reduction percentage for Option 3, and market share of compliance options.

The market share values were updated based on data from the Commercial Buildings Energy Consumption Survey (CBECS). According to CBECS 2012 data, approximately 50 percent of all buildings are 5,000 ft² or less (2,777,000 buildings out of 5,557,000 buildings) (Energy Information Administration 2016). To calculate the revised market share for Option 3, the original market share for Option 3 was multiplied by 50 percent. The Statewide CASE Team used 50 percent as a multiplier rather than the percent of target building size of the total floor area because the original market shares were based on the number of reported retrofit projects, which more likely corresponds to the number of buildings rather than the floor area. Given the lack of data to substantiate the percent change, the Statewide CASE Team did not adjust market shares to account for projects that would no longer qualify for an exception from the lighting alteration code, i.e., projects that modify between 50 and 70 luminaires. Also, the Statewide CASE Team did not adjust market share for Option 3 to account for the increased burden to demonstrate compliance under Option 3, i.e., the need to provide the documentation on building or tenant size. The revised market share values for Options 1, 2, and 3 are 48 percent, 40.5 percent, and 11.5 percent, respectively.

Table 3: Changes to Model Inputs After Final CASE Report Submission

Input Type	User Input in the Lighting Alteration Model	Base Case	Standards Case
LPD values, LPA threshold, wattage reduction percentage	2019 Title 24, Part 6 adopted LPD values	Yes	Yes
	LPA threshold between Option 1 and Option 2	85%	80%
	Option 3 wattage reduction percentage	35/50%	40%
Lighting controls[1]	For Option 1 compliance pathway, replacing the "daylighting dimming to OFF" control in applicable area categories with the "daylighting dimming to 65 percent of lighting power" control	Yes	Yes
	For Option 3 compliance pathway, partial occupant sensing controls in corridors and stairwells	No	Yes
Market of lighting retrofits	Market share of compliance pathways for regulated lighting retrofits	Unchanged from the Final CASE Report inputs Option 1 – 48% Option 2 – 29% Option 3 – 23%	Adjusted market share values to account for building size threshold limiting the use of Option 3 Option 1 – 48% Option 2 – 40.5% (summed 29% and 11.5%, the freed-up portion of Option 3) Option 3 – 11.5% (multiplied 23% by 50%)

Figure 1 and Figure 2 provide a high-level summary of per-unit energy use and per-unit demand for the base case and the standards case. Figure 3 summarizes per-unit and statewide energy savings and demand savings for the adopted lighting alteration code.

[1] The update reflects that the daylighting dimming to OFF measure was not adopted in 2019 Title 24, Part 6 code. Since the measure to require occupant sensing controls in restrooms was adopted, occupant sensing controls were applied in restrooms as in the Final CASE Report for both base and standards case. The savings for occupant sensing controls in restrooms are captured in the Final CASE Report on nonresidential lighting controls.

Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 "85-100% of 2019 LPA" PER-UNIT ENERGY USE	OPTION 2 "≤85% of 2019 LPA" PER-UNIT ENERGY USE	OPTION 3 "Reduction of Existing Wattage" PER-UNIT ENERGY USE (Weighted by Code Vintage)	OPTION 1 "85-100% of 2019 LPA" PER-UNIT DEMAND	OPTION 2 "≤85% of 2019 LPA" PER-UNIT DEMAND	OPTION 3 "Reduction of Existing Wattage" PER-UNIT DEMAND (Weighted by Code Vintage)	ENERGY USE Weighted by Market Share of Compliance Options	DEMAND Weighted by Market Share of Option 3
		kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	W/ft² per year	W/ft² per year	W/ft² per year	kWh/ft² per year	W/ft² per year
1%	Hotel (excl. rooms)	3.1	2.8	2.5	0.3	0.3	0.28	2.9	0.32
28%	Office Large	1.5	1.4	1.3	0.2	0.2	0.15	1.4	0.17
8%	Office Small	1.5	1.4	1.3	0.1	0.1	0.13	1.4	0.14
4%	Restaurant	2.8	2.5	3.4	0.5	0.4	0.56	2.8	0.47
12%	Retail Large	2.9	2.5	2.4	0.5	0.4	0.42	2.7	0.46
12%	Retail Small	2.4	2.0	2.2	0.4	0.3	0.37	2.2	0.37
13%	School	1.8	1.6	2.1	0.2	0.2	0.20	1.8	0.18
22%	Warehouse Non-Refrigerated	1.07	1.04	0.96	0.07	0.07	0.07	1.0	0.07
100%	**Weights by Market Share of Compliance Options**	48%	29%	23%				**100%**	

Figure 1: Base case per-unit energy use and demand by building type for Option 1, Option 2, and Option 3.

Source: Lighting Alteration Model v2.1.

Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 "80-100% of 2019 LPA" PER-UNIT ENERGY USE	OPTION 2 "≤80% of 2019 LPA" PER-UNIT ENERGY USE	OPTION 3 "Reduction of Existing Wattage" PER-UNIT ENERGY USE (Weighted by Code Vintage)	OPTION 1 "80-100% of 2019 LPA" PER-UNIT DEMAND	OPTION 2 "≤80% of 2019 LPA" PER-UNIT DEMAND	OPTION 3 "Reduction of Existing Wattage" PER-UNIT DEMAND (Weighted by Code Vintage)	ENERGY USE Weighted by Market Share of Compliance Options	DEMAND Weighted by Market Share of Option 3
		kWh/ft² per yea	kWh/ft² per year	kWh/ft² per year	W/ft² per year	W/ft² per year	W/ft² per year	kWh/ft² per year	W/ft² per year
1%	Hotel (excl. rooms)	3.1	2.6	2.5	0.3	0.3	0.28	2.8	0.31
28%	Office Large	1.5	1.3	1.4	0.2	0.2	0.16	1.4	0.17
8%	Office Small	1.5	1.3	1.4	0.1	0.1	0.13	1.4	0.14
4%	Restaurant	2.8	2.4	3.1	0.5	0.4	0.52	2.7	0.44
12%	Retail Large	2.9	2.4	2.8	0.5	0.4	0.48	2.7	0.46
12%	Retail Small	2.4	1.9	2.2	0.4	0.3	0.36	2.2	0.36
13%	School	1.8	1.5	1.9	0.2	0.1	0.19	1.7	0.17
22%	Warehouse Non-Refrigerated	1.07	0.98	0.91	0.07	0.07	0.06	1.0	0.07
	Weights by Market Share of Compliance Options	48%	40.5%	11.5%				**100%**	

Figure 2: Standards case per-unit energy use and demand by building type for Option 1, Option 2, and Option 3 for the adopted alteration code.

Source: Lighting Alteration Model v2.1.

Weights by Building Type Stock % of Considered Stock	Building Type	PER-UNIT ENERGY SAVINGS	PER-UNIT DEMAND SAVINGS	Annual Floor Stock Subject to Alteration Code	STATEWIDE ENERGY SAVINGS	STATEWIDE DEMAND SAVINGS
		kWh/ft² per year	W/ft² per year	million ft²	GWh per year	MW per year
1%	Hotel (excl. rooms)	0.03	0.003	7.4	0.22	0.02
28%	Office Large	0.00	0.001	159	0.76	0.09
8%	Office Small	0.01	0.001	42	0.56	0.05
4%	Restaurant	0.18	0.030	24	4.35	0.72
12%	Retail Large	0.01	0.002	77	1.02	0.17
12%	Retail Small	0.08	0.013	77	6.04	1.00
13%	School	0.10	0.010	57	5.90	0.56
22%	Warehouse Non-Refrigerated	0.02	0.002	98	2.12	0.15
100%						
					21.0	**2.8**

Figure 3: Statewide energy and demand savings by building type for the adopted lighting alteration code.

Source: Lighting Alteration Model v2.1.

4. EVOLUTION OF CODE REQUIREMENTS

The Statewide CASE Team submitted the final version of the CASE Report to the Energy Commission during August 2017. The Final CASE Report addresses input that was received during utility-sponsored stakeholder meetings held on September 8, 2016 and March 22, 2017 and during the Energy Commission's pre-rulemaking workshop that was held on June 22, 2017. This section describes how the code change proposal evolved between the time the Final CASE Report was submitted to the Energy Commission and the time the standards were adopted.

During the 2019 Title 24, Part 6 code cycle, two entities – the Statewide CASE Team and the California Energy Alliance (CEA) – each submitted a CASE Report on the lighting alteration topic. During the CASE Report development process, the Energy Commission provided straw-man code language to the Statewide CASE Team and the CEA to guide, and in some instances integrate, proposed changes to the lighting alteration code in Section 14.0(b)2I, J, and K. In this 2019 code cycle, the main intent of the Energy Commission was to significantly simplify the lighting alteration code language while achieving parity in terms of delivered energy savings among three compliance pathways.

Significant code changes in the Energy Commission's straw-man language included:

- Combining all types of lighting alterations distinguished in 2016 Title 24, Part 6 (entire luminaire, luminaire component modification, and lighting wiring) into a single category of lighting alterations (i.e., integrating Section 141.0(b)2I, J, and K into a single section);
- Introducing a universal threshold of ten percent of altered luminaires to trigger the lighting alteration code for all types of lighting alterations;
- Expanding the scope of Exception 6 to Section 141.0(b)2I to apply to all types of lighting alterations as opposed to applying only to component modification projects (in other words, exempting a larger number of projects from the lighting alteration code);
- Introducing a single table with the lighting control requirements for all types of lighting alterations, thus changing some of the provisions for lighting wiring alterations that differ from the provisions for entire luminaire alterations and luminaire component modifications; and
- Matching lighting control requirements between two compliance pathways – Option 2 and Option 3.

During the code development process, the Statewide CASE Team and the CEA used the lighting alteration model developed by the Statewide CASE Team to evaluate the parity of the three compliance options in terms of the delivered energy savings and to calculate overall energy savings from the code change proposals. The Statewide CASE Team and the CEA proposed two different approaches to achieve overall energy savings from the lighting alteration code.

In the model, the key parameters that affect the energy savings from each compliance pathway and the overall savings from the lighting alteration code are:

- Wattage reduction percentage for Option 3;
- LPA threshold for Option 2; and
- Market share of compliance pathways.

The Statewide CASE Team proposed a wattage reduction of 50 percent under Option 3, which resulted in Option 3 delivering as much, or greater, savings than the other two compliance pathways for seven out of eight considered building types. This scenario resulted in overall energy savings from the lighting

alteration code. Consequently, the need to lower the lighting power to 80 percent or less of the LPA under Option 2 and the need to limit the market share of Option 3 by introducing a building size limit were eliminated.

In comparison, CEA proposed a less strict wattage reduction of 40 percent under Option 3, which resulted in Option 3 delivering fewer energy savings than Option 2 for six out of eight considered building types. T this scenario resulted in overall energy losses from the lighting alteration code. To achieve overall energy savings, CEA included in their proposal the recommendation to lower the lighting power to 80 percent or less of LPA under Option 2 and to limit the market share of Option 3 by introducing a building size limit (CEA, 2017).

The Energy Commission decided to adopt the requirements following CEA's approach. Table 4 comparatively summarizes the code changes proposed by the Statewide CASE Team and CEA, and the final adoption status for each proposed code change.

Table 4: Adoption Statuses of Proposed Code Changes

Issue	Proposed Code Change in the Final CASE Report by the Statewide CASE Team	Proposed Code Change in the Final CASE Report by the California Energy Alliance	Adoption Status in 2019 Title 24, Part 6
Categorization of retrofit projects into entire luminaire, component modification, and lighting wiring project types	No changes were proposed.	Proposed to combine "entire luminaire" and "component modification" categories.	Adopted the code language that does not differentiate lighting alteration projects into entire luminaire, component modification, or lighting wiring project types.
Triggers of Title 24, Part 6 nonresidential lighting alteration code	Proposed to clarify that lighting alteration projects that increase lighting power are subject to the lighting alteration code.	Proposed an overarching code trigger of 10% of luminaires being affected per enclosed space.	Adopted an overarching code trigger of 10% of luminaires being affected per enclosed space.
Exempting projects that modify certain number of luminaires per year per building space or tenant space	No changes were proposed.	Proposed to decrease the existing threshold from 70 to 50 luminaires that are being modified per year per building or tenant space.	Adopted the revised exception threshold of 50 luminaires.
Exempting enclosed spaces where two or fewer luminaires are being altered	Proposed to decrease the exemption from 2 luminaires in an enclosed space to 1 luminaire in an enclosed space for all types of lighting alteration projects.	Proposed to decrease the exemption from 2 luminaires in an enclosed space to 1 luminaire in an enclosed space for entire luminaire and component modification projects.	Adopted the revised exemption by decreasing the exemption from 2 luminaires to 1 luminaire in an enclosed space for all types of lighting alteration projects.

The LPA threshold for Option 1 ("85-100% of LPA") and Option 2 ("≤85% of LPA")	No changes were proposed.	Proposed to change the threshold from 85% to 80% of LPA for Option 1 and 2.	Adopted the revised threshold of 80% of LPA for Option 1 and 2.
The Scope of Option 3 ("reduction of existing wattage")	No changes were proposed.	Proposed to make Option 3 available only for one-for-one luminaire alterations in buildings or tenant spaces of 5,000 ft² or less.	Adopted the code language limiting Option 3 to one-for-one luminaire alterations in buildings or tenant spaces of 5,000 ft² or less.
Requirements for Option 3	Proposed a universal power reduction requirement of 50%. Proposed to require a reduction of total existing lighting wattage in altered enclosed spaces (versus space type by space type as intended in 2016 Standards). Proposed to require partial OFF occupant sensing controls for stairwells.	Proposed a universal power reduction requirement of 40%.	Adopted a universal power reduction requirement of 40% of *total* existing lighting wattage. Adopted the language to match requirements for lighting controls between Option 2 and 3, including no longer requiring multi-level lighting controls under Option 2 and requiring occupant sensing controls for library stacks, stairwells, and corridors under Option 3.

5. ADOPTED CODE LANGUAGE

The adopted code language for the Standards and Reference Appendices are presented in the following sections. Additions to the 2016 Title 24, Part 6 code language are underlined and deletions are ~~struck~~.

5.1 Building Energy Efficiency Standards

5.1.1 Section 100.1 – Definitions and Rules of Construction

No changes were incorporated from the Final CASE Report on nonresidential lighting alterations.

5.1.2 Section 130.1 – Mandatory Indoor Lighting Controls

No changes were incorporated from the Final CASE Report on nonresidential lighting alterations.

5.1.3 Section 140.1 – Additions, Alterations, and Repairs to Existing Nonresidential, High-Rise Residential, and Hotel/Motel Buildings to Existing Outdoor Lighting, and to Internally and Externally Illuminated Signs

Section 141.0(b)2I

I. **Altered Indoor Lighting Systems.** Alterations to indoor lighting systems that include 10% or more of the luminaires serving an enclosed space shall meet the requirements of i, ii, or iii below:

i. The alteration shall comply with the indoor lighting power requirements specified in Section 140.6 and the lighting control requirements specified in Table 141.0-F;

ii. The alteration shall not exceed 80% of the indoor lighting power requirements specified in Section 140.6, and shall comply with the lighting control requirements specified in Table 141.0-F; or

iii. The alteration shall be a one-for-one luminaire alteration within a building or tenant space of 5,000 square feet or less, the total wattage of the altered luminaires shall be at least 40% lower compared to their total pre-alteration wattage, and the alteration shall comply with the lighting control requirements specified in Table 141.0-F.

Alterations to indoor lighting systems shall not prevent the operation of existing, unaltered controls, and shall not alter controls to remove functions specified in Section 130.1.

Alterations to lighting wiring are considered alterations to the lighting system. Alterations to indoor lighting systems are not required to separate existing general, floor, wall, display, or ornamental lighting on shared circuits or controls. New or completely replaced lighting circuits shall comply with the control separation requirements of Section 130.1(a)4 and 130.1(c)1D.

EXCEPTION 1 to Section 141.0(b)2I. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded as specified in Section 140.6(a)3.

EXCEPTION 2 to Section 141.0(b)2I. Any enclosed space with only one luminaire.

EXCEPTION 3 to Section 141.0(b)2I. Any alteration that would directly cause the disturbance of asbestos, unless the alteration is made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2I. Acceptance testing requirements of Section 130.4 are not required for alterations where lighting controls are added to control 20 or fewer luminaires.

EXCEPTION 5 to Section 141.0(b)2I. Any alteration limited to adding lighting controls or replacing lamps, ballasts, or drivers.

EXCEPTION 6 to Section 141.0(b)2I. One-for-one luminaire alteration of up to 50 luminaires either per complete floor of the building or per complete tenant space, per annum.

Entire Luminaire Alterations. Entire luminaire alterations shall meet the following requirements:

i. ~~For each enclosed space, alterations that consist of either (a) removing and reinstalling a total of 10 percent or more of the existing luminaires; or (b) replacing or adding entire luminaires; or (c) adding, removing, or replacing walls or ceilings along with any redesign of the lighting system, shall meet the lighting power allowance in Section 140.6, and the altered luminaires shall meet the applicable requirements in Table 141.0-E; or~~

ii. ~~For alterations where existing luminaires are replaced with new luminaires, and that do not include adding, removing, or replacing walls or ceilings along with redesign of the lighting system, the replacement luminaires in each office, retail, and hotel occupancy shall have at least 50 percent, and in all other occupancies at least 35 percent, lower rated power at full light output compared to the existing luminaires being replaced, and shall meet the requirements of Sections 130.1(a)1, 2, and 3, 130.1(c)1A through C, 130.1(c)2, 130.1(c)3, 130.1(c)4, 130.1(c)5, 130.1(c)6A, and for parking garages 130.1(c)7B.~~

~~EXCEPTION 1 to Section 141.0(b)2I. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded as specified in Section 140.6(a)3.~~

~~EXCEPTION 2 to Section 141.0(b)2I. In an enclosed space where two or fewer luminaires are replaced or reinstalled.~~

EXCEPTION 3 to Section 141.0(b)2I. Alterations that would directly cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2I. Acceptance testing requirements of Section 130.4 are not required for alterations where lighting controls are added to control 20 or fewer luminaires.

Section 141.0(b)J

J. **Reserved.****Luminaire Component Modifications.** Luminaire component modifications in place that include replacing the ballasts or drivers and the associated lamps in the luminaire, permanently changing the light source of the luminaire, or changing the optical system of the luminaire, where 70 or more existing luminaires are modified either on any single floor of a building or, where multiple tenants inhabit the same floor, in any single tenant space, in any single year, shall not prevent or disable the operation of any multi-level, shut-off, or daylighting controls, and shall:

i. Meet the lighting power allowance in Section 140.6 and comply with Table 141.0-E; or

ii. In office, retail, and hotel occupancies have at least 50 percent, and in all other occupancies have at least 35 percent, lower rated power at full light output as compared to the original luminaires prior to being modified, and meet the requirements of Sections 130.1(a)1, 2, and 3, 130.1(c)1A through C, 130.1(c)2, 130.1(c)3, 130.1(c)4, 130.1(c)5, 130.1(c)6A, and for parking garages 130.1(c)7B.

Lamp replacements alone and ballast replacements alone shall not be considered a modification of the luminaire provided that the replacement lamps or ballasts are installed and powered without modifying the luminaire.

EXCEPTION 1 to Section 141.0(b)2J. Modification of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by Section 140.6(a)3.

EXCEPTION 2 to Section 141.0(b)2J. In an enclosed space where two or fewer luminaires are modified.

EXCEPTION 3 to Section 141.0(b)2J. Modifications that would directly cause the disturbance of asbestos, unless the modifications are made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2J. Acceptance testing requirements of Section 130.4 are not required for modifications where lighting controls are added to control 20 or fewer luminaires.

Section 141.0(b)K

K. **Reserved..****Lighting Wiring Alterations.** For each enclosed space, wiring alterations that add a circuit feeding luminaires; that replace, modify, or relocate wiring between a switch or panelboard and luminaires; or that replace lighting control panels, panelboards, or branch circuit wiring; shall:

i. meet the lighting power allowance in Section 140.6;

ii. meet the requirements in Sections 130.1(a)1, 2, and 3, 130.1(c)1A through C, 130.1(c)3, and 130.1(c)4;

iii. for each enclosed space, be wired to create a minimum of one step between 30-70 percent of lighting power or meet Section 130.1(b); and

iv. for each enclosed space where wiring alterations include 10 or more luminaires that provide general lighting within the primary sidelit daylit zone or the skylit daylit zone, meet the requirements of 130.1(d).

NOTE: As specified in Section 141.0(b)2I, alterations that include adding, removing, or replacing walls or ceilings resulting in redesign of the lighting system shall meet the requirements of Table 141.0-E.

EXCEPTION 1 to Section 141.0(b)2K. Alterations strictly limited to addition of lighting controls.

EXCEPTION 2 to Section 141.0(b)2K. In an enclosed space where wiring alterations involve two or fewer luminaires.

EXCEPTION 3 to Section 141.0(b)2K. Alterations that would directly cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2K. Acceptance testing requirements of Section 130.4 are not required for wiring alterations where lighting controls are added to control 20 or fewer luminaires.

TABLE 141.0-E Control Requirements for Entire Luminaire Alterations

Control requirements that shall be met	**Resulting lighting power, compared to the lighting power allowance specified in Section 140.6(c)2, Area Category Method**	
	Lighting power is ≤ 85% of	**Lighting power is > 85% to 100% of**
Section 130.1(a)1, 2, and 3 Area Controls	Yes	Yes
Section 130.1(b) Multi-Level Lighting Controls – only for alterations to general lighting of enclosed spaces 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per square foot	For each enclosed space, minimum one step between 30-70 percent of lighting power regardless of luminaire type, or meet Section 130.1(b)	Yes
Section 130.1(c) Shut-Off Controls	Yes	Yes
Section 130.1(d) Automatic Daylight Controls	Not Required	Yes
Section 130.1(e) Demand Responsive Controls – only for alterations > 10,000 ft^2 in a single building, where the alteration also changes the area of the space, or changes the occupancy type of the space, or increases the lighting power	Not Required	Yes

Table 141.0-~~E~~F – Control Requirements for Indoor Lighting System Alterations

Control Specifications		**Projects complying with Section 141.0(b)2Ii**	**Projects complying with Sections 141.0(b)2Iii and 141.0(b)2Iiii**
Manual Area Controls	130.1(a)1	Required	Required
	130.1(a)2	Required	Required
	130.1(a)3	Only required for new or completely replaced circuits	Only required for new or completely replaced circuits
Multi-Level Controls	130.1(b)	Required	Not Required
Automatic Shut Off Controls	130.1(c)1	Required; 130.1(c)1D only required for new or completely replaced circuits	Required; 130.1(c)1D only required for new or completely replaced circuits
	130.1(c)2	Required	Required
	130.1(c)3	Required	Required
	130.1(c)4	Required	Required
	130.1(c)5	Required	Required
	130.1(c)6	Required	Required
	130.1(c)7	Required	Required
	130.1(c)8	Required	Required
Daylighting Controls	130.1(d)	Required	Not Required
Demand Responsive Controls	130.1(e)	Required	Not Required

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ATTACHMENT 1: FINAL CASE REPORT

The final version of the CASE Report is provided in full in Attachment 1 to this report.

Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Nonresidential Indoor Lighting Alterations – Final Report

Measure Number**:** 2019-NR-LIGHT6-F

Nonresidential Indoor Lighting

August 2017

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Authors:	Stefaniya Becking (Energy Solutions) and Mudit Saxena (Vistar Energy Consulting)
Project Management:	California Utilities Statewide Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, SoCalGas®, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District

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EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison, and SoCalGas®– and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

Measure Description

This CASE Report recommends revisions to the existing requirements for nonresidential lighting alterations. The proposed code changes and the rationale for the changes are summarized below.

Clarify that lighting alteration projects that increase lighting power are subject to the lighting alteration code.

Lighting retrofit projects that increase lighting power result in higher energy use in buildings. These projects should demonstrate that retrofitted areas can meet LPA and should be subject to the lighting alteration code. Also, requiring projects that increase lighting power to comply with the lighting alteration code aligns Title 24, Part 6 with ASHRAE 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings.

Reduce the number of luminaires from two to one per enclosed space in the existing exception to the lighting alteration code.

The current exception for enclosed spaces with one or two luminaires exempts private offices that often have two luminaires installed. Private offices should be subject to the lighting alteration code.

Require partial OFF occupant sensing controls for stairwells under Option 3 while continuing to exempt corridors from partial OFF occupant sensing controls under Option 3.

The installation of occupant sensing controls in stairwells during a retrofit project is generally feasible, unlike the installation of occupant sensing controls in corridors.

The luminaires in stairwells are often larger and can have occupancy sensors built into the luminaires. In addition, the wiring in stairwells is often exposed (providing easy access). However, the luminaires in corridors are often smaller and lack the space for occupancy sensors. The wiring in corridors is often concealed in hard ceilings or walls (leading to higher lighting retrofit cost).

Therefore, the lighting alteration code should not exempt stairwells from occupant sensing controls under Option 3, but should continue to exempt corridors.

Require a reduction of *total* existing lighting wattage of altered luminaires by 50 percent of the rated wattage under Option 3 rather than 50 percent for office, retail, and hotel and 35 percent for all other occupancies.

The parity in terms of delivered energy savings needs to be maintained among three compliance options. Lower 2019 LPD levels affect the parity of three compliance options, particularly for restaurants, schools, and small retail, as demonstrated by the results of the Lighting Alteration Model v2.0. In terms of delivered energy savings, Option 3 outperforms Option 1 and 2 for schools and small retail, when the reduction of existing wattage under Option 3 is set to 50 percent. The measure also improves the parity of Option 3 to Option 1 and 2 for restaurants.

Further, having two wattage reduction percentages under Option 3 led to inconsistent application of code requirements in the field. Reporting compliance under Option 3 on the space type by space type basis as intended in 2016 Standards is also burdensome. The code should specify a single wattage reduction percentage for Option 3 and should require reduction of *total* existing wattage of altered luminaires.

The Statewide CASE Team recognizes that if the measure to require 50 percent wattage reduction under Option 3 is adopted, compliance using Option 3 will not be feasible for some lighting retrofit projects (see Table 2 for a description of the three compliance pathways, or options). However, for those lighting retrofit projects, the other two compliance pathways will still be available.

In addition to proposing specific code changes, the Statewide CASE Team developed a spreadsheet-based model as a tool for the Energy Commission to perform a transparent analysis of the energy impacts from potential changes to the nonresidential lighting alteration requirements. This tool can be used to evaluate changes that may be proposed by various stakeholders throughout the 2019 code cycle. In this report, the model or tool is referred to as the lighting alteration analysis, lighting alteration model, or Lighting Alteration Model v2.0. This report provides technical documentation for the lighting alteration model.

The lighting alteration model assesses the relative energy savings resulting from each of the three prescriptive pathways to comply with Title 24, Part 6 nonresidential lighting alteration requirements. Specifically, the model quantifies the effects of lower 2019 lighting power density (LPD) levels, and consequently lower lighting power allowance (LPA), on energy savings from nonresidential lighting alterations. The model considers both entire luminaire and component modification retrofit types. The effects of the measures proposed in the 2019 CASE Report on indoor lighting controls (i.e., full OFF occupancy controls in restrooms and dimming to OFF for automatic daylighting controls) are also included in the model.

The lighting alteration model was adopted to calculate the expected per-unit and statewide energy savings resulting from the proposed measures. The lighting alteration model could be used in future Title 24, Part 6 code cycles to assess relevant code change proposals.

In sum, the lighting alteration model serves two main purposes:

- Compares three compliance options in terms of potential energy savings using the existing building stock as a baseline.
- Calculates incremental energy savings using proposed 2019 Standards with unchanged Option 3 as a baseline.

Table 1 provides an overview of entire luminaire and component modification alteration projects that require compliance with the 2016 Title 24, Part 6 Standards. Table 2 provides an overview of requirements for each compliance pathway per 2016 Title 24, Part 6 Standards. The terms – Option 1, Option 2, and Option 3 – do not appear in 2016 Title 24, Part 6 code language, but are used in this report as shorthand. The proposed options are ways to comply with the standards prescriptively and should not be confused with compliance options that can be modeled using the compliance software to demonstrate compliance with the standards using the performance approach.

Table 1: Overview of Alteration Projects that Require Compliance with the 2016 Title 24, Part 6 Standards and Criteria for Selecting Compliance Pathway (Option 1, 2, or 3)

Entire Luminaire Alterations (Section 141.0(b)2I)	Luminaire Component Modifications (Section 141.0(b)2J)
For each enclosed space: Use Option 1, 2, or 3 to comply IF: A. Replacing three or more luminaires as entire luminaires (also referred to as one-for-one luminaire replacement) without adding, removing, or replacing walls or ceilings. Use Option 1 or 2 to comply IF: B. Adding entire luminaire(s); OR C. Replacing three or more luminaires as entire luminaires while adding, removing, or replacing walls or ceilings; OR D. Removing ≥ 10% of existing luminaires and reinstalling the same luminaires while adding, removing, or replacing walls or ceilings.	Use Option 1, 2, or 3 to comply IF: Replacing ballasts or drivers and the associated lamps, permanently changing the light source, or the optical system; AND Modifying ≥ 70 existing luminaires per floor per tenant per year.

Table 2: Summary of Requirements for Available Compliance Pathways

Entire Luminaire Alterations and Luminaire Component Modifications	Option 1 "85-100% of LPA"	Option 2[a] "≤ 85% of LPA"	Option 3[b] "Reduction of Existing Wattage by 35/50%"
Resulting lighting power (watts), compared to the LPA specified in Section 140.6(c)2, Area Category Method	> 85 to 100% of LPA	≤ 85% of LPA	Not Applicable
Lighting wattage after luminaire alteration or modification as compared to existing lighting wattage	Not Applicable	Not Applicable	Existing wattage reduced by at least 50% from rated wattage for office, retail, and hotel occupancy and by at least 35% for all other occupancies
Section 130.1(a)1, 2, and 3 Area Controls	Yes	Yes	Yes
Section 130.1(b) Multi-Level Lighting Controls[c]	Yes	Yes, OR Bi-level	No
Section 130.1(c) Shut-OFF Controls[d]	Yes	Yes	Yes (applies partially)[e]
Section 130.1(d) Automatic Daylighting Controls[f]	Yes	Not Required	Not Required
Section 130.1(e) Demand Responsive Controls[g]	Yes	Not Required	Not Required

a. Introduced in 2013 Title 24, Part 6 code cycle; effective as of July 1, 2014.

b. Introduced in 2016 Title 24, Part 6 code cycle; effective as of April 13, 2016.

c. Applies to each enclosed space that is ≥ 100 square feet (ft^2), and has a lighting load of > 0.5 watts (W) per ft^2.

d. Note that automatic shut-OFF controls for all three compliance options can be met with occupant sensing controls or automatic time-switch controls (Section 130.1(c)1A except for areas specified in Section 130.1(c)5).

e. Exceptions include: Section 130.1(c)1D, separate shut-OFF controls for display/ornamental; Section 130.1(c)6B, full or partial OFF occupancy sensing in library stacks; Section 130.1(c)6C, full or partial OFF occupancy sensing in corridors and stairwells; Section 130.1(c)7A, partial OFF occupancy sensing in corridors and stairwells in high-rise residential buildings, hotels, and motels; and Section 130.1(c)8, guest room card key/occupancy sensing.

f. Applies for rooms, in which the combined total installed general lighting power in the Skylit Daylit Zone and Primary Sidelit Daylit Zone is ≥ 120 W, and the total glazing area is ≥ 24 ft^2.

g. Applies when altering > 10,000 ft^2/single building (excluding spaces with a lighting power density of 0.5 W/ft^2 or less) and only when the alteration also changes the area of the space, changes the occupancy type of the space, or increases the lighting power. Note that energy savings due to demand responsive (DR) controls are ignored in the lighting alteration model. Please refer to Section 4.1.3 for more details. The requirements for DR controls are listed in this table to provide a complete list of Title 24, Part 6 requirements around lighting controls.

Note that the following shorthand is used when referring to the prescriptive compliance pathways throughout the report:

- "85-100% of LPA" for Option 1 (indicating greater than 85% to 100% of LPA),
- "≤ 85% of LPA" for Option 2, and
- "Reduction of Existing Wattage" for Option 3.

Scope of Code Change Proposal

Table 3 summarizes the scope of the proposed changes and which sections of the Standards, Reference Appendices, and compliance documents will be modified as a result of the proposed change.

Table 3: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Sections of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document(s)
Nonresidential Indoor Lighting Alterations	Prescriptive	100.1, 130.1(c)6 and 7, 141.0(b)2I, 141.0(b)2J, 141.0(b)2K	N/A	No	NRCC-LTI-06-E

Market Analysis and Regulatory Impact Assessment

A number of issues were debated as part of the 2016 Title 24, Part 6 code update for nonresidential lighting alterations. The issues that were raised are still relevant in the 2019 Title 24, Part 6 code cycle. The following list summarizes the main points of contention documented as part of the docket log for the 2016 Title 24, Part 6 code cycle (California Energy Commission 2015a):

- Cost of lighting controls,
- Cost and time for obtaining a permit,
- Cost of labor (more specifically, cost of unionized labor versus nonunionized labor), and
- Payback period for lighting retrofit projects.

Cost-Effectiveness

This report explores opportunities for potential changes to Option 3, an alternate to the primary prescriptive compliance method, for compliance with nonresidential lighting alteration requirements. Alternate prescriptive options for compliance do not need to be cost effective, and, therefore, a cost-effectiveness analysis is not required. The 2019 Title 24, Part 6 CASE Reports for nonresidential indoor lighting power densities and nonresidential indoor lighting controls explore the cost-effectiveness of the changes that affect the primary compliance pathway (i.e., Option 1).

Statewide Energy Impacts

Table 4 shows the estimated energy savings over the first twelve months that the proposed code changes are in effect. See Section 6 for more details. The statewide energy savings from the proposed measures that are presented in Table 4 are in addition to savings presented in the 2019 CASE Reports on indoor lighting power densities and on indoor lighting controls. The energy savings presented in this report are primarily from the measure requiring a reduction of existing wattage by 50 percent.

Table 4: Estimated Statewide First-Year Energy and Water Savings[a]

Construction Type	First-Year Electricity Savings [a] (GWh/yr)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Water Savings (million gallons/yr)	First-Year Natural Gas Savings (million therms/yr)
New Construction	N/A	N/A	N/A	N/A
Alterations	30.2	3.8	N/A	N/A

a. Calculated energy savings are potential energy savings that do not account for compliance rate.

Figure 1 and Figure 2 provide a high-level summary of per-unit energy use for the base case and the standards case for the measure requiring a reduction of existing wattage by 50 percent. Figure 3 summarizes per-unit and statewide energy savings for the same measure. The results are based on expected building stock conditions in 2020. In accordance with the intent of Option 3 requirements in the 2016 Title 24, Part 6 Standards, the wattage reduction of 50 percent was applied in hotel function, office, and retail area categories in applicable building types – versus in all area categories within hotel, office, and retail building types. The figures are screenshots of the relevant portions of the lighting alteration model.

BASE CASE

Proposed 2019 LPDs, proposed 2019 controls when applicable (daylight dimming plus OFF, occupant sensing in restrooms), unchanged Option 3 (35/50% wattage reduction)

Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 "85-100% of 2019 LPA" PER-UNIT ENERGY USE kWh/ft² per year	OPTION 2 "≤85% of 2019 LPA" PER-UNIT ENERGY USE kWh/ft² per year	OPTION 3 "Reduction of Existing Wattage" PER-UNIT ENERGY USE (Weighted by Code Vintage) kWh/ft² per year	OPTION 3 "Reduction of Existing Wattage" PER-UNIT DEMAND (Weighted by Code Vintage) W/ft² per year	ENERGY USE Weighted by Market Share of Compliance Options kWh/ft² per year	DEMAND Weighted by Market Share of Option 3 W/ft² per year
1%	Hotel (excl. rooms)	3.0	2.8	2.5	0.28	2.9	0.065
28%	Office Large	1.5	1.4	1.3	0.15	1.4	0.034
8%	Office Small	1.5	1.4	1.3	0.13	1.4	0.029
4%	Restaurant	2.7	2.5	3.4	0.56	2.8	0.13
12%	Retail Large	3.0	2.6	2.4	0.42	2.8	0.096
12%	Retail Small	2.4	2.1	2.2	0.37	2.3	0.085
13%	School	1.8	1.6	2.1	0.20	1.8	0.046
22%	Warehouse Non-Refrigerated	0.99	0.98	0.96	0.068	1.0	0.016
100%	Weights by Market Share of Compliance Options	48%	29%	23%	23%	100%	

Figure 1: Base case per-unit energy use for Option 1, Option 2, and Option 3 using proposed 2019 Standards with unchanged Option 3.

Source: Lighting Alteration Model v2.0.

STANDARDS CASE

50% wattage reduction for all building spaces under Option 3 (this is the only input changed in the model for Standards Case)

Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 "85-100% of 2019 LPA" PER-UNIT ENERGY USE kWh/ft² per year	OPTION 2 "≤85% of 2019 LPA" PER-UNIT ENERGY USE kWh/ft² per year	OPTION 3 "Reduction of Existing Wattage" PER-UNIT ENERGY USE (Weighted by Code Vintage) kWh/ft² per year	OPTION 3 "Reduction of Existing Wattage" PER-UNIT DEMAND (Weighted by Code Vintage) W/ft² per year	ENERGY USE Weighted by Market Share of Compliance Options kWh/ft² per year	DEMAND Weighted by Market Share of Option 3 W/ft² per year
1%	Hotel (excl. rooms)	3.0	2.8	2.1	0.24	2.8	0.055
28%	Office Large	1.5	1.4	1.2	0.14	1.4	0.031
8%	Office Small	1.5	1.4	1.2	0.11	1.4	0.026
4%	Restaurant	2.7	2.5	2.6	0.43	2.6	0.099
12%	Retail Large	3.0	2.6	2.3	0.40	2.7	0.092
12%	Retail Small	2.4	2.1	1.8	0.30	2.2	0.069
13%	School	1.8	1.6	1.6	0.16	1.7	0.036
22%	Warehouse Non-Refrigerated	0.99	0.98	0.76	0.054	0.93	0.012
	Weights by Market Share of Compliance Options	48%	29%	23%	23%	100%	

Figure 2: Standards case per-unit energy use for Option 1, Option 2, and Option 3, with wattage reduction of 50 percent for all space types under proposed Option 3.

Source: Lighting Alteration Model v2.0.

INCREMENTAL ENERGY SAVINGS

2019 CASE Report on Nonresidential Lighting Alterations

Weights by Building Type Stock % of Considered Stock	Building Type	PER-UNIT ENERGY SAVINGS kWh/ft² per year	PER-UNIT DEMAND SAVINGS W/ft² per year	Annual Floor Stock Subject to Alteration Code million ft²	STATEWIDE ENERGY SAVINGS GWh per year	STATEWIDE DEMAND SAVINGS MW per year
1%	Hotel (excl. rooms)	0.088	0.010	7.4	0.65	0.072
28%	Office Large	0.024	0.0028	159	3.8	0.44
8%	Office Small	0.031	0.0029	42	1.3	0.12
4%	Restaurant	0.17	0.029	24	4.1	0.69
12%	Retail Large	0.029	0.0048	77	2.2	0.37
12%	Retail Small	0.097	0.016	77	7.4	1.2
13%	School	0.10	0.010	57	5.9	0.56
22%	Warehouse Non-Refrigerated	0.046	0.0033	98	4.6	0.32
100%					**29.9**	**3.8**

Figure 3: Statewide energy savings by building type for the proposed measure that requires the reduction of wattage by 50 percent under Option 3.

Source: Lighting Alteration Model v2.0.

Compliance and Enforcement

According to some interviewed stakeholders, changes to the lighting alteration code introduced in the 2013 code cycle resulted in a situation where a majority of lighting retrofit projects are being completed without a permit. With the simplified code language and simplified Option 3 requirements recommended in this report, the Statewide CASE Team anticipates more building owners and decision-makers will opt for implementing lighting retrofit projects and for obtaining a permit for the projects, when applicable. The following phases of compliance will benefit from simplified code requirements:

- Design phase, since it will be easier for designers to create a compliant design,
- Permit application phase, since it will be easier for plan checkers to verify a compliant design, and
- Inspection phase, since it will be easier for inspectors to verify compliance.

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric, Southern California Edison, and SoCalGas® – and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy efficient design practices and technologies.

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The overall goal of this CASE Report is to provide technical documentation for the lighting alteration model and to propose code changes for nonresidential lighting alterations. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders, including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. Furthermore, the proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on September 8, 2016, and March 22, 2017.

Section 2 of this CASE Report provides a measure description and background. This section also presents a detailed description of how this change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.

Section 3 presents the market analysis, including a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards such as fire, seismic, and other safety standards and whether technical, compliance, or enforceability challenges exist.

Section 4 presents the per-unit energy and demand savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy and demand savings.

Section 5 explains why the lifecycle cost and cost-effectiveness analysis was not applicable for this report.

Section 6 presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2019 Standards take effect. This includes the amount of energy that will be saved by California building owners and tenants, and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic. Statewide water consumption impacts are also considered.

Section 7 concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.

2. MEASURE DESCRIPTION

2.1 Measure Overview

This CASE Report recommends revisions to the existing requirements for nonresidential lighting alterations. The proposed code changes and the rationale for the changes are summarized below.

Clarify that lighting alteration projects that increase lighting power are subject to the lighting alteration code.

Lighting retrofit projects that increase lighting power result in higher energy use in buildings. These projects should demonstrate that retrofitted areas can meet LPA and should be subject to the lighting alteration code. Also, requiring projects that increase lighting power to comply with the lighting alteration code aligns Title 24, Part 6 with ASHRAE 90.1-2016: Energy Standard for Buildings Except Low-Rise Residential Buildings.

Reduce the number of luminaires from two to one per enclosed space in the existing exception to the lighting alteration code.

The current exception for enclosed spaces with one or two luminaires exempts private offices that often have two luminaires installed. Private offices should be subject to the lighting alteration code.

Require partial OFF occupant sensing controls for stairwells under Option 3 while continuing to exempt corridors from partial OFF occupant sensing controls under Option 3.

The installation of occupant sensing controls in stairwells during a retrofit project is generally feasible, unlike the installation of occupant sensing controls in corridors.

The luminaires in stairwells are often larger and can have occupancy sensors built into the luminaires. In addition, the wiring in stairwells is often exposed (providing easy access). However, the luminaires in corridors are often smaller and lack the space for occupancy sensors. The wiring in corridors is often concealed in hard ceilings or walls (leading to higher lighting retrofit cost).

Therefore, the lighting alteration code should not exempt stairwells from occupant sensing controls under Option 3, but should continue to exempt corridors.

Require a reduction of *total* existing lighting wattage of altered luminaires by 50 percent of the rated wattage under Option 3 rather than 50 percent for office, retail, and hotel and 35 percent for all other occupancies.

The parity in terms of delivered energy savings needs to be maintained among three compliance options. Lower 2019 LPD levels affect the parity of three compliance options, particularly for restaurants, schools, and small retail, as demonstrated by the results of the Lighting Alteration Model v2.0. In terms of delivered energy savings, Option 3 outperforms Option 1 and 2 for schools and small retail, when the reduction of existing wattage under Option 3 is set to 50 percent. The measure also improves the parity of Option 3 to Option 1 and 2 for restaurants.

Further, having two wattage reduction percentages under Option 3 led to inconsistent application of code requirements in the field. Reporting compliance under Option 3 on the space type by space type basis as intended in 2016 Standards is also burdensome. The code should specify a single wattage

reduction percentage for Option 3 and should require reduction of *total* existing wattage of altered luminaires.

The Statewide CASE Team recognizes that if the measure to require 50 percent wattage reduction under Option 3 is adopted, compliance using Option 3 will not be feasible for some lighting retrofit projects (see Table 2 for a description of the three compliance pathways, or options). However, for those lighting retrofit projects, the other two compliance pathways will still be available.

In addition to proposing specific code changes, the Statewide CASE Team developed a spreadsheet-based model as a tool for the Energy Commission to perform a transparent analysis of the energy impacts from potential changes to the nonresidential lighting alteration requirements. This tool can be used to evaluate changes that may be proposed by various stakeholders throughout the 2019 code cycle. In this report, the model or tool is referred to as the lighting alteration analysis, lighting alteration model, or Lighting Alteration Model v2.0. This report provides technical documentation for the lighting alteration model.

2.2 Measure History

Prior to the 2013 Title 24, Part 6 code cycle, one prescriptive compliance pathway was available for nonresidential alteration projects (i.e., projects that modified an entire luminaire or luminaire components). The primary prescriptive compliance pathway required calculations of LPA based on applicable LPD and affected square footage values, but did not require the installation of lighting controls unless luminaires were added or moved. Also, prior to the 2013 Standards, significantly fewer retrofit projects triggered the alteration requirements. The threshold that triggered alteration requirements prior to the 2013 Standards was 50 percent or more of the luminaires in an enclosed space being changed as part of indoor alteration projects.

In the 2013 code cycle, a second compliance pathway – the "≤ 85% of LPA" option, or Option 2 – was introduced for projects that modified the entire luminaire or luminaire components. Both compliance pathways required calculations of LPA based on applicable LPD and affected square footage values. Both compliance pathways required some combination of lighting controls.

In addition, the 2013 Standards required dimmable lighting in accordance with Table 130.1-A (Multi-Level Lighting Controls and Uniformity Requirements). Many lighting retrofit companies objected to the added cost of dimming, the cost of other controls, and the cost of acceptance testing. Some of these requirements were scaled back in 2016 code cycle. See 2016 Title 24, Part 6, Sections 141.0(b)2Ii and 2Ji for more details on the current requirements for the two compliance options.

In the 2016 code cycle, a third compliance pathway – the "reduction of existing wattage by 35/50%" option, or Option 3 – was introduced, allowing lighting alteration projects (i.e., projects that modified an entire luminaire or luminaire components) to more simply demonstrate certain reductions in existing fixture wattages without needing to calculate LPA. No longer requiring these calculations was an important simplification of the compliance process since obtaining square footage of altered areas is burdensome for some retrofit projects. Additional concerns associated with obtaining square footage of the space is that some building departments might require a reflected ceiling plan to prove compliance. Given that many retrofit projects are conducted in spaces with no plans, this would increase the cost of demonstrating compliance.

The third compliance pathway also contained less stringent lighting control requirements compared to Option 1 and Option 2. Option 3 removed some of the controls requirements that were found to be most onerous in lighting retrofit projects (not including gut remodel projects). Specifically, Option 3 required only area lighting controls and, with some exceptions, automatic shut-OFF lighting controls. Option 3 did not require bi-level or multi-level lighting controls, automatic daylighting controls, or demand responsive controls.

As for exceptions for automatic shut-OFF lighting controls under Option 3, Option 3 excluded a few places where installing occupancy controls could be problematic, namely:[1]

- Section 130.1(c)1D – Where occupancy controls are required to control the following separately: general, display, ornamental, and display case lighting. If the lighting is not already circuited, this could incur a significant rewiring cost for what is, in many cases, relatively small energy savings.
- Section 130.1(c)6B – Regarding full or partial OFF occupant sensing controls in library stacks per stack aisle. In a retrofit situation, the lighting may be circuited perpendicularly to the stacks. Rewiring the stack lighting to comply with the provision would be expensive especially if wiring is within a hard ceiling.
- Section 130.1(c)6B and 7A – Regarding occupant sensing controls for corridor and stairwell lighting. Lighting in corridors often uses small downlights or sconces without feasible space for occupancy sensors, and wiring is often concealed in hard ceilings or in walls, which makes breaking into circuiting more difficult.

The third compliance pathway was the result of stakeholder outreach and negotiations. It provided a simpler and less expensive way to comply with Title 24, Part 6 lighting requirements for alteration projects, while delivering more energy savings than the other two compliance pathways. The third compliance pathway became available on April 13, 2016, while 2016 Title 24, Part 6 code language became effective as scheduled, on January 1, 2017. The availability of the third compliance pathway prior to January 1, 2017, highlights its importance to stakeholders.

2.3 Summary of Proposed Changes to Code Documents

The sections below summarize how each Title 24, Part 6 document will be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Standards Change Summary

This proposal modifies the following sections of the Building Energy Efficiency Standards as shown below. See Section 7.1 of this report for the detailed proposed revisions to the code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Subsection 100.1: Add definitions for "luminaire alteration" and "one-for-one alteration." The Energy Commission provided straw-man code language to use as a starting point for rewriting the entirety of Section 141.0(b)2I, J, and K. This language simplified the code language substantially, but did not include key definitions. Hence, the Statewide CASE Team proposes to add definitions for "luminaire alteration" and "one-for-one alteration."

SECTION 130.1 - MANDATORY INDOOR LIGHTING CONTROLS

Subsection 130.1(c)6 and 7: Separate a provision for corridors and stairwells in code language into two provisions, so requirements in the alteration code could simply reference a corresponding provision on occupant sensing controls for stairwells only. Reorder provisions in Section 130.1(c)6 and 130.1(c)7 to simplify referencing required versus non-required provisions in the lighting alteration code.

Other changes to Section 130.1(c)6 and 7 are discussed in the 2019 CASE Report on indoor lighting controls.

[1] See 2016 Title 24, Part 6, Section 141.0(b)2I and Section 141.0(b)2J for more details.

SECTION 141.0 - ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS, TO EXISTING OUTDOOR LIGHTING, AND TO INTERNALLY AND EXTERNALLY ILLUMINATED SIGNS

Subsection 141.0(b)2I, J, K: Add language to clarify that lighting alteration projects that increase lighting power are subject to the lighting alteration code.

Reduce the number of luminaires from two to one per enclosed space in the existing exception to the lighting alteration code.

Section 141.0(b)2I, J: Require partial OFF occupant sensing controls for stairwells under Option 3 by referencing a corresponding provision in Section 130.1.

Require a reduction of total existing lighting wattage of altered luminaires by 50 percent of the rated wattage under Option 3 (rather than 50 percent for office, retail, and hotel and 35 percent for all other occupancies).

2.3.2 Reference Appendices Change Summary

The proposed code change does not modify the appendices of the standards.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

The proposed code change does not modify the ACM Reference Manual.

2.3.4 Compliance Manual Change Summary

Chapter 5.9 of the Nonresidential Compliance Manual will need to be revised.

2.3.5 Compliance Documents Change Summary

The indoor lighting existing conditions certificate of compliance document (NRCC-LTI-06-E) will need to be revised.

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

Standards for nonresidential lighting alterations already exist and are described in Title 24, Part 6, Section 141.0.

The nonresidential lighting alteration requirements in Title 24, Part 6 are directly affected by changes in other parts of Title 24, Part 6 that define requirements for newly constructed buildings. In the context of this analysis, the proposed changes to Section 130.1 (Mandatory Indoor Lighting Controls) and Section 140.6 (Prescriptive Requirements for Indoor Lighting) impact the requirements of the lighting alteration requirements in Section 141.0.

2.4.2 Relationship to Other Title 24 Requirements

There are no requirements in other parts of Title 24, Part 6 that are relevant to the nonresidential lighting alteration requirements.

2.4.3 Relationship to State or Federal Laws

No federal requirements for nonresidential lighting alterations are in effect.

2.4.4 Relationship to Industry Standards

ASHRAE Standard 90.1-2016 Energy Standard for Buildings Except Low-Rise Residential Buildings covers lighting alteration projects. The threshold that triggers ASHRAE 90.1-2016 requirements for

alteration projects is 20 percent or more of the connected lighting load being changed as part of indoor or outdoor alteration projects. When 20 percent or more of the connected lighting load is being changed, the LPD requirements apply and all the lighting control requirements apply except for daylighting controls.

ASHRAE 90.1-2016 does not offer a compliance pathway analogous to the "reduction of existing wattage by 35/50%" option in the 2016 Title 24, Part 6 Standards. ASHRAE 90.1-2016 specifies one compliance pathway, which requires meeting LPD allowances as well as most lighting control requirements.

2.5 Compliance and Enforcement

The Statewide CASE Team interviewed lighting retrofit industry stakeholders to understand current compliance issues as well as potential compliance issues due to proposed measures.

The following organizations provided feedback on the proposed measures via phone interviews (companies are listed in alphabetical order):

- ACIES Engineering (lighting designer),
- Confidential company name (commissioning agent),
- Confidential company name (electrical contractor A),
- Confidential company name (electrical contractor B),
- Confidential company name (energy service company A),
- Confidential company name (energy service company B),
- Dynaelectric Company (electrical contractor),
- Ecology Action (energy service company),
- Gabel Energy (energy consulting company),
- Lime Energy (energy service company),
- San Francisco Department of Environment (local government),
- San Joaquin Valley Clean Energy Organization (energy service company), and
- Sprig Electric (electrical contractor).

The Statewide CASE Team selected target interviewees that represent different stakeholder types by evaluating the following data sources:

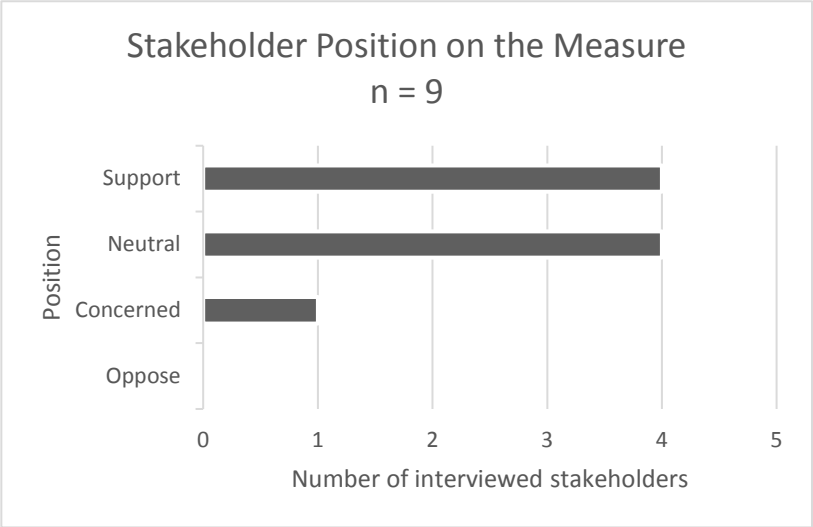
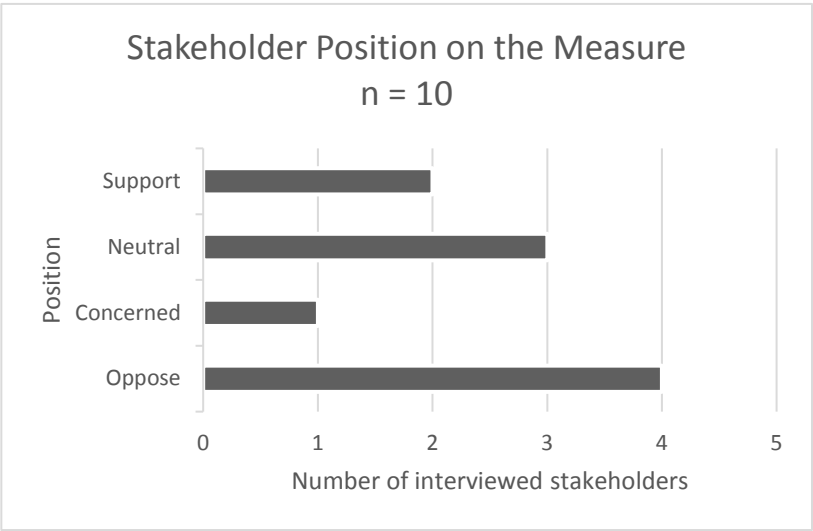
- The Energy Commission's docket log for 2016 Title 24, Part 6 Standards (California Energy Commission 2015a) and
- The list of respondents to 2017 Codes and Standards (C&S) Lighting Alteration Survey (see Appendix I for more details).

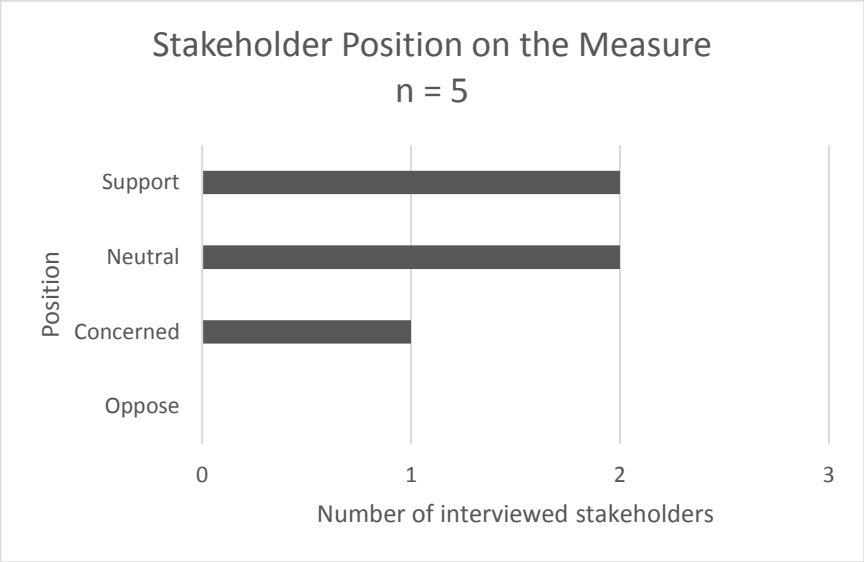
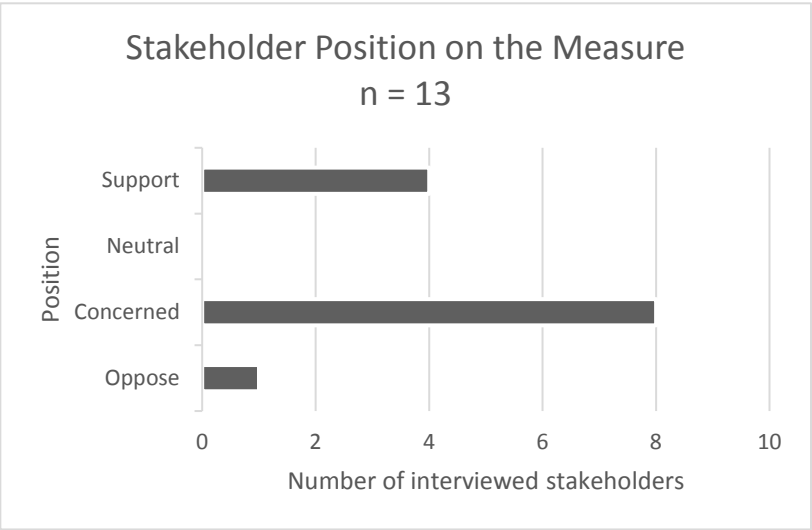
The Statewide CASE Team contacted a total of 25 stakeholders via email and phone, requesting an informational interview. Thirteen stakeholders agreed to participate in an informational interview; each lasted about an hour. The measures as proposed in the Draft CASE Report dated June 2017 were discussed during the phone interviews. For some measures, the interviewees did not provide feedback due to lack of time to discuss a measure or insufficient grounds to state a position on the measure.

In addition to discussing the proposed measures, the Statewide CASE Team asked some of the interviewees (four implementers of utility energy efficiency programs and one lighting designer) a question regarding introducing a building size limit for Option 3. All five interviewees opposed the idea of introducing a building size limit for Option 3.

The results of interviews are summarized in Table 5. The results of stakeholder outreach for other measures that were proposed in the Draft CASE Report dated June 2017 can be found in Appendix J.

Table 5: Results of Stakeholder Outreach by Proposed Measure

Measure Description	Summary of Stakeholder Outreach
Clarify that lighting alteration projects that increase lighting power are subject to the lighting alteration code.	 Raised Concern Future impact of the measure on lighting projects when majority of existing building stock converts to LED lighting is a potential issue.
Reduce the number of luminaires from two to one per enclosed space in the existing exception to the lighting alteration code.	 Raised Concerns • Stranding energy savings due to higher cost to comply with the code is of great concern (e.g., it will be more expensive to retrofit private offices with the stricter exemption). • The exemption (as is and as proposed) is unreasonable when applied to open plan office.

Require partial OFF occupant sensing controls for stairwells under Option 3 (while continuing to exempt corridors from partial OFF occupant sensing controls under Option 3).	 Raised Concern The measure may not be cost-effective for some component modification projects which retrofit fixtures that are not designed to be dimmable.
Require a reduction of *total* existing lighting wattage of altered luminaires by 50 percent of the rated wattage under Option 3 (rather than 50 percent for office, retail, and hotel and 35 percent for all other occupancies).	 Raised Concerns • Reducing wattage by 50 percent may not be feasible in high lighting applications (e.g., labs, churches). • Making Option 3 stricter will continue to strand energy savings (return on investment time frame will be longer due to incremental cost of compliance paperwork and lighting controls; Savings to Investment Ratio will be below 1 for Proposition 39 retrofit projects in schools). • Gaming the system when Option 3 is used by some market actors is of great concern. • With the proposed measures, businesses that have already installed efficient lighting may not be able to use Option 3.

According to some interviewed stakeholders (one energy consultant, one electrical contractor, and one energy efficiency program implementer), changes to the lighting alteration code introduced in the 2013 code cycle resulted in a situation where a majority of lighting retrofit projects are being completed without a permit. With the simplified code language and simplified Option 3 requirements recommended in this report, the Statewide CASE Team anticipates more building owners and decision-makers will opt for implementing lighting retrofit projects and for obtaining a permit for the projects, when applicable. The following phases of compliance will benefit from simplified code requirements:

- Design phase, since it will be easier for designers to create a compliant design,
- Permit application phase, since it will be easier for plan checkers to verify a compliant design, and
- Inspection phase, since it will be easier for inspectors to verify compliance.

A number of stakeholders raised a concern about using an honor system for Option 3 (since pre-retrofit wattage cannot be verified by a building official). For projects completed as part of a utility energy efficiency program, the pre-retrofit wattage is documented as part of the process. For other projects, the inability to verify pre-retrofit wattage could be a concern. As the first step to address the enforceability issue of Option 3, the Statewide CASE Team recommends that the Energy Commission put in place a mechanism to track code compliance – in particular, the use of compliance pathways in the field.

3. MARKET ANALYSIS

The Statewide CASE Team considered how the proposed standard may impact the market in general and individual market actors. The Statewide CASE Team gathered information and input through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in utility-sponsored stakeholder meetings held on September 8, 2016 and March 22, 2017.

3.1 Market Structure

Stakeholders most affected by the lighting retrofit code are listed in alphabetical order below:

- Building officials (plan reviewers, inspectors),
- Building owners,
- Commissioning providers/acceptance testers,
- Distributors of lighting products,
- Electrical contractors,
- Electrical engineers,
- Lighting designers,
- Lighting retrofit contractors,
- Manufacturers of lighting products, and
- Utility program implementers.

3.2 Technical Feasibility, Market Availability, and Current Practices

Refer to Table 5 for stakeholder concerns regarding technical feasibility. Not all lighting retrofit projects will be able to use Option 3 as proposed. For projects where Option 3 is not feasible, Option 1 or Option 2 can be used to demonstrate code compliance.

3.3 Market Impacts and Economic Assessments

A number of issues were debated as part of the 2016 Title 24, Part 6 code update for nonresidential lighting alterations. The issues that were raised are still relevant in the 2019 Title 24, Part 6 code cycle. The following list summarizes the main points of contention documented as part of the docket log for 2016 Title 24, Part 6 code cycle (California Energy Commission 2015a):

- Cost of lighting controls,
- Cost and time for obtaining a permit,
- Cost of labor (more specifically, cost of unionized labor versus non-unionized labor), and
- Payback period for lighting retrofit projects.

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all of the proposed changes to Title 24, Part 6. Market actors will need to invest in training and education to ensure the workforce, including designers and those working in construction trades, know how to comply with the proposed requirements. Workforce training is not unique to the building industry and is common in many fields associated with the production of goods and services. Costs associated with workforce training are typically accounted for in long-term financial planning and spread out across the unit price of many units as to avoid price spikes when changes in designs and/or processes are implemented.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building Code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials, and ASHRAE 90.1) are typically updated on a three-year revision cycle. As discussed in Section 3.3.1 all market actors, including building designers and energy consultants, should (and do) plan for training and education that may be required to adjusting design practices to accommodate compliance with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2019 code cycle aim to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility in how requirements can be met.

3.3.3 Impact on Occupational Safety and Health

The proposed code changes do not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants

Building owners and occupants will benefit from lower energy bills. As discussed in Section 3.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy.

3.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

If the market share of projects that comply using Option 3 grows, the demand for advanced lighting controls (i.e., multi-level controls, automatic daylighting controls, and demand responsive controls) may decrease. The decrease in the demand may not be significant because strict code currently discourages

building owners to complete lighting retrofits, or pushes building owners to complete lighting retrofits without a permit and installation of some or all of the advanced lighting controls.

3.3.6 Impact on Building Inspectors

The simplified code language will help building inspectors since code requirements will be more transparent.

3.3.7 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to Title 24, Part 6.

3.4 Economic Impacts

3.4.1 Creation or Elimination of Jobs

In 2015, California's building energy efficiency industry employed more than 321,000 workers who worked at least part time or a fraction of their time on activities related to building efficiency. Employment in the building energy efficiency industry grew six percent between 2014 and 2015 while the overall statewide employment grew three percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's report titled *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth* (2010) provides details on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes (Goldman, et al. 2010).

Building codes that reduce energy consumption provide jobs through *direct employment*, *indirect employment*, and *induced employment*.[2] Title 24, Part 6 creates jobs in all three categories with a significant amount attributed to induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non industry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. Wei, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years[3] per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. Using the mid-point for the energy efficiency range (0.38 net job-years per GWh saved) and estimates that this proposed code change will result in a statewide first-year savings of 30.2 GWh, this measure will result in approximately 11.5 jobs created in the first year. See Section 6.1 for statewide savings estimates.

The Statewide CASE Team anticipates an increase in lighting retrofit projects due to preserving a viable Option 3 and clarified code requirements.

3.4.2 Creation or Elimination of Businesses in California

There are approximately 43,000 businesses that play a role in California's advanced energy economy (BW Research Partnership 2016). California's clean economy grew ten times more than the total state

[2] The definitions of direct, indirect, and induced jobs vary widely by study. Wei et al (2010) describes the definitions and usage of these categories as follows: "*Direct employment* includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. *Indirect employment* refers to the ''supplier effect'' of upstream and downstream suppliers. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. *Induced employment* accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees, e.g., non industry jobs created such as teachers, grocery store clerks, and postal workers."

[3] One job-year (or ''full-time equivalent'' FTE job) is full time employment for one person for a duration of 1 year.

economy between 2002 and 2012 (20 percent compared to 2 percent). The energy efficiency industry, which is driven in part by recurrent updates to the building code, is the largest component of the core clean economy (Ettenson and Heavey 2015). Adopting cost-effective code changes for the 2019 Title 24, Part 6 code cycle will help maintain the energy efficiency industry.

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

In 2014, California's electricity statewide costs were 1.7 percent of the state's gross domestic product (GDP) while electricity costs in the rest of the United States were 2.4 percent of GDP (Thornberg, Chong and Fowler 2016). As a result of spending a smaller portion of overall GDP on electricity relative to other states, Californians and California businesses save billions of dollars in energy costs per year relative to businesses located elsewhere. Money saved on energy costs can be otherwise invested, which provides California businesses with an advantage that will only be strengthened by the adoption of the proposed codes changes that impact nonresidential buildings.

3.4.4 Increase or Decrease of Investments in the State of California

The proposed changes to the building code are not expected to impact investments in California on a macroeconomic scale, nor are they expected to affect investments by individual firms. The allocation of resources for the production of goods in California is not expected to change as a result of this code change proposal.

3.4.5 Effects on the State General Fund, State Special Funds and Local Governments

The proposed code changes are not expected to have a significant impact on the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are: personal income taxes, corporation taxes, sales and use taxes, and property taxes. The proposed changes for the 2019 Title 24, Part 6 Standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected to change.

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals.

Cost to Local Governments

All revisions to Title 24, Part 6 will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.5, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters or persons by age, race, or religion.

4. ENERGY SAVINGS

Energy savings from the newly proposed 2019 LPD levels for lighting alterations are captured in the 2019 CASE Report on nonresidential indoor lighting power densities. The energy savings from the newly proposed indoor lighting controls for lighting alterations are included in the 2019 CASE Report on nonresidential lighting indoor controls.

This section provides technical documentation for the lighting alteration model that the Statewide CASE Team developed and presents model outputs.

4.1 Key Assumptions for Energy Savings Analysis

The analysis considers the following building types: office (small and large), restaurant, retail (small and large), warehouse (non-refrigerated), school, and hotel (excluding guest rooms). Collectively, these building types account for approximately 85 percent of the existing building stock in 2020 (see Figure 7 for more details).

The analysis is performed at the area category level, which is also referred to as space type or activity area, for the considered building types. In other words, for each area category in a considered building prototype, lighting system characteristics typical for the area category are used (i.e., LPD values, baseline lighting schedules, and control factor profiles specific to the considered area category).

4.1.1 Assumptions Related to Lighting Power Allowance

Table 6 lists key model assumptions that are related to lighting power allowance.

Table 7 provides a high-level summary of assumed LPD values as percentages of allowed lighting power for entire luminaire and component modification retrofit projects for the three available prescriptive compliance options.

Table 8 lists vintage, current, and proposed future LPD values for the area categories in the considered building prototypes. For 2001, 2005, 2008, 2013, and 2016 Title 24, Part 6 code cycles, LPD values for area category method are used.

Table 6: Key Model Assumptions Related to Lighting Power Allowance

Affected Calculations	Assumption	Rationale
Calculations of baseline (existing building stock) per-unit energy use values	The baseline per-unit energy use is a blend of Title 24, Part 6 code cycles (2001, 2005, 2008, 2013, and 2016) representing existing building stock in California in 2020. Option 1 requirements were assumed for 2001, 2005, and 2008 code cycles (i.e., 100% of LPD). Option 2 requirements were assumed for 2013 and 2016 code cycles (i.e., 85% of LPD).	Prior to 2013 code cycle, only one compliance pathway (Option 1) was available and significantly fewer retrofit projects triggered the nonresidential lighting alteration code. Therefore, Option 1 requirements were assumed for 2001, 2005, and 2008 code cycles. For 2013 and 2016 code cycles, Option 2 requirements were used based on the literature review that suggests a low uptake rate of automatic daylighting controls in the existing building stock (Heschong Mahone Group, Inc. 2005, Saxena 2011, U.S. Energy Information Administration 2016, Navigant Consulting, Inc. 2014, Navigant Consulting, Inc. 2016). For more details on the uptake rate of automatic daylighting controls, see Appendix H. Note that automatic daylighting controls are required under Option 1 but are not required under Option 2.
Calculations of baseline (existing building stock) and 2019 Standards per-unit energy use values	For Option 3, it was assumed that: • 50% wattage reduction applies in hotel function, office, and retail area category; and • 35% wattage reduction applies for all other area categories. Further, it was assumed that existing wattage is represented by LPD values required in the following Title 24, Part 6 code cycles: 2001, 2005, 2008, 2013, and 2016.	The language around wattage reduction is somewhat ambiguous in the 2016 Standards (due to the lack of definition for the term “occupancy”). In the lighting alteration model, for an alteration project in an office building, wattage reduction by 50% is applied for office space type (private offices and open plan offices), and the wattage reduction by 35% is applied for the rest of space types within the office building (e.g., corridors, lobby).
	Allowed LPD for accent/display/feature/decorative lighting for applicable area categories is ignored for all building types.	Publicly available data was not identified to estimate accent/display/feature/decorative lighting portion of lighting power allowance.
	Allowed LPD for task lighting for applicable area categories is ignored for all building types.	Publicly available data was not identified to estimate the task lighting portion of lighting power allowance.

Table 7: Summary of Assumed Wattages in the Lighting Alteration Analysis for Three Compliance Pathways

Assumed Percent of LPD in Considered Buildings	OPTION 1 "85-100% of LPA"	OPTION 2 "≤ 85% of LPA"	OPTION 3 "Reduction of Existing Wattage"[a]
Hotel (Excluding Rooms)	100% of LPD for all area categories within a considered building prototype	85% of LPD for all area categories within a considered building prototype	50% of LPD for hotel lobby, bar/casino, and office area category 65% of LPD for all other area categories
Office			50% of LPD for office area category 65% of LPD for all other area categories
Restaurant			50% of LPD for office area category 65% of LPD for all other area categories
Retail			50% of LPD for office and retail area category 65% of LPD for all other area categories
School			50% of LPD for office area category 65% of LPD for all other area categories
Warehouse Non-Refrigerated			50% of LPD for office area category 65% of LPD for all other area categories

Source: Lighting Alteration Model v2.0.

a. Wattage reduction percentages were applied to LPD values of area categories within the considered building types for 2001, 2005, 2008, 2013, and 2016 code vintages (as a proxy of *existing* lighting wattage).

Table 8: Vintage, Current, and Proposed Future LPD Values for Considered Area Categories

Area Category	2001 (effective June 2001) W/ft^2	2005 (effective October 2005) W/ft^2	2008 (effective January 2010) W/ft^2	2013 (effective July 2014) W/ft^2	2016 (effective January 2017) W/ft^2	2019 Title 24, Part 6 Proposed W/ft^2	ASHRAE 90.1-2016[f] W/ft^2
Classroom, Lecture	1.6	1.2	1.2	1.2	1.2	0.72	0.92
Commercial Storage[a]	0.6	0.6	0.6	0.6	0.6	0.46	0.46
Corridors[b]	0.6	0.6	0.6	0.6	0.6	0.60	0.66
Convention, Conference, Multipurpose and Meeting Center Areas	1.5	1.4	1.4	1.4	1.2	0.85	1.07
Copy/Print Room[c]	0.6	0.6	0.6	0.6	0.6	0.50	0.56
Dining Area[d]	1.1	1.1	1.1	1.1	1.0	0.47	0.73
Electrical, Mechanical, Telephone Rooms	0.7	0.7	0.7	0.7	0.55	0.39	0.43
Exercise, Gym	1.0	1.0	1.0	1.0	1.0	0.50	0.50
General Commercial Low Bay	1.0	1.0	0.9	0.9	0.9	0.61	0.96
Hotel Function Area	2.2	1.5	1.5	1.5	1.4	0.78	-
Kitchen, Food Preparation Areas	1.7	1.6	1.6	1.6	1.2	0.92	1.06
Laundry Area	0.9	0.9	0.9	0.9	0.7	0.43	0.43
Library Reading Areas	1.2	1.2	1.2	1.2	1.1	0.77	0.82
Lobby Area Hotel	1.7	1.1	1.1	1.1	0.95	0.78	1.06
Lobby Area Main Entry	1.5	1.5	1.5	1.5	0.95	0.82	1.00
Office Area > 250 ft^2[e]	1.3	1.2	0.9	0.75	0.75	0.62	0.87
Office Area ≤ 250 ft^2	1.3	1.2	1.1	1.0	1.0	0.68	0.93
Retail	2.0	1.7	1.6	1.2	1.2	0.92	0.9
Restrooms[b]	0.6	0.6	0.6	0.6	0.6	0.65	0.85
Waiting Area	1.1	1.1	1.1	1.1	0.8	0.60	1.00
Average LPD	**1.2**	**1.1**	**1.1**	**1.0**	**0.92**	**0.65**	**0.80**

Source: 2016 and 2013 Title 24, Part 6, Table 140.6-C; 2008 Title 24, Part 6, Table 146-F; ASHRAE 90.1-2016.

a. 2019 Title 24, Part 6 LPD value is a weighted average of two proposed "Commercial/Industrial Storage" LPD value in W/ft^2: "Warehouse" (0.42) and "Shipping & Handling" (0.58) with weights of 75% and 25%, respectively.

b. In 2001, 2005, 2008, 2013, 2016 Title 24, Part 6 code cycles, corridors and restrooms were combined in a single area category ("Corridor, Restroom, Stair, and Support Areas").

c. Copy/Print Room area category was not present in 2001, 2005, 2008, 2013, and 2016 Title 24, Part 6 code cycles. LPD values for "Corridor, Restroom, Stair, and Support Areas" were used in those code cycles.

d. 2019 Title 24, Part 6 LPD value is an average of three proposed "Dining" LPD values in W/ft^2: "Bar/lounge or leisure" (0.52), "Cafeteria/fast food" (0.40), and "Family" (0.48).

e. 2019 Title 24, Part 6 LPD value is an average of two proposed "Office" LPD values in W/ft^2: ">250 square feet" (0.64) and "Open plan" (0.60).

f. ASHRAE 90.1-2016 values are not used in the lighting alteration model, but are provided in this table for readers' convenience in comparing Title 24, Part 6 LPD values with ASHRAE 90.1-2016 values.

Figure 4 presents the area categories that have been considered in each building type. The Statewide CASE Team used the Database for Energy Efficient Resources (DEER) as the source for typical activity areas found in the considered building types and for the percentages of activity areas of the total building area (California Public Utilities Commission 2015). For more information on the rationale for selecting DEER as the data source, see Section 4.1.2. DEER activity areas were mapped to Title 24, Part 6 area categories as shown in Figure 4. In the figure, the grey fill color highlights area categories that are subject to 50-percent wattage reduction under Option 3 per 2016 Title 24, Part 6 Standards. The white fill color identifies area categories that are subject to 35-percent wattage reduction under Option 3 per 2016 Title 24, Part 6 Standards.

Area Category (as Percent of Total Building Area) [a]	Hotel [b]	Office Large	Office Small	Restaurant	Retail Large	Retail Small	School	Warehouse
Classroom, Lecture							57%	
Commercial Storage		5%	10%	6%	15%	32%	4%	92%
Corridors, Stair, and Support Areas	10%	13%	6%	2%	2%	2%	4%	
Convention, Conference, Multipurpose and Meeting Center Areas		3%	6%					
Copy/Print Room		1%	1%					
Dining Area	1%	2%	4%	50%	2%	2%	3%	
Electrical, Mechanical, Telephone Rooms		2%	2%		0.4%	1%		
Exercise, Gym							8%	
General Commercial Low Bay			1%		14%			
Hotel Function Area	1%							
Kitchen, Food Preparation Areas	1%			28%			5%	
Laundry Area	2%							
Library Reading Areas							4%	
Lobby Area Hotel	4%							
Lobby Area Main Entry		4%	6%					
Office Area > 250 ft²		46%	36%		4%		8%	7%
Office Area ≤ 250 ft²	1%	20%	25%	5%	4%	11%		
Retail					56%	49%		
Restrooms	1%	3%	4%	6%	3%	3%	5%	1%
Waiting Area				3%			1%	
Total	**20%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Figure 4: Area categories included in the considered building types (as percent of total building area).

Source: The spreadsheet titled "DEER2016-ComLtgProfilesSummary-15May2015" (http://www.deeresources.com/index.php/deer-versions/deer2016#LightingProfiles) and Lighting Alteration Model v2.0.

a. The percentages are rounded, hence, in some cases, may appear not to add up to the displayed total.

b. The total area of a hotel building is 20 percent since guest rooms are excluded from the lighting alteration analysis.

4.1.2 Assumptions Related to Baseline Lighting Schedules

Lighting schedules available from DEER and the California Building Energy Code Compliance for Commercial/Nonresidential Buildings software (CBECC-Com) were evaluated for their suitability as baseline lighting schedules for the lighting alteration analysis. This section discusses the rationale for selecting DEER lighting schedules over lighting schedules defined in the ACM Reference Manual and used in CBECC-Com.

The Statewide CASE Team concluded that DEER lighting schedules are the most suitable for the lighting alteration analysis for the following reasons:

- DEER provides lighting schedules for each area category (versus an averaged schedule for a particular building type found in CBECC-Com); and
- DEER lighting schedules are informed by actual field data collected as part of evaluation and measurement verification (EM&V) efforts.

Furthermore, the Statewide CASE Team evaluated DEER2014 versus DEER2016 lighting profiles. The Statewide CASE Team concluded that for the purposes of the lighting alteration analysis, DEER2014 profiles are more appropriate than DEER2016 profiles.

In a meeting between PG&E and California Public Utilities Commission (CPUC) staff on August 29, 2014, CPUC staff stated that:

- The original DEER profiles date back to a 1994 California Conservation Inventory Group study (NEOS Corporation 1994).
- DEER profiles are informed by field monitoring EM&V data collected for multiple buildings over many years.
- Field monitoring data gathered as late as 2004 and 2005 as part of EM&V studies are reflected in DEER2014 lighting profiles.
- DEER2014 lighting profiles have not changed since 2005.

Since the August 29, 2014, meeting, new DEER2016 profiles have been released. DEER2016 profiles were updated further based on field monitoring data gathered in 2015 as an effort to true-up energy savings claimed by utilities. For most building spaces, the annual hours for lighting load were reduced going from DEER2014 to DEER2016 lighting profiles. The Statewide CASE Team attributes the reduction, in part, to the higher uptake of lighting controls installed in the monitored buildings between 2004 through 2005 and in 2015 (years when the field monitoring data was gathered).

In a meeting on March 17, 2017, between the Statewide CASE Team and those directly responsible for maintaining DEER lighting profiles, the following key points were made:

- The buildings monitored as part of EM&V are post-retrofit buildings that went through an energy efficiency incentive program. Note that most subsidized lighting retrofit projects include replacement of fixtures, but do not include the installation of lighting controls.
- EM&V field monitoring data does not track absence and presence of lighting controls in the monitored buildings. The field data is averaged, so the resulting lighting profiles are influenced by the various combinations of lighting controls installed in the monitored buildings and to some extent account for lighting controls (e.g., automatic time-switch, manual multi-level controls). The contribution of lighting controls in reducing annual hours cannot be extracted from DEER profiles.
- Attempts are being made to include a statistically significant number of buildings with occupancy and automatic daylighting controls in EM&V studies, but have not been successful so far.

Since the lighting alteration analysis presented in this CASE Report explicitly accounts for reduction in energy use due to occupancy controls and daylighting controls, and since 2005 is closer to the earliest code vintage being considered for this analysis, DEER2014 was selected as the source for the baseline lighting schedules.

In addition to selecting a data source for lighting profiles, the Statewide CASE Team evaluated the source for the typical breakdown of area categories within a building type. In DEER2016, more areas were identified within building prototypes. Over the years, DEER data became important not only for analysis related to heating, ventilation, and air conditioning (HVAC), but also for analysis related to

lighting. While larger zones within a building provide sufficient detail for HVAC analysis, more granularity was needed for lighting analysis. The CPUC responded to this need by adding more area categories for 23 representative commercial building types. Some of the new area categories (e.g., corridors, stairwells, restrooms, conference rooms) are important for this analysis to properly account for lighting controls. For this analysis, DEER2016 was selected as the source for typical breakdown of area categories within a building type. The Statewide CASE Team mapped DEER2016 area categories to DEER2014 baseline lighting schedules. See Appendix C for more details about the mapping of area categories between DEER2016 and DEER2014.

Table 9 summarizes the findings about the lighting schedules available through DEER and CBECC-Com.

Table 9: Comparison of DEER and ACM/CBECC-Com Lighting Schedules

DEER Lighting Schedules	2016 ACM/CBECC-Com Lighting Schedules
General Notes about Data Source	
• The original DEER profiles date back to 1994 Final Report on Technology Energy Savings Prepared for the California Conservation Inventory Group by Neos Corporation (NEOS Corporation 1994). • DEER profiles are informed by field monitoring EM&V data collected for multiple buildings over many years (post-retrofit buildings that went through an energy efficiency program). • Field monitoring data gathered as late as 2004 and 2005 as part of EM&V studies are reflected in DEER2014 lighting profiles. • DEER2014 lighting profiles have not changed since 2005. • DEER2016 profiles were updated further based on field monitoring data gathered in 2015. For most building spaces, the annual hours for lighting load were reduced going from DEER2014 to DEER2016 lighting profiles. The Statewide CASE Team attributes the reduction, in part, to the higher uptake of lighting controls installed in the monitored buildings between 2004 through 2005 and 2015 (years when the field monitoring data was gathered).	• Lighting schedules currently used in CBECC-Com, referred to as 2016 ACM lighting schedules, are available as a supporting Excel file for the 2016 Nonresidential ACM Reference Manual (California Energy Commission 2016). • Current ACM lighting schedules were introduced in the 2013 Title 24, Part 6 code cycle as part of the migration effort from DOE2.1E to EnergyPlus as the simulation engine for the compliance software. • The 2013 and 2016 ACM lighting schedules come from ASHRAE 90.1-2010 User Manual, Section G. • Note that ASHRAE 90.1-2010 user manual presents two values for percent of maximum load for some of the hours of a workday. The lower values for percent of maximum load account for the requirement for occupancy sensors in ASHRAE 90.1-2010, Section 9.4.1 Lighting Control and were used as the basis for the 2013 and 2016 ACM lighting schedules. • For reference, the higher values for percent of maximum load in lighting schedules in ASHRAE 90.1-2010 were based on ASHRAE 90.1-1989 schedules, documented in 90.1-1989 ECB Compliance Supplement, Table 7.1C.

DEER Lighting Schedules	2016 ACM/CBECC-Com Lighting Schedules
Notes about Included Building Types and/or Function Areas	
• DEER2014 and DEER2016 data sets describe 23 representative commercial building types. • For 23 prototype buildings, there are 110 unique space types, also referred to as activity areas. • There are three types of schedules: Standard, Break, and Summer. Break and Summer schedule types are available for building types found in the education sector. • For each lighting schedule type, a lighting schedule set – consisting of weekday, Saturday/Sunday, holiday – is provided. Not all lighting schedule sets are unique for space types. • For certain activity areas, DEER2014 provides separate lighting schedules for Compact Fluorescent Lighting and Linear Fluorescent Lighting. • For certain activity areas, DEER2016 provides a separate lighting schedule for High Bay Lighting in addition to lighting schedules for Compact Fluorescent and Linear Fluorescent Lighting. • In total, there are 164 unique 24-hour lighting schedules identified by their unique Profile IDs.	• The 2016 ACM provides lighting schedule sets (workday, Saturday, Sunday) for total of 13 building/area types: 1. Assembly 2. Data 3. Health 4. Laboratory 5. Manufacturing 6. Office 7. Parking 8. Residential Living 9. Residential Common 10. Restaurant 11. Retail 12. School 13. Warehouse • In CBECC-Com standard building prototype models, a building prototype may use one or more lighting schedules. For example, the small office building prototype uses only "Office" lighting schedule by default. The large office building prototype uses "Office" and "Assembly" lighting schedules by default.

4.1.3 Assumptions Related to Indoor Lighting Controls

To account for the energy savings due to occupant sensing and automatic daylighting controls in the applicable area categories, control factor profiles for occupant and daylighting controls were used. The control factor profile is an array of 24 values that are used as multipliers to discount the lighting load in a 24-hour baseline lighting schedule, when applicable. The value of one in a control factor profile means no energy savings due to a lighting control. The value of zero in a control factor profile means the load is turned OFF due to a lighting control.

The control factor profile for occupant sensing controls is a flat line, and hence can be described by a single value. The control factor profile for automatic daylighting controls has ones from 8pm to 5am (when the sun is down) and values between zero and one during daytime. For more details on control factor profiles used in the lighting alteration model, see Appendix C.

Control factor profiles for occupant sensing controls were used for area categories that explicitly require an occupant sensing control in accordance with the 2013 and 2016 Title 24, Part 6 Standards, Section 130.1(c)5: Areas where Occupant Sensing Controls are Required to Shut OFF All Lighting. The meta-study published by LBNL in 2011 was used as the source for control factors for occupant sensing controls in the considered building types (Williams, Atkinson, et al. 2011).

Control factor profiles for daylighting controls were developed using Radiance-based daylighting simulations and a daylighting template-based approach. This approach is described in the Public Interest Energy Research (PIER) study (Saxena 2011).

Table 10 lists key model assumptions related to lighting controls.

Table 10: Key Model Assumptions Related to Lighting Controls

Affected Calculations	Assumption	Rationale
Baseline (existing building stock) per-unit energy use values	The baseline per-unit energy use is a blend of code cycles (2001, 2005, 2008, 2013, and 2016) representing existing building stock in California in 2020. No lighting controls were applied for 2001, 2005, and 2008 code cycles. Option 2 requirements were assumed for 2013 and 2016 code cycles (i.e., occupant sensing controls were assumed).	Prior to 2013 code cycle, "entire luminaire" and "component modification" alteration projects were not subject to lighting controls in most cases (2008 Title 24, Part 6, Section 149(b) NOTE and Section 149(b)1I). For 2013 and 2016 code cycles, Option 2 requirements were used based on the literature review that suggests a low uptake rate of automatic daylighting controls in the existing building stock (Heschong Mahone Group, Inc. 2005, Saxena 2011, U.S. Energy Information Administration 2016, Navigant Consulting, Inc. 2014, Navigant Consulting, Inc. 2016). For more details on the uptake rate of automatic daylighting controls, see Appendix H. Note that automatic daylighting controls are required under Option 1 but are not required under Option 2.
	The energy savings from automatic daylighting controls in baseline per-unit energy use calculations are ignored.	The uptake rate of automatic daylighting controls has been reported to be very low in the existing building stock (for considered sources, see Appendix H).
	Full OFF occupant sensing controls were applied to 2013 and 2016 code cycles in offices ≤ 250 ft^2, classrooms, and conference rooms.	Full OFF occupant sensing controls were applied in offices ≤ 250 ft^2, classrooms, and conference rooms in accordance with 2013 and 2016 Title 24, Part 6, Section 130.1(c)5.
	Full OFF occupant sensing controls were applied to 2013 and 2016 code cycles in commercial storage area category of warehouses and in corridors and stairwells.	Partial OFF occupant sensing controls were applied in warehouses and corridors/stairwells in accordance with 2013 and 2016 Title 24, Part 6, Section 130.1(c)6A, 6C, and 7A.
2019 Standards per-unit energy use values	The savings from automatic daylighting controls were assessed for only one climate zone (Climate Zone 2 using the Energy Commission's nomenclature).	Modeled savings in Radiance were readily available for the considered scenarios for Climate Zones 2, 6, 12, and 13. The range in savings was approximately 2%. As a conservative approach, the most conservative climate zone was selected.
	Automatic daylighting controls were assumed to dim to OFF.	Dimming to OFF is proposed in the 2019 CASE Report on indoor lighting controls.
	The savings from automatic daylighting controls were discounted by 10%.	The savings from automatic daylighting controls were discounted by 10% based on the findings from a study published by LBNL, reporting that modeled savings tend to overestimate actual savings from automatic daylighting controls by at least 10% (Williams, Atkinson, et al. 2011). In other words, an adjustment factor of 90% was applied to control factor profile for daylighting controls.

Affected Calculations	Assumption	Rationale
	Warehouse building type is a blend of two building prototypes: pre-2005 code cycle without skylights and post-2005 code cycle with skylights. The average of annual full load equivalent (FLE) hours for two prototypes is used for warehouse building type.	Based on the Energy Commission's new construction data (for years 2013–2019) and 2012 California Commercial Saturation Survey (CSS) data on building construction date for warehouses, roughly three quarters of warehouse building stock in 2020 can be categorized as built before 2005 and roughly one quarter after 2005. To account for the fact that it was a common practice to put in skylights in warehouses even before it was required by code (starting with 2005 Title 24, Part 6 per Section 143(c)), the Statewide CASE Team assumed 50% of warehouses to be skylit and 50% non-skylit in 2020.
	Full OFF occupant sensing controls were applied in offices ≤ 250 ft^2, classrooms, conference rooms, and restrooms.	Full OFF occupant sensing controls were applied in offices ≤ 250 ft^2, classrooms, and conference rooms in accordance with 2016 Title 24, Part 6, Section 130.1(c)5. Full OFF occupant sensing controls were applied in restrooms as proposed in the 2019 CASE Report on indoor lighting controls.
	Partial OFF occupant sensing controls were applied in commercial storage area category of warehouses and in corridors/stairwells.	Partial OFF occupant sensing controls were applied in warehouses and corridors/stairwells in accordance with 2016 Title 24, Part 6, Section 130.1(c)6A, 6C, and 7A.
	The savings from occupancy controls were discounted by 5%.	The baseline per-unit energy use calculations assume required occupancy controls for code cycles 2013 and 2016. If a building with a lighting system installed in accordance with the 2013 or 2016 code cycle is going through another lighting retrofit, the savings from occupancy controls would be pre-existing and could not be claimed for 2019 Standards calculations. To account for the scenario described above, an adjustment factor of 95% is applied to control factor for occupancy controls.
	Energy savings due to demand responsive controls are ignored.	Title 24, Part 6 requires that certain buildings have demand responsive controls, but does not require actual participation in demand response programs. For buildings participating in demand response programs and lowering lighting levels during demand response events, the energy savings are expected to be negligible given the annual demand response hours compared to total annual operating hours.
	Manual area controls, manual multi-level or bi-level controls, and automatic time-switch controls are not considered separately like occupant sensing controls or automatic daylighting controls in the lighting alteration model.	DEER lighting schedules used as baseline lighting schedules in the lighting alteration model are based on field monitoring data of buildings that likely had some basic lighting controls at the time of data collection. Those basic lighting controls likely included area controls, automatic time-switch controls, and to some extent manual multi-level or bi-level controls. In other words, energy savings from those controls are accounted in the baseline lighting schedules at least to a certain extent.

Table 11 summarizes control factors developed for each building type considered in the lighting alteration model for occupant sensing controls. For an illustration of the use of control factors in the lighting alteration model, consider a school as an example. For a school with occupant sensing controls in classrooms, the baseline lighting profile for classrooms is multiplied by a control factor of 0.82, thereby reducing the lighting load hours in classrooms and, consequently, the per-unit energy use in the school.

Table 11: Control Factors for Full OFF and Partial OFF Occupant Sensing Controls

Building Type[a]	Control Factor for Full OFF Occupant Sensing Control[b]	Control Factor for Partial OFF Occupant Sensing Control[c]
Hotel	0.93	0.965
Office Large	0.78	0.89
Office Small	0.78	0.89
Restaurant	0.93	0.965
Retail	0.93	0.965
School	0.82	0.91
Warehouse	0.69	0.845

a. Control factors for occupant sensing controls are based on data collected from a meta-study on lighting controls (Williams, Atkinson, et al. 2012). However, for restrooms, the control factor of 0.66 was used for full OFF controls across all building types based on the report published by Pacific Northwest National Laboratory (Thornton, et al. 2011).

b. The following area categories were affected by the control factors: offices ≤ 250 ft^2, classrooms, conference rooms, commercial storage area in warehouses, and corridors/stairwells.

c. Control factors for partial OFF occupant sensing control is 50 percent of load reduction from full OFF occupant sensing controls.

4.1.4 Assumptions Related to Market of Lighting Retrofits

The Statewide CASE Team deployed an alteration survey, referred to in this report as the 2017 C&S Lighting Alteration Survey, to inform assumptions related to the market of lighting retrofits. The survey responses were collected from February 18 through April 10, 2017. To clarify some of the responses or collect missing information, the Statewide CASE Team held follow-up calls with some survey respondents in June and July of 2017.

Three core questions were asked in the survey to inform the following model inputs:

- The distribution of the age of lighting systems (i.e., the market share of lighting systems at each vintage of historical Title 24, Part 6 codes in existing building stock for 2020).
- The rate of lighting alterations for considered building types. This assumption is applicable for extrapolating per-unit energy savings to statewide savings; this assumption was informed by the data gathered on the average age of lighting systems.
- The market share of each compliance pathway for regulated lighting alterations (entire luminaire and component modification type of retrofits).

Table 12 summarizes key model assumptions related to the market of nonresidential lighting alterations and highlights where the results of the 2017 C&S Lighting Alteration Survey were applied. See Appendix I for more details on the 2017 C&S Lighting Alteration Survey.

Table 12: Key Model Assumptions Related to Market of Lighting Alterations

Affected Calculations	Assumptions and Sources	Rationale
Baseline (existing building stock) and 2019 Standards Option 3 per-unit energy use values	**Distribution of the Age of Lighting Systems** The distribution averaged across building types of interest was used. See Figure 5 for more details. The distribution of the age of lighting systems was informed by adjusted 2014 CSS data on the distribution of linear lamps by system installation year (Itron, Inc. 2014). Note that the 2014 CSS study used the following bins for system installation year: Pre-1990, 1990-1999, 2000-2003, 2004-2008, and 2009-2012. As part of adjusting these results to year 2020: • The "Pre-1990" bin was mapped to 1995; however, the bin's value was lumped with 2001 code cycle in the lighting alteration model. • The "1990-1999" bin was redistributed between 2001 code cycle (two-thirds of bin's value) and 2005 code cycle (one-third of bin's value). • The "2000-2003" bin was mapped to 2008 code cycle. • The "2004-2008" bin was mapped to 2013 code cycle. • The "2009-2012" bin was mapped to 2016 code cycle. See Figure 6 for more details.	2014 CSS values were used instead of the results gathered from the 2017 C&S Lighting Alteration Survey since 2014 CSS values are based on a fairly recent, large-scale, and robust study.

Affected Calculations	Assumptions and Sources	Rationale
Statewide energy savings	**Rate of Lighting Alterations** The rate of lighting alterations specific to building type was used. The rate of lighting alterations was informed by the results of the 2017 C&S Lighting Alteration Survey. **Statewide Floor Space** Only 20% of floor space for hotel building type was used in the Lighting Alteration Model v2.0 since the DEER2016 hotel profile assigns 80% of the total area to guest rooms that are not subject to nonresidential Title 24, Part 6 code. Floor space for relevant subtypes of college building type was added to the square footage of appropriate building types (office small, office large, and school). Subtypes of college building type not considered in the lighting alteration model were excluded from the considered building stock. See Figure 7 for more details.	**Rate of Lighting Alterations** The results of 2017 C&S Lighting Alteration Survey on the rate of lighting alterations are in line with other data sources. For example, per comment letter by International Brotherhood of Electrical Workers (IBEW) dated November 6, 2015: "IBEW on record states that lighting systems are typically retrofitted every 10 to 15 years, and know that for retail buildings, lighting systems are typically upgraded at least every 7 years" (International Brotherhood of Electrical Workers 2015). As another example, the assumed rate of alterations used in the 2016 U.S. Department of Energy Report on Solid-State Lighting Forecast was 10% per year or once every 10 years (Navigant Consulting, Inc. 2016). **Statewide Floor Space** See more details about the considered building floor space in Appendix A.
Statewide energy savings	**Market Share of Each Compliance Pathway for Regulated Lighting Alterations** The percent of total regulated alterations for performance approach was added to the Option 1 percentage of total regulated alterations in an effort to be conservative in calculating statewide energy savings. The market share of regulated lighting alterations was informed by the results of the 2017 C&S Lighting Alteration Survey. The results gathered in 2017 were assumed to apply in year 2020. See Figure 8 for more details.	**Market Share of Each Compliance Pathway for Regulated Lighting Alterations** The statewide energy savings are more conservative when the percent for performance approach is added to the Option 1 percentage, because Option 1 results in smaller energy savings compared to Option 2 and 3.

For the considered building types, Figure 6, Figure 7, and Figure 8 provide more detailed information about the market-related key assumptions in the lighting alteration model. Please refer to Appendix I for more details on the market-related assumptions.

As noted in Figure 5, the distribution of the age of lighting systems was informed by adjusted 2014 CSS data on the distribution of linear lamps by system installation year (Itron, Inc. 2014).

Distribution of the age of lighting systems by 2001-2016 Title 24, Part 6 code vintage	
	Adjusted 2014 California Commercial Saturation Survey (CSS) (to forecast 2020 distribution, shifted percentages by two code cycles forward compared to CSS original data)
2001 Title 24, Part 6	22%
2005 Title 24, Part 6	4%
2008 Title 24, Part 6	9%
2013 Title 24, Part 6	22%
2016 Title 24, Part 6	44%
	100%

Figure 5: Distribution of the age of lighting systems used in the lighting alteration model.

Source: Lighting Alteration Model v2.0.

As indicated in Figure 6, as part of adjusting CSS results to year 2020:

- The "Pre-1990" bin was mapped to 1995; however, the bin's value was lumped with 2001 code cycle in the lighting alteration model.
- The "1990-1999" bin was redistributed between 2001 code cycle (two-thirds of bin's value) and 2005 code cycle (one-third of bin's value).
- The "2000-2003" bin was mapped to 2008 code cycle.
- The "2004-2008" bin was mapped to 2013 code cycle.
- The "2009-2012" bin was mapped to 2016 code cycle.

CSS Original Data Collected in 2012	Mapping CSS Original Data to Title 24, Part 6 Code Vintages	Shifting by Two Code Cycles (~Expected Distribution in 2020)	Mapping to Code Cycles Used in the Alteration Model
Pre-1990	1978, 1980, 1982, 1984, 1986, 1987, 1988	1982, 1984, 1987, 1988, 1992, 1995	1995
1990-1999	1992, 1995, 1998	1998, 2001, 2005	1998, 2001, 2005
2000-2003	2001	2008	2008
2004-2008	2005	2013	2013
2009-2012	2008	2016	2016

Figure 6: Adjustments to CSS original data on the distribution of linear lamps by system installation year.

Sources: 2014 CSS study (Itron, Inc. 2014) and the Statewide CASE Team assumptions.

Figure 7 summarizes lighting alteration model inputs used to determine statewide annual energy savings. As indicated in the figure, the lighting alteration analysis considers office (small and large),

restaurant, retail (small and large), warehouse (non-refrigerated), school, and hotel (excluding guest rooms) building types. Collectively, these building types account for approximately 85 percent of the existing building stock in 2020.

Figure 8 summarizes the results of the 2017 C&S Lighting Alteration Survey for the market share of each compliance pathway. The results gathered in 2017 were assumed to apply in year 2020.

Considered building floor stock and rate of lighting alterations

Building Type	Building Stock in 2020 (million ft^2)	Percent of Total Building Stock	Percent of Considered Building Stock	Rate of Lighting Alterations (once in X years)
Hotel (excl. rooms)	89	1%	1%	12
Office Large	1,752	23%	28%	11
Office Small	503	7%	8%	12
Restaurant	241	3%	4%	10
Retail Large	766	10%	12%	10
Retail Small	766	10%	12%	10
School	856	11%	13%	15
Warehouse Non-Refrigerated	1,372	18%	22%	14
All Other Building Types (food, refrigerated warehouse, college *partial floorspace*, hospital)	1,151	15%		
TOTAL	**7,496**	**100%**		
TOTAL Considered Building Stock	6,345	85%	**100%**	

Figure 7: Considered building floor stock and the rate of lighting alterations.

Source: The Energy Commission Demand Analysis Office (see Appendix A), 2017 C&S Lighting Alteration Survey, and Statewide CASE Team calculations.

Market share of compliance options for regulated lighting alterations

Compliance Option	
Prescriptive approach (three options)	
OPTION 1 | 85%-100% of 2019 LPA	37%
OPTION 2 | ≤ 85% of 2019 LPA	29%
OPTION 3 | Reduction of existing wattage	23%
Performance approach	11%
	100%

Figure 8: Market share of each compliance pathway.

Source: 2017 C&S Lighting Alteration Survey and Statewide CASE Team calculations.

4.2 Energy Savings Methodology

As noted earlier, the developed lighting alteration model serves two main purposes:

- Compares three compliance pathways in terms of potential energy savings using the existing building stock as baseline.
- Calculates incremental energy savings from the measure that requires the reduction of existing wattage by 50 percent under Option 3 (using proposed 2019 Standards with unchanged Option 3 as baseline).

Table 13 summarizes the approach to calculate per-unit and statewide energy savings using the existing building stock as baseline. To calculate the incremental energy savings from the measure that requires the reduction of existing wattage by 50 percent, the results from Step 3 in Table 13 were used.

Table 14 summarizes the approach to calculate per-unit and statewide energy savings for the measure that requires the reduction of existing wattage by 50 percent under Option 3, using proposed 2019 Standards with unchanged Option 3 as baseline.

Table 13: Step-by-Step Methodology to Calculate Per-Unit and Statewide Energy Savings Using Existing Building Stock as Baseline

Step	Key Details and Step Output
Step 1 Calculate **baseline per-unit energy use** based on 2001-2016 code cycles for considered building types (in kWh/ft^2 per year)	• For each building type, estimate per-unit energy use for the building's lighting load for five code cycles (2001, 2005, 2008, 2013, 2016), using the following formula: $$Per\ Unit\ Energy\ Use\left[\frac{kWh}{sf}per\ year\right] = \sum_{i=1}^{n} Percent\ of\ Building\ Area_{area\ category_i} \times (LPD_{area\ category_i}[\frac{W}{sf}] \times Annual\ FLE\ Hours_{area\ category\ _i}[hr] \times \frac{1}{1000}\left[\frac{kW}{W}\right])$$ Where Percent of Building Area is the percent of the area category of the total building area, LPD is the lighting power density for an area category, and Annual FLE Hours are annual full load equivalent hours that account for savings from the considered lighting controls. The concept of FLE hours is used here to account for reduction in operating hours as well as in LPD levels from automatic daylighting controls. For example, in a room with a functioning automatic daylighting control, the value for the annual operation hours for lighting load is larger than the value for the annual FLE hours, since the lights are only partially on in the room at certain times throughout a given year. • Use area category LPD for 2001, 2005, 2008, 2013, and 2016 Title 24, Part 6 code cycles. • For each area category in the considered building types, use the appropriate DEER lighting schedule for annual hour profile as the baseline lighting schedule. As applicable, modify the baseline lighting schedules using control factor profiles for occupant sensing controls. • Consider the following building types: hotel, office large, office small, restaurant, retail large, retail small, school, and warehouse. The cumulative square footage for the considered building types equals 85% of existing building stock (see Figure 7 for more details on calculations). **Output** Baseline per-unit energy use for the considered building types for five code cycles in kWh/ft^2 per year.

Step 2 Calculate **average baseline per-unit energy use (in kWh/ft^2 per year) weighted by** market share of code vintage and by building type stock	• Use the assumed distribution of the age of lighting systems by 2001-2016 Title 24, Part 6 code cycles. • To weigh by building type stock, use the Energy Commission's forecast of building stock by building type in 2020. **Output** Single baseline per-unit energy use value in kWh/ft^2 per year.
Step 3 Calculate **2019 Standards per-unit energy use** for considered building types for each compliance pathway (in kWh/ft^2 per year)	• For each building type, estimate per-unit energy use for building's lighting load, using the following formula: $$Per\ Unit\ Energy\ Use\left[\frac{kWh}{ft^2}per\ year\right] = \sum_{i=1}^{n} Percent\ of\ Building\ Area_{area\ category_i} \times (LPD_{area\ category_i}[\frac{W}{ft^2}] \times Annual\ FLE\ Hours_{area\ category\ _i}[hr] \times \frac{1}{1000}\left[\frac{kW}{W}\right])$$ Where Percent of Building Area is the percent of the area category of the total building area, LPD is the lighting power density for an area category, and Annual FLE Hours are annual full load equivalent hours that account for savings from the considered lighting controls. For each function area, annual hours are calculated as follows: $Annual\ FLE\ Hours[hr] = 251\ Workdays \times (\sum_{i=1}^{24} Baseline\ Weekday\ Hour\ Fraction_i\ [hr] \times Hour\ Control\ Factor_i) + 104\ Weekend\ Days \times (\sum_{i=1}^{24} Baseline\ Weekend\ Hour\ Fraction_i\ [hr] \times Hour\ Control\ Factor_i) + 10\ Holidays \times (\sum_{i=1}^{24} Baseline\ Holiday\ Hour\ Fraction_i\ [hr] \times Hour\ Control\ Factor_i)$ Where 251 is the number of workdays excluding the ten federal holidays in 2021 (a non-leap year) and 104 is the number of Saturdays and Sundays in 2021 (a non-leap year). Note that the total number of days in a considered year is 365 (251+104+10). • For the "85-100% of 2019 LPA" option, assume 100% of proposed 2019 area category LPD values. For each area category in the considered building types, use the appropriate DEER lighting schedule for annual hour profile as the baseline lighting schedule. As applicable, modify the baseline lighting schedules using control factor profiles for occupant sensing and automatic daylighting controls. • For the "≤ 85% of 2019 LPA" option, assume 85% of proposed 2019 area category LPD values. For each area category in the considered building types,

	use the appropriate DEER lighting schedule as the baseline lighting schedule. As applicable, modify the baseline lighting schedules using control factor profiles for occupant sensing controls. • For the "reduction of existing wattage" option, assume 50% of area category LPD in hotel function, office, and retail area category and 65% of LPD for all other area categories. Use 2001, 2005, 2008, 2013, and 2016 code cycles as existing, "pre-retrofit" area category LPD values. For each area category in the considered building types, use the appropriate DEER lighting schedule for annual hour profile as the baseline lighting schedule. As applicable, modify the baseline lighting schedules using control factor profiles for occupant sensing controls. Use the assumed distribution of lighting systems by 2001-2016 Title 24, Part 6 code cycles as weights to calculate a single per-unit energy use value for the "reduction of existing wattage" option for each building type. **Output** 2019 Standards per-unit energy use values for the considered building types in kWh/ft^2 per year (i.e., three values per each building type corresponding to three compliance pathways).
Step 4 Calculate **average 2019 Standards per-unit energy use weighted by** building type floor stock (in kWh/ft^2 per year)	To weigh 2019 Standards per-unit energy values by building type stock, use the Energy Commission's forecast of building stock by building type in 2020. **Output** 2019 Standards per-unit energy use values for three compliance pathways in kWh/ft^2 per year.
Step 5 Calculate **expected per-unit energy savings for each compliance pathway** (in kWh/ft^2 per year)	To calculate expected energy savings, use the following formula: Energy savings [kWh/ft^2 per year] = Baseline per-unit energy use (2001-2016 code cycles) – 2019 Standards per-unit energy use under Option X. Where X is Option 1, Option 2, or Option 3. **Output** Expected per-unit energy savings for three compliance pathways in kWh/ft^2 per year.
Step 6 Calculate **expected statewide energy savings for each compliance pathway** (in GWh per year)	• Use the rate of lighting alterations by building type to determine the annual percentage of existing building stock that is being altered. • To calculate statewide energy saving for three compliance pathways, assume that all regulated lighting alteration projects are first subject to Option 1, then Option 2, and then Option 3. **Output** Statewide energy savings for three compliance pathways in GWh per year.
Step 7 Calculate **expected statewide energy savings weighted by** the market share of compliance pathways (in GWh per year)	Use the market share of compliance pathways for regulated alterations as weights to blend the statewide energy savings under each compliance pathway. **Output** Single statewide energy savings value in GWh per year.

Table 14: Step-by-Step Methodology to Calculate Per-Unit and Statewide Energy Savings for the Measure that Requires the Reduction of Existing Wattage by 50 Percent under Option 3

Step	Key Details and Step Output
Step 1 Calculate **per-unit energy use for base case and standards** case for considered building types weighted by market share of compliance pathways (in kWh/ft^2 per year)	• The base case is 2019 Standards with unchanged Option 3. For base case, use model outputs from Step 3 in Table 13 (Option 3 is unchanged).. • For standards case, use model outputs from Step 3 in Table 13 with wattage reduction set to 50% for all area categories under Option 3. • Use the market share of compliance pathways for regulated alterations as weights to blend the per-unit energy use values for each considered building type under each compliance pathway. **Output** Base case and standards case per-unit energy use for the considered building types for each compliance pathway in kWh/ft^2 per year.
Step 2 Calculate **statewide energy savings** for considered building types (in GWh per year**)**	• Subtract standards case per-unit energy use values from base case per-unit energy use values to arrive at per-unit energy savings for the measure. • Use the rate of lighting alterations by building type to determine the annual stock subject to the lighting alteration code. • Scale the per-unit energy savings to statewide energy savings by multiplying the per-unit energy savings by annual floor stock subject to the lighting alteration code. **Output** Statewide energy savings for the considered building types in GWh per year.
Step 3 Calculate **expected statewide energy savings** for the measure (in GWh per year)	Add statewide energy savings for the considered building types. **Output** Statewide energy savings for the measure in GWh per year.

4.3 Per-Unit Energy Impacts Results

The results of per-unit energy use calculations for baseline (existing building stock) and buildings compliant with the proposed 2019 Standards (referred to as 2019 Standards) in kilowatt-hours per square foot per year (kWh/ft^2 per year) for the considered building types are presented in Figure 9, Figure 10, and Figure 11.

BASELINE Per-Unit Energy Use							
Weights by Building Type Stock % of Considered Stock	Building Type	2001 T24 P6	2005 T24 P6	2008 T24 P6	2013 T24 P6	2016 T24 P6	Weighted by Code Vintage
		kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year
1%	Hotel (excl. rooms)	5.0	4.2	4.2	3.5	3.2	3.8
28%	Office Large	3.2	3.0	2.5	1.8	1.7	2.2
8%	Office Small	3.2	3.0	2.7	1.9	1.8	2.2
4%	Restaurant	5.8	5.6	5.6	4.7	4.1	4.8
12%	Retail Large	6.2	5.4	5.1	3.4	3.4	4.3
12%	Retail Small	4.7	4.2	4.0	2.8	2.7	3.3
13%	School	4.5	3.6	3.6	2.6	2.6	3.1
22%	Warehouse Non-Refrigerated	1.8	1.8	1.8	1.3	1.3	1.4
100%	**Weighted AVERAGE (by Building Type Stock)**	**3.74**	**3.38**	**3.14**	**2.25**	**2.18**	**2.66**
	Weights by Code Vintage	22%	4%	9%	22%	44%	
	100%						

Figure 9: Calculated baseline (existing building stock) per-unit energy use values for Option 1, Option 2, and Option 3.

Source: Lighting Alteration Model v2.0.

2019 STANDARDS Per-Unit Energy Use									
		ENERGY							
Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 85-100% of 2019 LPA PER-UNIT ENERGY USE	OPTION 2 ≤ 85% of 2019 LPA PER-UNIT ENERGY USE	OPTION 3 Reduction of Existing Wattage PER-UNIT ENERGY USE (Weighted by Code Vintage)	2001 Title 24, Part 6	2005 Title 24, Part 6	2008 Title 24, Part 6	2013 Title 24, Part 6	2016 Title 24, Part 6
		kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year	kWh/ft^2 per year
1%	Hotel (excl. rooms)	3.0	2.8	2.5	2.9	2.5	2.5	2.5	2.3
28%	Office Large	1.5	1.4	1.3	1.6	1.5	1.3	1.2	1.1
8%	Office Small	1.5	1.4	1.3	1.6	1.5	1.4	1.3	1.2
4%	Restaurant	2.7	2.5	3.4	3.7	3.6	3.6	3.6	3.0
12%	Retail Large	3.0	2.6	2.4	3.2	2.8	2.7	2.1	2.1
12%	Retail Small	2.4	2.1	2.2	2.5	2.7	2.6	2.1	2.1
13%	School	1.8	1.6	2.1	2.5	2.0	2.0	2.0	1.9
22%	Warehouse Non-Refrigerated	1.0	0.98	1.0	1.0	1.0	0.96	0.95	0.95
100%	**Weighted AVERAGE (by Building Type Stock)**	**1.79**	**1.61**	**1.67**	**1.99**	**1.86**	**1.74**	**1.58**	**1.52**
				Weights by Code Vintage	22%	4%	9%	22%	44%
				100%					

Figure 10: Calculated 2019 Standards per-unit energy use values for Option 1, Option 2, and Option 3 with wattage reduction of 35/50% under current Option 3.

Source: Lighting Alteration Model v2.0.

2019 STANDARDS Per-Unit Energy Use

		ENERGY							
Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 85-100% of 2019 LPA PER-UNIT ENERGY USE	OPTION 2 ≤ 85% of 2019 LPA PER-UNIT ENERGY USE	OPTION 3 Reduction of Existing Wattage PER-UNIT ENERGY USE (Weighted by Code Vintage)	2001 Title 24, Part 6	2005 Title 24, Part 6	2008 Title 24, Part 6	2013 Title 24, Part 6	2016 Title 24, Part 6
		kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	kWh/ft² per year	kWh/ft² per year
1%	Hotel (excl. rooms)	3.0	2.8	2.1	2.5	2.1	2.1	2.1	2.0
28%	Office Large	1.5	1.4	1.2	1.5	1.4	1.2	1.1	1.0
8%	Office Small	1.5	1.4	1.2	1.5	1.4	1.2	1.1	1.1
4%	Restaurant	2.7	2.5	2.6	2.9	2.8	2.8	2.8	2.4
12%	Retail Large	3.0	2.6	2.3	3.1	2.7	2.5	2.0	2.0
12%	Retail Small	2.4	2.1	1.8	2.3	2.1	2.0	1.6	1.6
13%	School	1.8	1.6	1.6	1.9	1.6	1.6	1.5	1.5
22%	Warehouse Non-Refrigerated	1.0	0.98	0.8	0.8	0.8	0.76	0.74	0.74
100%	**Weighted AVERAGE (by Building Type Stock)**	**1.79**	**1.61**	**1.42**	**1.76**	**1.60**	**1.48**	**1.32**	**1.28**
				Weights by Code Vintage	22%	4%	9%	22%	44%
				100%					

Figure 11: Calculated 2019 Standards per-unit energy use values for Option 1, Option 2, and Option 3 with wattage reduction of 50% under proposed Option 3.

Source: Lighting Alteration Model v2.0.

For comparison, Table 15 summarizes per-unit energy use values by building type obtained from the previous large-scale studies.

Table 15: Historical Per-Unit Energy Use Values for Comparison

	Per-Unit Energy Use for Indoor Lighting (kWh/ft² per year)		
Data Source	2006 03/The Energy Commission/California Commercial End Use Study (CEUS), Data Gathered 2000-2003	2012 01/Department of Energy/2010 U.S. Lighting Market Characterization	2014 08/CPUC/California Commercial Saturation Survey (CSS), Study Covered the Period from November 2011 to May 2013
All Commercial	3.92	-	-
Lodging	3.50	2.4	-
Office	-	4.1	2.4
Office Large (≥30,000 ft²)	4.46	-	-
Office Small (<30,000 ft²)	3.83	-	-
Restaurant	6.45	-	4.5
Food Service	-	5.4	-
Retail	6.05	6.3	3.7
School	2.88	2.5	1.5
Warehouse Non-Refrigerated	2.21	4.3	0.71

The results of per-unit energy savings calculations for 2019 Standards in kWh/ft² per year for the considered building types (using existing building stock as baseline) are presented in Figure 12 and Figure 13 for the following two cases:

- Currently required reductions of existing wattage under Option 3 (i.e., reduction by 35 or 50 percent of existing wattage depending on space type).
- Revised reduction of existing wattage under Option 3 (i.e., reduction by 50 percent for all space types per proposed measure).

The color-coded columns – "Percent Change between Option 1 and 3" and "Percent Change between Option 2 and 3" – indicate the level of parity among the three compliance pathways at the building level. Per communications with the Energy Commission staff, the goal is to have as much or more energy savings under Option 3 as compared to Option 2 on a kWh/ft² basis. A positive value and green

color in these last two columns indicate that the stated goal is met: a whole building lighting retrofit project compliant with Option 3 would deliver as much or more energy savings as the same project compliant with Option 2. A negative value and red color in these last two columns indicate that the stated goal is not met.

2019 STANDARDS Per-Unit and Statewide Energy Savings

Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 85-100% of 2019 LPA PER-UNIT ENERGY SAVINGS kWh/ft² per year	OPTION 2 ≤ 85% of 2019 LPA PER-UNIT ENERGY SAVINGS kWh/ft² per year	OPTION 3 Reduction of Existing Wattage PER-UNIT ENERGY SAVINGS kWh/ft² per year	Percent Change b/w OPTION 1 and 3	Percent Change b/w OPTION 2 and 3
1%	Hotel (excl. rooms)	0.80	1.0	1.3	66%	27%
28%	Office Large	0.66	0.80	0.91	36%	13%
8%	Office Small	0.79	0.88	0.93	17%	6%
4%	Restaurant	2.1	2.3	1.4	-32%	-38%
12%	Retail Large	1.3	1.7	1.8	44%	9%
12%	Retail Small	0.93	1.3	1.1	18%	-13%
13%	School	1.3	1.5	1.0	-18%	-29%
22%	Warehouse Non-Refrigerated	0.46	0.47	0.49	6%	4%
100%	**Weighted AVERAGE (by Building Type Stock)**	**0.87**	**1.05**	**0.99**	**14%**	**-5%**

Figure 12: Calculated 2019 Standards per-unit energy savings values for Option 1, 2, and 3 with wattage reduction of 35/50% under current Option 3.

Source: Lighting Alteration Model v2.0.

2019 STANDARDS Per-Unit and Statewide Energy Savings

Weights by Building Type Stock % of Considered Stock	Building Type	OPTION 1 85-100% of 2019 LPA PER-UNIT ENERGY SAVINGS kWh/ft² per year	OPTION 2 ≤ 85% of 2019 LPA PER-UNIT ENERGY SAVINGS kWh/ft² per year	OPTION 3 Reduction of Existing Wattage PER-UNIT ENERGY SAVINGS kWh/ft² per year	Percent Change b/w OPTION 1 and 3	Percent Change b/w OPTION 2 and 3
1%	Hotel (excl. rooms)	0.80	1.0	1.7	114%	63%
28%	Office Large	0.66	0.80	1.01	52%	26%
8%	Office Small	0.79	0.88	1.06	34%	21%
4%	Restaurant	2.1	2.3	2.2	4%	-6%
12%	Retail Large	1.3	1.7	1.9	54%	17%
12%	Retail Small	0.93	1.3	1.5	63%	20%
13%	School	1.3	1.5	1.5	17%	2%
22%	Warehouse Non-Refrigerated	0.46	0.47	0.69	51%	48%
100%	**Weighted AVERAGE (by Building Type Stock)**	**0.87**	**1.05**	**1.24**	**42%**	**18%**

Figure 13: Calculated 2019 Standards per-unit energy savings values for Option 1, 2, and 3 with the wattage reduction of 50% under proposed Option 3.

Source: Lighting Alteration Model v2.0.

See Appendix F for detailed model outputs for a specific building type and energy impact results for the measure that requires occupant sensing controls in stairwells under Option 3. See Appendix D for the results of calculations of demand savings.

5. LIFECYCLE COST AND COST-EFFECTIVENESS

This report explores opportunities for potential changes to Option 3 for compliance with nonresidential lighting alteration requirements. Option 3 is an alternative prescriptive pathway. Alternative pathways

do not need to be cost-effective, so a cost-effectiveness analysis was not completed for this report. The 2019 Title 24, Part 6 CASE Reports for nonresidential indoor lighting power densities and nonresidential indoor lighting controls explore the cost-effectiveness of the changes that affect the primary compliance pathway (Option 1).

6. FIRST-YEAR STATEWIDE IMPACTS

6.1 Statewide Energy Savings

The Statewide CASE Team calculated the first-year statewide savings by multiplying the per-unit savings by the statewide expected lighting alterations in 2020, which is presented in more detail in Appendix A.

Table 16 summarizes the expected reduction in annual statewide electricity use in gigawatt hours (GWh) and associated demand reduction in megawatt (MW) for two proposed measures. The statewide savings presented in this report are in addition to the savings presented in the two other 2019 CASE Reports that cover nonresidential indoor lighting.

Table 16: Statewide Energy and Energy Cost Impacts

Measure	Annual Floor Stock Subject to Alteration Code (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year[a] Peak Electrical Demand Reduction (MW)	First-Year[a] Natural Gas Savings (million therms)	Lifecycle Present Valued Energy Cost Savings (PV $ million)
Occupant Sensing Controls in Stairwells under Option 3	2.2[b]	0.29	0.035	N/A	Not Assessed
Reduction of Existing Wattage by 50% under Option 3	541	29.9	3.8	N/A	Not Assessed
Total		**30.2**	**3.8**		

a. First-year savings from all buildings altered statewide in 2020.

b. The estimated annual floor stock of stairwells subject to the lighting alteration code s is 9.6 million ft^2. The table lists the estimated stairwell floor stock, for which Option 3 would be used to comply with the lighting alteration code.

As noted earlier, the developed lighting alteration model serves two main purposes:

- Compares three compliance pathways in terms of potential energy savings using the existing building stock as baseline.
- Calculates incremental energy savings from the measure that requires the reduction of existing wattage by 50 percent under Option 3 (using proposed 2019 Standards with unchanged Option 3 as baseline).

Consequently, the Lighting Alteration Model v2.0 estimates statewide energy savings for two considered baselines: existing building stock and 2019 Standards with unchanged Option 3. The statewide energy savings using existing building stock are presented in Appendix G. The statewide energy savings for the measure that requires the reduction of existing wattage by 50 percent are presented in Figure 14.

Table 17 summarizes key points related to calculating statewide energy savings for proposed code changes.

INCREMENTAL ENERGY SAVINGS

2019 CASE Report on Nonresidential Lighting Alterations

Weights by Building Type Stock % of Considered Stock	Building Type	PER-UNIT ENERGY SAVINGS kWh/ft² per year	PER-UNIT DEMAND SAVINGS W/ft² per year	Annual Floor Stock Subject to Alteration Code million ft²	STATEWIDE ENERGY SAVINGS GWh per year	STATEWIDE DEMAND SAVINGS MW per year
1%	Hotel (excl. rooms)	0.09	0.010	7.4	0.65	0.07
28%	Office Large	0.02	0.003	159	3.78	0.44
8%	Office Small	0.03	0.003	42	1.28	0.12
4%	Restaurant	0.17	0.029	24	4.14	0.69
12%	Retail Large	0.03	0.005	77	2.23	0.37
12%	Retail Small	0.10	0.016	77	7.41	1.23
13%	School	0.10	0.010	57	5.88	0.56
22%	Warehouse Non-Refrigerated	0.05	0.003	98	4.56	0.32
100%					**29.9**	**3.8**

Figure 14: Statewide energy and demand savings from the measure that requires the reduction of existing wattage by 50% (using proposed 2019 Standards with unchanged Option 3 as base case).

Source: Lighting Alteration Model v2.0.

Table 17: Summary of Key Points on Statewide Energy Savings

Measure Description	Notes Related to Calculating Statewide Energy Savings
Clarify that lighting alteration projects that increase lighting power are subject to the lighting alteration code.	The energy savings were not calculated for this measure.
Reduce the number of luminaires from two to one per enclosed space in the existing exception to the lighting alteration code.	The energy savings were not calculated separately for this measure. Some energy savings are captured as part of another measure since the alteration model assumes that private offices that often have two luminaires installed are subject to the lighting alteration code.
Require partial OFF occupant sensing controls for stairwells under Option 3 (while continuing to exempt corridors from partial OFF occupant sensing controls under Option 3).	This measure results in statewide energy savings of 0.29 GWh per year. The per-unit energy savings were calculated using the Lighting Alteration Model v2.0. The statewide savings for this measure were calculated outside of the Lighting Alteration Model v2.0. See Appendix E for more details on the calculation methodology.
Require a reduction of *total* existing lighting wattage of altered luminaires by 50 percent of the rated wattage under Option 3 (rather than 50 percent for office, retail, and hotel and 35 percent for all other occupancies).	This measure results in the statewide energy savings of 29.9 GWh per year with assumptions in the Lighting Alteration Model v2.0 (see Figure 14).

6.2 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.3 Statewide Material Impacts

Material impacts were not considered in this analysis.

6.4 Other Non-Energy Impacts

Other non-energy impacts were not considered in this analysis.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The Statewide CASE Team worked closely with the Energy Commission to develop proposed language that drastically simplifies the code language for all types of lighting alterations (entire luminaire, luminaire component modification, and lighting wiring). The Energy Commission provided straw-man code language to use as a starting point for rewriting the entirety of Section 141.0(b)2I, J, and K. This language includes substantive changes that are not proposed and analyzed as part of, nor included in, this report.

The Statewide CASE Team then modified the Energy Commission's straw-man language, based on stakeholder feedback and the proposed measures evaluated in this report.

Given that most of the proposed code language for Section 141.0(b)2I, J, and K differs from the current 2016 Standards, and that the straw-man language developed by the Energy Commission is not otherwise included, Section 141.0 is provided below in two parts. Section 0 includes the proposed code language with underlining and ~~strikethroughs~~ to the relevant portions of the aforementioned straw-man language. Section 7.2 includes the current 2016 Standards language, for ease in comparing the proposed code language to 2016 Standards language.

The substantive changes that are not proposed and analyzed as part of this report, but are in the aforementioned straw-man language, include:

- Combining all types of lighting alterations distinguished in 2016 Title 24, Part 6 (entire luminaire, luminaire component modification, and lighting wiring) into a single category of lighting alterations.
- Introducing a universal threshold of 10 percent of altered luminaires to trigger the lighting alteration code for all types of lighting alterations.
- Changing the scope of the exception that is based on the number of altered luminaires to cover all types of lighting alterations (currently, only component modification projects altering 69 or fewer luminaires are exempt from the lighting alteration code in 2016 Title 24, Part 6).
- Introducing a single table with the lighting control requirements for all types of lighting alterations, thus changing some of the provisions for lighting wiring alterations that differ from the provisions for entire luminaire alterations and luminaire component modifications.
- Removing one of the criteria that triggers the lighting alteration code, i.e., the scenario of removing 10 percent or more of existing luminaires and reinstalling the same luminaires while adding, removing, or replacing walls or ceilings.

7.1 Proposed Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

[…]

LUMINAIRE ALTERATION is adding luminaires, removing and reinstalling luminaires, or combined replacement of lamps and ballasts or drivers. Luminaire alterations do not include repairs, such as replacing lamps only, ballasts or drivers only, diffusers, shades, or luminaire covers.

ONE-FOR-ONE ALTERATION is either replacement of whole luminaires one for one, in which the only electrical modification involves disconnecting the existing luminaire and reconnecting the replacement luminaire, or when components of a luminaire are modified without replacing the entire luminaire.

[…]

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

[…]

(c) **Shut-OFF Controls**

[…]

6. **Areas where full or partial OFF occupant sensing controls are required.** Lighting installed in the following areas shall meet the following requirements in addition to complying with Section 130.1(c)1.

   A. In aisle ways and open areas in warehouses, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the aisle way being controlled by the sensor.

      ~~**EXCEPTION 1 to Section 130.1(c)6A:** In aisle ways and open areas in warehouses in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce lighting power by at least 40 percent.~~

      ~~**EXCEPTION 2 to Section 130.1(c)6A:** When metal halide lighting or high pressure sodium lighting is installed in warehouses, occupant sensing controls shall reduce lighting power by at least 40 percent.~~

   B. Lighting installed in stairwells shall be controlled by occupant sensing controls that separately reduce the lighting power of each luminaire in each space by at least 50 percent when the space is unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated when entered from all designed paths of egress.

   C. Lighting installed in corridors ~~and stairwells~~ shall be controlled by occupant sensing controls that separately reduce the lighting power of each luminaire in each space by at least 50 percent when the space is unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated when entered from all designed paths of egress.

   ~~B~~ D. In library book stack aisles 10 feet or longer that are accessible from only one end, and library book stack aisles 20 feet or longer that are accessible from both ends, lighting

shall be controlled with occupant sensing controls that automatically reduce lighting power of each luminaire by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the aisle way being controlled by the sensor.

7. **Areas where partial OFF occupant sensing controls are required.** Lighting installed in the following areas shall meet the following requirements instead of complying with Section 130.1(c)1.

~~B~~A. In parking garages, parking areas and loading and unloading areas, general lighting shall be controlled by occupant sensing controls having at least one control step that reduces the lighting power of each controlled luminaire to between 20 percent and 50 percent of design lighting power. No more than 500 watts of rated lighting power shall be controlled together as a single zone. ~~A reasonably uniform level of illuminance shall be achieved in accordance with the applicable requirements in TABLE 130.1-A.~~ The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled ~~space~~ zone, and shall be automatically activated when entered from all designed paths of egress.

Interior areas of parking garages are classified as indoor lighting for compliance with Section 130.1(c)7B. Parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in Section 130.2.

~~**EXCEPTION to Section 130.1(c)7B:** Metal halide luminaires with a lamp plus ballast mean system efficacy of greater than 75 lumens per watt, used for general lighting in parking garages, parking areas and loading and unloading areas, shall be controlled by occupant sensing controls having at least one control step between 20 percent and 60 percent of design lighting power.~~

B. Lighting in stairwells that provide access to guestrooms and dwelling units of high-rise residential buildings and hotel/motels shall be controlled with occupant sensing controls that automatically reduce lighting power of each luminaire by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated when entered from all designed paths of egress.

~~A~~ C. Lighting in ~~stairwells and~~ common area corridors that provide access to guestrooms and dwelling units of high-rise residential buildings and hotel/motels shall be controlled with occupant sensing controls that automatically reduce lighting power of each luminaire by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated when entered from all designed paths of egress.

~~**EXCEPTION to Section 130.1(c)7A:** In corridors and stairwells in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce power by at least 40 percent.~~

[…]

SECTION 141.0 – ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS, TO EXISTING OUTDOOR LIGHTING, AND TO INTERNALLY AND EXTERNALLY ILLUMINATED SIGNS

[…]

(b) **Alterations.** Alterations to components of existing nonresidential, high-rise residential, hotel/motel, or relocatable public school buildings, including alterations made in conjunction with a change in building occupancy to a nonresidential, high-rise residential, or hotel/motel occupancy, shall meet item 1, and either Item 2 or 3 below:

[…]

2. Prescriptive approach.

[…]

I. **Altered Indoor Lighting Systems.** Alterations to indoor lighting systems that affect or include 10 percent or more of the luminaires serving an indoor space or that increase lighting power shall meet the requirements of either i, ii, or iii below:

i. OPTION 1: The alteration shall comply with the indoor lighting power requirements in Section 140.6, and the lighting control requirements specified in the Option 1 column of Table 141.0-E; or

ii. OPTION 2: The alteration shall not exceed ~~XX~~ 85 percent of the indoor lighting power requirements in Section 140.6, and shall comply with the lighting control requirements specified in the Option 2 column of Table 141.0-E; or

iii. OPTION 3: The alteration type shall be a one-for-one alteration within a building ~~or tenant space of XX square feet or less, shall have at least XX% lower rated power in the affected spaces compared to the system~~, and the total wattage of the altered luminaires shall be no greater than 50 percent of total rated wattage of these luminaires prior to the alteration. The rated wattage shall be calculated in accordance with Section 130.0. The alteration~~, and~~ shall comply with the lighting control requirements specified in the Option 3 column of Table 141.0-E.

Alterations to indoor lighting systems shall permit or incorporate the function of existing lighting controls. Alterations to indoor lighting systems are not required to ~~separate~~ control separately existing ~~shared~~ general, floor, wall, display, or ornamental lighting ~~circuits~~. Any new or complete replacement lighting circuits shall comply with the ~~separation~~ separate control requirements for different types of lighting in ~~of~~ Section 130.1(a)4 and 130.1(c)1D.

EXCEPTION 1 to Section 141.0(b)2I. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded as specified in Section 140.6(a)3.

EXCEPTION ~~3~~ 2 to Section 141.0(b)2I. Any alteration that would directly cause the disturbance of asbestos, unless the alteration is made in conjunction with asbestos abatement.

EXCEPTION ~~4~~ 3 to Section 141.0(b)2I. Acceptance testing requirements of Section 130.4 are not required for alterations where lighting controls are added to control 20 or fewer luminaires per project.

EXCEPTION ~~5~~ 4 to Section 141.0(b)2I. Any alteration limited solely to adding lighting controls or replacing lamps, ballasts, or drivers.

EXCEPTION ~~6~~ 5 to Section 141.0(b)2I. ~~For each tenant space, alteration of up to XX luminaires per floor of the tenant space, per annum.~~ Alteration, where 69 or less existing luminaires are modified, without increasing lighting power, either on any single floor of a building or, where multiple tenants inhabit the same floor, in any single tenant space, in any single calendar year.

EXCEPTION ~~2~~ 6 to Section 141.0(b)2I. Any enclosed space with only one luminaire where the alteration does not increase lighting power.

~~[…]~~

Table 141.0-E – Control Requirements for Indoor Lighting System Alterations

Control specifications		**OPTION 1: Projects complying with Section 141.0(b)2Ii**	**OPTION 2: Projects complying with Section 141.0(b)2Iii**	**OPTION 3: Projects complying with Section 141.0(b)2Iiii**
Manual Area Controls	130.1(a)1	Required	Required	Required
	130.1(a)2	Required	Required	Required
	130.1(a)3	Required	Required	Required
	130.1(a)4	~~Only r~~ Required for new or complete replacement circuits	~~Only r~~ Required for new or complete replacement circuits	~~Only r~~ Required for new or complete replacement circuits
Multi-Level Controls	130.1(b)	Required	One ~~C~~control ~~S~~step ~~B~~between 30% and 70% ~~R~~required for enclosed spaces > 100 ft^2 with a connected lighting load > 0.5 W/ft^2	Not Required
Automatic Shut-OFF Controls	130.1(c)1A-C	Required~~; 130.1(c)1D only required for new or complete replacement circuits~~	Required~~; 130.1(c)1D only required for new or complete replacement circuits~~	Required~~; 130.1(c)1D only required for new or complete replacement circuits~~
	130.1(c)1D	Required for new or complete replacement circuits	Required for new or complete replacement circuits	Required for new or complete replacement circuits
	130.1(c)2-5	Required	Required	Required
	~~130.1(c)3~~	~~Required~~	~~Required~~	~~Required~~
	~~130.1(c)4~~	~~Required~~	~~Required~~	~~Required~~
	~~130.1(c)5~~	~~Required~~	~~Required~~	~~Required~~
	130.1(c)6A, B	Required	Required	~~Partial OFF not required for corridors, stairwells, and library stack aisles~~ Required
	130.1(c)6C, D	Required	Required	Not Required
	130.1(c)7A, B	Required	Required	~~Partial OFF not required for corridors, stairwells~~ Required
	130.1(c)7C	Required	Required	Not Required
	130.1(c)8	Required	Required	Not Required
Automatic Daylighting Controls	130.1(d)	Required	Not Required	Not Required
Demand Responsive Controls	130.1(e)	Required when the area of all altered enclosed spaces > 10,000 ft^2 (excluding spaces with a lighting power density ≤ 0.5 W/ft^2)	Not Required	Not Required

7.2 Existing 2016 Title 24, Part 6 Standards

The existing 2016 Title 24, Part 6 Standards language is copied below for comparison with the changes for 2019 Title 24, Part 6 proposed language in the prior section. This existing code language is shown below without ~~strikethroughs~~ for ease of reading.

SECTION 141.0 – ADDITIONS, ALTERATIONS, AND REPAIRS TO EXISTING NONRESIDENTIAL, HIGH-RISE RESIDENTIAL, AND HOTEL/MOTEL BUILDINGS, TO EXISTING OUTDOOR LIGHTING, AND TO INTERNALLY AND EXTERNALLY ILLUMINATED SIGNS

[…]

(b) **Alterations**. Alterations to existing nonresidential, high-rise residential, or hotel/motel buildings, relocatable public school buildings or alterations in conjunction with a change in building occupancy to a nonresidential, high-rise residential, or hotel/motel occupancy are not subject to Subsection (a) and shall meet item 1, and either Item 2 or 3 below:

[…]

2. **Prescriptive approach**. The altered components of the envelope, or space conditioning, lighting, electrical power distribution and water heating systems, and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110.0 through 110.9, Sections 120.0 through 120.6, and Sections 120.9 through 130.5

[…]

I. **Entire Luminaire Alterations**. Entire luminaire alterations shall meet the following requirements:

i. For each enclosed space, alterations that consist of either (a) removing and reinstalling a total of 10 percent or more of the existing luminaires; or (b) replacing or adding entire luminaires; or (c) adding, removing, or replacing walls or ceilings along with any redesign of the lighting system, shall meet the lighting power allowance in Section 140.6, and the altered luminaires shall meet the applicable requirements in Table 141.0-E; or

ii. For alterations where existing luminaires are replaced with new luminaires, and that do not include adding, removing, or replacing walls or ceilings along with redesign of the lighting system, the replacement luminaires in each office, retail, and hotel occupancy shall have at least 50 percent, and in all other occupancies at least 35 percent, lower rated power at full light output compared to the existing luminaires being replaced, and shall meet the requirements of Sections 130.1(a)1, 2, and 3, 130.1(c)1A through C, 130.1(c)2, 130.1(c)3, 130.1(c)4, 130.1(c)5, 130.1(c)6A, and for parking garages 130.1(c)7B.

EXCEPTION 1 to Section 141.0(b)2I. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded as specified in Section 140.6(a)3.

EXCEPTION 2 to Section 141.0(b)2I. In an enclosed space where two or fewer luminaires are replaced or reinstalled.

EXCEPTION 3 to Section 141.0(b)2I. Alterations that would directly cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2I. Acceptance testing requirements of Section 130.4 are not required for alterations where lighting controls are added to control 20 or fewer luminaires.

J. **Luminaire Component Modifications**. Luminaire component modifications in place that include replacing the ballasts or drivers and the associated lamps in the luminaire, permanently changing the light source of the luminaire, or changing the optical system of the luminaire, where 70 or more

existing luminaires are modified either on any single floor of a building or, where multiple tenants inhabit the same floor, in any single tenant space, in any single year, shall not prevent or disable the operation of any multi-level, shut-off, or daylighting controls, and shall:

i. Meet the lighting power allowance in Section 140.6 and comply with Table 141.0-E; or

ii. In office, retail, and hotel occupancies have at least 50 percent, and in all other occupancies have at least 35 percent, lower rated power at full light output as compared to the original luminaires prior to being modified, and meet the requirements of Sections 130.1(a)1, 2, and 3, 130.1(c)1A through C, 130.1(c)2, 130.1(c)3, 130.1(c)4, 130.1(c)5, 130.1(c)6A, and for parking garages 130.1(c)7B.

Lamp replacements alone and ballast replacements alone shall not be considered a modification of the luminaire provided that the replacement lamps or ballasts are installed and powered without modifying the luminaire.

EXCEPTION 1 to Section 141.0(b)2J. Modification of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by Section 140.6(a)3.

EXCEPTION 2 to Section 141.0(b)2J. In an enclosed space where two or fewer luminaires are modified.

EXCEPTION 3 to Section 141.0(b)2J. Modifications that would directly cause the disturbance of asbestos, unless the modifications are made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2J. Acceptance testing requirements of Section 130.4 are not required for modifications where lighting controls are added to control 20 or fewer luminaires.

K. **Lighting Wiring Alterations**. For each enclosed space, wiring alterations that add a circuit feeding luminaires; that replace, modify, or relocate wiring between a switch or panelboard and luminaires; or that replace lighting control panels, panelboards, or branch circuit wiring; shall:

i. meet the lighting power allowance in Section 140.6;

ii. meet the requirements in Sections 130.1(a)1, 2, and 3, 130.1(c)1A through C, 130.1(c)3, and 130.1(c)4;

iii. for each enclosed space, be wired to create a minimum of one step between 30-70 percent of lighting power or meet Section 130.1(b); and

iv. for each enclosed space where wiring alterations include 10 or more luminaires that provide general lighting within the primary sidelit daylit zone or the skylit daylit zone, meet the requirements of 130.1(d).

NOTE: As specified in Section 141.0(b)2I, alterations that include adding, removing, or replacing walls or ceilings resulting in redesign of the lighting system shall meet the requirements of Table 141.0-E.

EXCEPTION 1 to Section 141.0(b)2K. Alterations strictly limited to addition of lighting controls.

EXCEPTION 2 to Section 141.0(b)2K. In an enclosed space where wiring alterations involve two or fewer luminaires.

EXCEPTION 3 to Section 141.0(b)2K. Alterations that would directly cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.

EXCEPTION 4 to Section 141.0(b)2K. Acceptance testing requirements of Section 130.4 are not required for wiring alterations where lighting controls are added to control 20 or fewer luminaires.

[…]

TABLE 141.0-E CONTROL REQUIREMENTS FOR ENTIRE LUMINAIRE ALTERATIONS

Control requirements that shall be met	Resulting lighting power, compared to the lighting power allowance specified in Section 140.6(c)2, Area Category Method	
	Lighting power is ≤ 85% of allowance	Lighting power is > 85% to 100% of allowance
Section 130.1(a)1, 2, and 3 Area Controls	Yes	Yes
Section 130.1(b) Multi-Level Lighting Controls – only for alterations to general lighting of enclosed spaces 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per square foot	For each enclosed space, minimum one step between 30-70 percent of lighting power regardless of luminaire type, or meet Section 130.1(b)	Yes
Section 130.1(c) Shut-Off Controls	Yes	Yes
Section 130.1(d) Automatic Daylight Controls	Not Required	Yes
Section 130.1(e) Demand Responsive Controls – only for alterations > 10,000 ft^2 in a single building, where the alteration also changes the area of the space, or changes the occupancy type of the space, or increases the lighting power	Not Required	Yes

7.3 Reference Appendices

There are no proposed changes to the Reference Appendices to reflect the proposed changes in this CASE Report.

7.4 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual to reflect the proposed changes in this CASE Report.

7.5 Compliance Manuals

Chapter 5.9 of the Nonresidential Compliance Manual will need to be revised.

7.6 Compliance Documents

The indoor lighting existing conditions certificate of compliance document (NRCC-LTI-06-E) will need to be revised.

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Appendix A: STATEWIDE SAVINGS METHODOLOGY

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide new construction estimates for 2020, the first year the standards will be in effect. The Energy Commission Demand Analysis Office provided the Statewide CASE Team with the nonresidential new construction forecast. The raw data presented annual total building stock and new construction estimates for twelve building types by forecast climate zones (FCZ). The building types included in the Energy Commission's forecast are summarized in Table 18. The Statewide CASE Team completed the following steps to refine the data and develop estimates of statewide floor space that will be impacted by the proposed code changes:

1. Translated data from FCZ data into building standards climate zones (BSCZ). Since Title 24, Part 6 uses BSCZ, the Statewide CASE Team converted the construction forecast from FCZ to BSCZ using conversion factors supplied by the Energy Commission. The conversion factors, which are presented in Table 20, represent the percentage of building square footage in FCZ that is also in BSCZ. For example, looking at the first column of conversion factors in Table 20, 22.5 percent of the building square footage in FCZ 1 is also in BSCZ 1 and 0.1 percent of building square footage in FCZ 4 is in BSCZ 1. To convert from FCZ to BSCZ, the total forecasted construction for a specific building type in each FCZ was multiplied by the conversion factors for BSCZ 1, then all square footage from all FCZs that are found to be in BSCZ 1 are summed to arrive at the total construction for that building type in BSCZ 1. This process was repeated for every climate zone and every building type. See Table 21 for an example calculation to convert from FCZ to BSCZ. In this example, construction BSCZ 1 is made up of building floor space from FCZs 1, 4, and 14.
2. Redistributed square footage allocated to the "Miscellaneous" building type. The building types included in the Energy Commissions' forecast are summarized in Table 18. The Energy Commission's forecast allocated 18.5 percent of the total square footage from the nonresidential existing building stock in 2020 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements will apply to the miscellaneous building types, and savings will be realized from this floor space. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types in such a way that the percentage of building floor space in each climate zone, net of the miscellaneous square footage, will remain constant.

Table 18: Description of Building Types and Subtypes (Prototypes) in Statewide Construction Forecast

Energy Commission Building Type ID	Energy Commission Description	Prototype Description			
		Prototype ID	Floor Area (ft^2)	Stories	Notes
OFF-SMALL	Offices less than 30,000 square feet	Small Office	5,502	1	Five zone office model with unconditioned attic and pitched roof.
REST	Any facility that serves food	Small Restaurant	2,501	1	Similar to a fast food restaurant with a small kitchen and dining areas.
RETAIL	Retail stores and shopping centers	Stand-Alone Retail	24,563	1	Stand-alone store similar to Walgreens or Banana Republic.
		Large Retail	240,000	1	Big box retail building, similar to a Target or Best Buy store.
		Strip Mall	9,375	1	Four-unit strip mall retail building. West end unit is twice as large as other three.
		Mixed-Use Retail	9,375	1	Four-unit retail representing the ground floor units in a mixed-use building. Same as the strip mall with adiabatic ceilings.
FOOD	Any service facility that sells food and or liquor	N/A	N/A	N/A	N/A
NWHSE	Non-refrigerated warehouses	Warehouse	49,495	1	High ceiling warehouse space with small office area.
RWHSE	Refrigerated warehouses	N/A	N/A	N/A	N/A
SCHOOL	Schools K-12, not including colleges	Small School	24,413	1	Similar to an elementary school with classrooms, support spaces and small dining area.
		Large School	210,886	2	Similar to high school with classrooms, commercial kitchen, auditorium, gymnasium and support spaces.
COLLEGE	Colleges, universities, community colleges	Small Office	5,502	1	Five zone office model with unconditioned attic and pitched roof.
		Medium Office	53,628	3	Five zones per floor office building with plenums on each floor.
		Medium Office/Lab		3	Five zones per floor building with a combination of office and lab spaces.
		Public Assembly		2	TBD
		Large School	210,886	2	Similar to high school with classrooms, commercial kitchen, auditorium, gymnasium and support spaces.
		High Rise Apartment	93,632	10	75 residential units along with common spaces and a penthouse. Multipliers are used to represent typical floors.
HOSP	Hospitals and other health-related facilities	N/A	N/A	N/A	N/A
HOTEL	Hotels and motels	Hotel	42,554	4	Hotel building with common spaces and 77 guest rooms.
MISC	All other space types that do not fit another category	N/A	N/A	N/A	N/A
OFF-LRG	Offices larger than 30,000 square feet	Medium Office	53,628	3	Five zones per floor office building with plenums on each floor.
		Large Office	498,589	12	Five zones per floor office building with plenums on each floor. Middle floors represented using multipliers.

Table 19: Estimated Existing Nonresidential Floor Space in 2020, by Climate Zone and Building Type (million ft^2)

Climate Zone	Existing Floor Space in 2020 (million ft^2)											
	Small Office	Restaurant	Retail	Food	Non-Refrigerated Warehouse	Refrigerated Warehouse	School	College	Hospital	Hotel	Large Office	TOTAL
1	2.7	0.9	4.8	1.6	2.4	0.1	3.5	1.8	2.1	0.3	3	**23**
2	12	4.5	36	9.6	25	2.0	20	11	13	2.6	42	**179**
3	39	18	151	35	132	9.1	77	45	53	12	254	**825**
4	28	10	88	23	60	5.1	45	25	32	5.9	99	**420**
5	5.4	2.0	17	4.4	12	1.0	8.8	4.8	6.2	1.1	19	**82**
6	39	26	152	38	141	5.7	67	38	40	8.4	186	**739**
7	45	13	92	28	61	0.6	44	24	33	7.8	101	**449**
8	53	37	216	54	198	7.9	94	52	59	12	270	**1,053**
9	48	39	209	51	188	6.4	84	55	71	12	325	**1,088**
10	57	37	181	50	194	3.7	87	36	42	8.3	97	**794**
11	15	4.3	32	11	35	4.1	22	8.9	13	1.4	16	**162**
12	75	21	179	47	160	12	92	42	63	9.3	176	**877**
13	32	9.6	69	23	59	10	49	18	27	3.0	28	**330**
14	9.4	7.0	35	9.3	36	1.1	16	6.4	8.4	1.4	23	**153**
15	12	4.6	28	9.4	35	0.9	14	4.1	5.6	1.4	11	**126**
16	12	7.2	42	11	33	1.8	18	11	12	1.8	47	**196**
TOTAL	**484**	**241**	**1,532**	**406**	**1,372**	**72**	**741**	**382**	**482**	**89**	**1,695**	**7,495**

Table 20: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ)

		Building Standards Climate Zone (BSCZ)																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Forecast Climate Zone (FCZ)	**1**	22.5%	20.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	33.1%	0.2%	0.0%	0.0%	13.8%	**100%**
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	75.7%	0.0%	0.0%	0.0%	2.3%	**100%**
	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.9%	22.8%	54.5%	0.0%	0.0%	1.8%	**100%**
	4	0.1%	13.7%	8.4%	46.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%	0.0%	0.0%	0.0%	**100%**
	5	0.0%	4.2%	89.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%	0.0%	0.0%	**100%**
	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	**100%**
	7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.8%	7.1%	0.0%	17.1%	**100%**
	8	0.0%	0.0%	0.0%	0.0%	0.0%	40.1%	0.0%	50.8%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	**100%**
	9	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	26.9%	54.8%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%	5.8%	**100%**
	10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	74.9%	0.0%	0.0%	0.0%	12.3%	7.9%	4.9%	**100%**
	11	0.0%	0.0%	0.0%	0.0%	0.0%	27.0%	0.0%	30.6%	42.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**100%**
	12	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	4.2%	95.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	**100%**
	13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.6%	0.0%	0.0%	28.8%	0.0%	0.0%	0.0%	1.6%	0.1%	0.0%	**100%**
	14	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.1%	**100%**
	15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	99.9%	0.0%	**100%**
	16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	**100%**

Table 21: Converting from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ) – Example Calculation

Climate Zone	Total Statewide Small Office Square Footage in 2020 by FCZ (million ft^2) **[A]**	Conversion Factor FCZ to BSCZ 1 **[B]**	Small Office Square Footage in BSCZ 1 (million ft^2) **[C] = A x B**
1	0.204	22.5%	0.046
2	0.379	0.0%	0.000
3	0.857	0.0%	0.000
4	1.009	0.1%	0.001
5	0.682	0.0%	0.000
6	0.707	0.0%	0.000
7	0.179	0.0%	0.000
8	1.276	0.0%	0.000
9	0.421	0.0%	0.000
10	0.827	0.0%	0.000
11	0.437	0.0%	0.000
12	0.347	0.0%	0.000
13	1.264	0.0%	0.000
14	0.070	2.9%	0.002
15	0.151	0.0%	0.000
16	0.035	0.0%	0.000
Total	**8.844**		**0.049**

Table 22: Example of Redistribution of Miscellaneous Category - 2020 New Construction in Climate Zone 1

Building Type	**2020 Forecast** (million ft^2) **[A]**	**Distribution Excluding Miscellaneous Category** **[B]**	**Redistribution of Miscellaneous Category** (million ft^2) **[C] = B × 0.11**	**Revised 2020 Forecast** (million ft^2) **[D] = A + C**
Small Office	0.049	12%	0.013	0.062
Restaurant	0.016	4%	0.004	0.021
Retail	0.085	20%	0.022	0.108
Food	0.029	7%	0.008	0.036
Non-Refrigerated Warehouse	0.037	9%	0.010	0.046
Refrigerated Warehouse	0.002	1%	0.001	0.003
Schools	0.066	16%	0.017	0.083
College	0.028	7%	0.007	0.035
Hospital	0.031	7%	0.008	0.039
Hotel/Motel	0.025	6%	0.007	0.032
Miscellaneous	**0.111**	---	-	---
Large Offices	0.055	13%	0.014	0.069
Total	0.534	100%	**0.111**	0.534

Table 23: Percent of Floor Space Impacted by Proposed Measure (Reduction of Existing Wattage by 50%), by Building Type

Building Type *Building Sub-Type*	**Composition of Building Type by Sub-Types**[a]	**Percent of Square Footage Included in Existing Building Stock (Alterations)**[b]
Small Office		100%
Restaurant		100%
Retail		100%
Stand-Alone Retail	*10%*	100%
Large Retail	*75%*	100%
Strip Mall	*5%*	100%
Mixed-Use Retail	*10%*	100%
Food		100%
Non-Refrigerated Warehouse		100%
Refrigerated Warehouse		100%
Schools		100%
Small School	*60%*	100%
Large School	*40%*	100%
College[c]		100%
Small Office	*5%*	100%
Medium Office	*15%*	100%
Medium Office/Lab	*20%*	100%
Public Assembly	*5%*	100%
Large School	*30%*	100%
High Rise Apartment	*25%*	100%
Hospital		100%
Hotel/Motel[d]		20%
Large Offices		100%
Medium Office	*50%*	100%
Large Office	*50%*	100%

a. Presents the assumed composition of the main building type category by the building subtypes. All 2019 CASE Reports assumed the same percentages of building subtypes except for retail building type category. The Lighting Alteration Model v2.0 assumes 50/50% split between large and small retail (where small retail is composed of stand-alone retail, strip mall, and mixed-use retail).

b. When the building type is composed of multiple subtypes, the overall percentage for the main building category was calculated by weighing the contribution of each subtype.

c. Floor space for Small Office subtype was added to Office Small building type in the Lighting Alteration Model v2.0; floor space for Medium Office subtype was added to Office Large building type; and floor space for Large School subtype was added to School building type.

d. Only 20% of floor space for Hotel building type was used in the Lighting Alteration Model v2.0 since the DEER2016 hotel profile assigns 80% of the total area to guest rooms that are not subject to nonresidential Title 24, Part 6 code.

Further, note that the energy savings from the newly proposed 2019 LPD levels for lighting alterations are captured in the 2019 CASE Report on nonresidential indoor lighting power densities.

Table 24 summarizes the key differences in the assumptions between the two 2019 CASE Reports – nonresidential indoor lighting alterations and nonresidential indoor lighting power densities – when calculating energy savings for lighting alterations.

Table 24: Differences in Key Assumptions in the 2019 CASE Reports (Alterations and Indoor Lighting Power Densities) to Calculate Energy Savings from Nonresidential Lighting Alterations

	2019 CASE Report – Nonresidential Indoor Lighting Alterations (the reduction of wattage by 50 percent under proposed Option 3)	**2019 CASE Report – Nonresidential Indoor Lighting Power Densities**
Baseline	• Proposed 2019 Title 24, Part 6 LPD levels for area categories with Option 3 in accordance with Title 24, Part 6 2016. • DEER2014 lighting schedules.	• 2016 Title 24, Part 6 LPD levels for area categories. • CASE Report only captures incremental savings from 2016 to 2019 code cycle. • 2016 CBECC-Com ACM lighting schedules.
Considered Compliance Pathways	• "85-100% of LPA" option; • "≤ 85% of LPA" option; and • "Reduction of existing wattage" option.	• "85-100% LPA" option (the primary option); not accounting for lighting controls.
Annual Rate of Lighting Retrofits	• Rate of lighting retrofits varies depending on the building type.	• 1/15 (~7%) of building stock per year (retrofitting lighting once in 15 years).

Appendix B: DESCRIPTIONS OF BUILDING PROTOTYPES

To develop estimates of per-unit energy use under three compliance pathways, the Statewide CASE Team relied on detailed DEER prototypes and DEER 24-hour lighting schedule profiles. The lighting alteration model allows the use of either DEER2014 or DEER2016 as baseline lighting schedules. Note that the results presented in this report are based on DEER2014 baseline lighting schedules.

DEER is a database sponsored by the Energy Commission and CPUC. DEER provides well-documented estimates of energy and peak demand savings for various energy efficiency measures. To estimate these savings, DEER authors developed a set of 23 representative commercial building prototypes as DOE 2.2 (eQuest) simulation models.

A report prepared by Itron provides a detailed account of all assumptions built into the DEER prototypes (Itron, Inc. 2005). The report cites the following resources used in development of the prototypes:

- Final Report on Technology Energy Savings, Volume II: Building Prototypes prepared for The California Conservation Inventory Group by Neos Corporation, 1994;
- CaNCCalc Building Energy Efficiency Measure Analysis Software (NCC) developed by James J. Hirsch & Associates for the Savings by Design new construction energy efficiency program, offered by California's IOUs as authorized by the CPUC;
- High Performance Commercial Building Systems, Element 6, Project 2.1, Relocatable Classroom DOE-2 Analysis Report prepared by Davis Energy Group, Inc. for the California Energy Commission, Public Interest Energy Research Program, 2002; and
- Detailed site data from 2004-05 EM&V studies monitored data (logger data).

The lighting alteration model uses DEER data for the following building types:

- Hotel;
- Office Large;
- Office Small;
- Restaurant;
- Retail Large;
- Retail Small;
- School; and
- Warehouse (combination of skylit and non-skylit prototypes).

Each building prototype consists of space types that represent typical spaces found in that building type. Further information about windows and skylights for each prototype was required to calculate savings from automatic daylighting controls. The DEER dataset provides information about window to wall ratios for a building. DEER information was augmented with further information about window orientation, and window and skylit visible lighting transmittance for the prototypes, by referencing Pacific Northwest National Laboratory Commercial Building Prototypes.

Office Large Building Prototype

The Office Large prototype was modified to split "corridor/stairway" area category into two area categories – corridor (55%) and stairway (45%) – to calculate per-unit energy savings from a proposed measure to require occupant sensing controls in stairwells under Option 3.

Retail Large Building Prototype

The Retail Large prototype was modified to include two new space types, Corridor and Office Small, that were originally not part of the DEER2016 space type descriptions. The corridor space type was added as a two percent area fraction (reducing the retail sales area from 58 percent to 56 percent) and the Office Small was added as a four percent area fraction (reducing the Office General from eight percent to four percent).

Warehouse Building Prototype

The Warehouse prototype was modeled as two versions, a non-skylit and skylit version. Unlike the skylit version, the non-skylit version had no skylights in the "Warehouse Unconditioned" space type.

Figure 15 through Figure 23 list the assumptions used for each considered building type.

							Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)								
Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	WWR North	WWR South	WWR East	WWR West	SFR	Window VLT	Skylight VLT	Light Well	Racks/Shelves
Hotel	Dining	0.9%	9	22%	100	30%	22%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	GuestRmCorrid	10.1%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	GuestRmOcc	60.2%	9	22%	50	20%	22%	22%	22%	22%	0%	VT: 40%	NA	NA	NA
	HotelLobby	4.1%	9	22%	100	50%	22%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	Kitchen	0.5%	9	0%	500	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Laundry	2.1%	9	0%	300	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	BarCasino	0.5%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	OfficeGeneral	1.0%	9	22%	300	20%	22%	22%	22%	22%	0%	VT: 40%	NA	NA	NA
	RestRoom	0.5%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	StockRoom	0.0%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	GuestRmUnOcc	20.1%	9	22%	50	20%	22%	22%	22%	22%	0%	VT: 40%	NA	NA	NA

Figure 15: Hotel building prototype.

							Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)								
Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	WWR North	WWR South	WWR East	WWR West	SFR	Window VLT	Skylight VLT	Light Well	Racks/Shelves
Office Large	OfficeOpen	46.0%	9	33%	300	10%	33%	33%	33%	33%	0%	VT: 40%	NA	NA	NA
	OfficeSmall	20.4%	9	33%	300	50%	33%	33%	33%	33%	0%	VT: 40%	NA	NA	NA
	CorridorStairway	13.4%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	StorageSmlCond	4.7%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	LobbyWaiting	3.9%	9	33%	200	20%	33%	33%	0%	0%	0%	VT: 40%	NA	NA	NA
	Conference	3.2%	9	33%	300	10%	33%	33%	33%	33%	0%	VT: 40%	NA	NA	NA
	Restroom	3.0%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Break	2.5%	9	33%	100	20%	33%	33%	33%	33%	0%	VT: 40%	NA	NA	NA
	MechElecRoom	1.9%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	CopyRoom	1.0%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 16: Office Large building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
Office Small	OfficeOpen	35.7%	9	33%	300	20%	33%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	OfficeSmall	24.7%	9	33%	300	50%	33%	33%	33%	33%	0%	VT: 40%	NA	NA	NA
	StorageSmlCond	9.8%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Hall	6.4%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	LobbyWaiting	5.9%	9	33%	200	20%	33%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	Conference	5.7%	9	33%	300	10%	33%	33%	0%	0%	0%	VT: 40%	NA	NA	NA
	Restroom	4.3%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Break	3.7%	9	33%	100	30%	33%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	MechElecRoom	1.6%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	CompRoomData	1.3%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	CopyRoom	1.0%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 17: Office Small building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
Restaurant	Dining	41.5%	10	11%	100	30%	11%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	Kitchen	32.7%	10	0%	500	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	StockRoom	8.3%	10	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	LobbyWaiting	6.8%	10	11%	200	50%	11%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	Restroom	5.7%	10	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	OfficeGeneral	3.5%	10	11%	300	20%	11%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	CorridorStairway	1.5%	10	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 18: Restaurant building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
Retail Large	RetailSales	56.0%	20.5	3%	400	10%	3%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	Corridor	2.0%	20.5	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	StockRoom	14.8%	20.5	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Work	13.6%	20.5	3%	300	20%	3%	3%	0%	0%	0%	VT: 40%	NA	NA	NA
	OfficeGeneral	4.0%	20.5	3%	300	20%	3%	3%	0%	0%	0%	VT: 40%	NA	NA	NA
	OfficeSmall	4.0%	20.5	3%	300	20%	3%	3%	0%	0%	0%	VT: 40%	NA	NA	NA
	Restroom	3.0%	20.5	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Break	2.0%	20.5	3%	100	30%	3%	3%	0%	0%	0%	VT: 40%	NA	NA	NA
	MechElecRoom	0.4%	20.5	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 19: Retail Large building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
Retail Small	RetailSales	49.0%	12	25%	400	10%	25%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	StockRoom	32.0%	12	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Hall	2.0%	12	25%	300	20%	25%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	OfficeGeneral	11.0%	12	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Restroom	3.0%	12	25%	100	30%	25%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	Break	2.0%	12	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	MechElecRoom	1.0%	12	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 20: Retail Small building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
School	Classroom	56.1%	9	18%	400	20%	18%	18%	18%	18%	0%	VT: 40%	NA	NA	NA
	Gymnasium	8.4%	9	18%	300	30%	18%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	OfficeGeneral	8.0%	9	18%	300	10%	18%	0%	18%	0%	0%	VT: 40%	NA	NA	NA
	Kitchen	5.1%	9	0%	500	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	RestRoom	4.9%	9	18%	50	10%	0%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	LibraryReading	4.3%	9	18%	400	10%	0%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	StorageSmlCond	3.7%	9	0%	100	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	CorridorStairway	3.7%	9	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	Dining	3.2%	9	18%	100	30%	18%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	CompRoomClassrm	1.4%	9	18%	300	20%	18%	0%	0%	0%	0%	VT: 40%	NA	NA	NA
	LobbyWaiting	1.3%	9	0%	200	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 21: School building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
Warehouse (Non-Skylit)	WarehouseUnCond	92.2%	48	0%	100	50%	0%	0%	0%	0%	0%	NA	NA	NA	NA
	OfficeGeneral	6.7%	48	1%	300	20%	1%	1%	1%	0%	0%	VT: 40%	NA	NA	NA
	RestRoom	1.1%	48	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 22: Warehouse (non-skylit) building prototype.

Building Type	Space Type	Area Fraction	Ceiling Ht	WWR	Setpoint (lux)	% Area in Daylit Zone	Window to Wall Ratio (WWR) & Skylight to Floor Ratio (SFR)					Window VLT	Skylight VLT	Light Well	Racks/Shelves
							WWR North	WWR South	WWR East	WWR West	SFR				
Warehouse (Skylit)	WarehouseUnCond	92.2%	48	0%	100	50%	0%	0%	0%	0%	3%	VT: 40%	VT: 50%	2 ft	33.6
	OfficeGeneral	6.7%	48	1%	300	20%	1%	1%	1%	0%	0%	VT: 40%	NA	NA	NA
	RestRoom	1.1%	48	0%	50	0%	0%	0%	0%	0%	0%	NA	NA	NA	NA

Figure 23: Warehouse (skylit) building prototype.

Note About DEER2014 and DEER2016 Mapping of Activity Areas

In DEER2016, additional activity areas were introduced. To take advantage of a more granular breakdown of building area by activity areas in DEER2016, the Statewide CASE Team mapped DEER2016 and DEER2014 activity areas. Based on this mapping, the DEER2014 lighting schedule profiles were assigned to activity areas that were introduced in DEER2016. Figure 24 shows the mapping.

In the Lighting Alteration Model v2.0, when a user selects the DEER2016 setting for baseline lighting schedules, DEER2016 activity areas and DEER2016 baseline lighting schedules are used in the model. When a user selects DEER2014 setting, mapping between DEER2014 and DEER2016 is applied to match the most appropriate DEER2014 baseline lighting schedules to DEER2016 activity areas.

DEER2016 MAPPED TO DEER2014 SPACES		
Building Type	**DEER2016**	**DEER2014**
Hotel	2016_HTL_Dining	2014_HTL_Dining Area
	2016_HTL_GuestRmCorrid	2014_HTL_Corridor
	2016_HTL_GuestRmOcc	2014_HTL_Hotel/Motel Guest Room (Includes Toilets) - Occupied
	2016_HTL_HotelLobby	2014_HTL_Lobby (Hotel)
	2016_HTL_Kitchen	2014_HTL_Kitchen and Food Preparation
	2016_HTL_Laundry	2014_HTL_Laundry
	2016_HTL_BarCasino	2014_HTL_Bar, Cocktail Lounge
	2016_HTL_OfficeGeneral	2014_HTL_Office (General)
	2016_HTL_RestRoom	2014_HTL_Lobby (Hotel)
	2016_HTL_StockRoom	2014_HTL_Office (General)
	2016_HTL_GuestRmUnOcc	2014_HTL_Hotel/Motel Guest Room (Includes Toilets) - Unoccupied
Office Large	2016_OFL_OfficeOpen	2014_OFL_Office (Open Plan)
	2016_OFL_OfficeSmall	2014_OFL_Office (Executive/Private)
	2016_OFL_CorridorStairway	2014_OFL_Corridor
	2016_OFL_StorageSmlCond	2014_OFL_Mechanical/Electrical Room
	2016_OFL_LobbyWaiting	2014_OFL_Lobby (Office Reception/Waiting)
	2016_OFL_Conference	2014_OFL_Conference Room
	2016_OFL_Restroom	2014_OFL_Restrooms
	2016_OFL_Break	2014_OFL_Conference Room
	2016_OFL_MechElecRoom	2014_OFL_Mechanical/Electrical Room
	2016_OFL_CopyRoom	2014_OFL_Copy Room (Photocopying Equipment)
Office Small	2016_OFS_OfficeOpen	2014_OFS_Office (Executive/Private)
	2016_OFS_OfficeSmall	2014_OFS_Office (Executive/Private)
	2016_OFS_StorageSmlCond	2014_OFS_Copy Room (Photocopying Equipment)
	2016_OFS_Hall	2014_OFS_Corridor
	2016_OFS_LobbyWaiting	2014_OFS_Lobby (Office Reception/Waiting)
	2016_OFS_Conference	2014_OFS_Conference Room
	2016_OFS_Restroom	2014_OFS_Restrooms
	2016_OFS_Break	2014_OFS_Conference Room
	2016_OFS_MechElecRoom	2014_OFS_Mechanical/Electrical Room
	2016_OFS_CompRoomData	2014_OFS_Copy Room (Photocopying Equipment)
	2016_OFS_CopyRoom	2014_OFS_Copy Room (Photocopying Equipment)
Restaurant	2016_RES_Dining	2014_RES_Dining Area
	2016_RES_Kitchen	2014_RES_Kitchen and Food Preparation
	2016_RES_Restroom	2014_RES_Restrooms
	2016_RES_StockRoom	2014_RES_Lobby (Main Entry and Assembly)
	2016_RES_OfficeGeneral	2014_RES_Lobby (Main Entry and Assembly)
	2016_RES_LobbyWaiting	2014_RES_Lobby (Main Entry and Assembly)
	2016_RES_CorridorStairway	2014_RES_Lobby (Main Entry and Assembly)
Retail Large	2016_RTL_RetailSales	2014_RTL_Retail Sales and Wholesale Showroom
	2016_RTL_StockRoom	2014_RTL_Storage (Conditioned)
	2016_RTL_Work	2014_RTL_Auto Repair Workshop
	2016_RTL_OfficeGeneral	2014_RTL_Office (General)
	2016_RTL_Restroom	2014_RTL_Office (General)
	2016_RTL_Break	2014_RTL_Office (General)
	2016_RTL_MechElecRoom	2014_RTL_Storage (Conditioned)
Retail Small	2016_RTS_RetailSales	2014_RTS_Retail Sales and Wholesale Showroom
	2016_RTS_StockRoom	2014_RTS_Storage (Conditioned)
	2016_RTS_Hall	2014_RTS_Retail Sales and Wholesale Showroom
	2016_RTS_OfficeGeneral	2014_RTS_Retail Sales and Wholesale Showroom
	2016_RTS_Restroom	2014_RTS_Retail Sales and Wholesale Showroom
	2016_RTS_Break	2014_RTS_Retail Sales and Wholesale Showroom
	2016_RTS_MechElecRoom	2014_RTS_Storage (Conditioned)
School	2016_SCH_Classroom	2014_SCH_Classroom/Lecture
	2016_SCH_Gymnasium	2014_SCH_Exercising Centers and Gymnasium
	2016_SCH_OfficeGeneral	2014_SCH_Classroom/Lecture
	2016_SCH_Kitchen	2014_SCH_Kitchen and Food Preparation
	2016_SCH_RestRoom	2014_SCH_Classroom/Lecture
	2016_SCH_LibraryReading	2014_SCH_Classroom/Lecture
	2016_SCH_StorageSmlCond	2014_SCH_Classroom/Lecture
	2016_SCH_CorridorStairway	2014_SCH_Classroom/Lecture
	2016_SCH_Dining	2014_SCH_Dining Area
	2016_SCH_CompRoomClassrm	2014_SCH_Classroom/Lecture
	2016_SCH_LobbyWaiting	2014_SCH_Classroom/Lecture
Warehouse	2016_WHS_WarehouseUnCond	2014_WHS_Storage (Unconditioned)
	2016_WHS_OfficeGeneral	2014_WHS_Storage (Unconditioned)
	2016_WHS_RestRoom	2014_WHS_Storage (Unconditioned)

Black color indicates exact match.

Red color indicates a 2016 space type that had no equivalent in 2014, but was matched to the closest space type.

Figure 24: Mapping of activity areas between DEER2014 and DEER2016.

Appendix C: Baseline Lighting Schedules, Control Factor Profiles, and Final Lighting Schedules

This appendix provides detailed description of inputs for the Lighting Alteration Model v2.0.

Baseline Lighting Schedules

Baseline lighting schedules, titled baseline lighting energy use profiles in the following figures, were obtained from DEER2016 and DEER2014 for each activity area for each building prototype (California Public Utilities Commission 2015). Note that in the lighting alteration model, a user can choose to apply either DEER2014 or DEER2016 baseline lighting schedules.

These lighting schedules have values between zero and one, with zero representing no lighting energy use and one representing full lighting energy use. A value of 0.8 typically means that, on average, the lights were using full power 80 percent of the time. The DEER lighting schedules were developed to represent the lighting energy use for a space type by averaging monitored energy use (logger data) from multiple sites and for multiple months and years.

Figure 25 and Figure 26 provide final baseline lighting schedules for each activity area in the considered building prototypes. When applicable, the final schedules blend lighting schedules provided in DEER for three lighting technology types: compact fluorescent lamps, linear fluorescent, and high bay metal halides. The final schedules blend workday, weekend, and holiday lighting schedules for each activity area.

Building Type	Space Type	Baseline Lighting Energy Use Profiles																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Hotel	Dining	0.14	0.13	0.12	0.12	0.13	0.16	0.23	0.32	0.42	0.54	0.65	0.66	0.70	0.76	0.74	0.70	0.65	0.55	0.42	0.38	0.31	0.30	0.21	0.19
	GuestRmCorrid	0.43	0.41	0.41	0.41	0.42	0.45	0.49	0.54	0.58	0.57	0.54	0.51	0.47	0.48	0.48	0.50	0.50	0.52	0.55	0.58	0.57	0.55	0.52	0.47
	GuestRmOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HotelLobby	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Kitchen	0.23	0.22	0.21	0.20	0.20	0.29	0.37	0.45	0.52	0.51	0.45	0.34	0.24	0.20	0.19	0.18	0.21	0.21	0.25	0.31	0.36	0.35	0.29	0.25
	Laundry	0.15	0.15	0.15	0.15	0.21	0.33	0.53	0.73	0.80	0.83	0.83	0.83	0.83	0.83	0.83	0.80	0.73	0.53	0.33	0.21	0.15	0.15	0.15	0.15
	BarCasino	0.14	0.13	0.12	0.12	0.13	0.16	0.23	0.32	0.42	0.54	0.65	0.66	0.70	0.76	0.74	0.70	0.65	0.55	0.42	0.38	0.31	0.30	0.21	0.19
	OfficeGeneral	0.05	0.05	0.04	0.04	0.04	0.05	0.09	0.21	0.34	0.43	0.44	0.44	0.44	0.44	0.43	0.42	0.39	0.26	0.20	0.18	0.17	0.16	0.15	0.08
	RestRoom	0.24	0.23	0.23	0.23	0.24	0.27	0.30	0.34	0.36	0.33	0.31	0.28	0.27	0.26	0.26	0.26	0.28	0.27	0.28	0.29	0.30	0.30	0.29	0.26
	StockRoom	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.08	0.25	0.27	0.25	0.27	0.24	0.22	0.21	0.20	0.15	0.04	0.03	0.03	0.03	0.02	0.02	0.02
	GuestRmUnOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Office Large	OfficeOpen	0.08	0.07	0.07	0.07	0.07	0.08	0.13	0.25	0.42	0.52	0.55	0.56	0.54	0.53	0.53	0.53	0.49	0.32	0.20	0.14	0.11	0.09	0.08	0.08
	OfficeSmall	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.15	0.26	0.32	0.34	0.34	0.32	0.31	0.34	0.32	0.25	0.13	0.08	0.05	0.02	0.01	0.01	0.01
	CorridorStairway	0.26	0.24	0.23	0.21	0.21	0.22	0.27	0.40	0.55	0.64	0.66	0.66	0.66	0.66	0.65	0.63	0.57	0.41	0.35	0.32	0.29	0.27	0.24	0.27
	StorageSmlCond	0.04	0.04	0.04	0.04	0.04	0.04	0.08	0.13	0.22	0.29	0.30	0.31	0.31	0.31	0.31	0.28	0.22	0.15	0.11	0.11	0.10	0.07	0.04	0.04
	LobbyWaiting	0.18	0.16	0.16	0.15	0.15	0.15	0.19	0.27	0.38	0.44	0.45	0.45	0.45	0.45	0.44	0.43	0.39	0.29	0.25	0.22	0.20	0.19	0.17	0.19
	Conference	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.13	0.22	0.24	0.24	0.24	0.25	0.25	0.22	0.22	0.22	0.20	0.18	0.10	0.03	0.01	0.01	0.00
	Restroom	0.05	0.04	0.04	0.04	0.04	0.04	0.06	0.09	0.12	0.16	0.18	0.18	0.19	0.19	0.18	0.17	0.17	0.15	0.13	0.10	0.08	0.07	0.06	0.06
	Break	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.23	0.31	0.43	0.43	0.43	0.45	0.43	0.41	0.39	0.35	0.29	0.19	0.14	0.11	0.10	0.10	0.09
	MechElecRoom	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.14	0.17	0.20	0.23	0.24	0.25	0.26	0.26	0.25	0.24	0.22	0.22	0.20	0.17	0.15	0.14	0.14
	CopyRoom	0.11	0.11	0.11	0.12	0.11	0.11	0.13	0.24	0.28	0.34	0.42	0.47	0.48	0.48	0.48	0.45	0.36	0.22	0.19	0.16	0.13	0.11	0.11	0.11
Office Small	OfficeOpen	0.03	0.03	0.03	0.03	0.04	0.03	0.09	0.20	0.36	0.48	0.50	0.50	0.48	0.47	0.48	0.48	0.43	0.26	0.15	0.09	0.06	0.04	0.04	0.04
	OfficeSmall	0.02	0.02	0.01	0.01	0.01	0.02	0.05	0.13	0.27	0.40	0.45	0.46	0.43	0.42	0.44	0.44	0.39	0.26	0.15	0.09	0.06	0.04	0.03	0.02
	StorageSmlCond	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.12	0.16	0.21	0.24	0.25	0.24	0.24	0.25	0.23	0.21	0.14	0.10	0.08	0.06	0.06	0.05	0.05
	Hall	0.09	0.08	0.08	0.08	0.08	0.09	0.13	0.21	0.38	0.49	0.53	0.54	0.52	0.50	0.51	0.50	0.46	0.35	0.24	0.17	0.13	0.12	0.10	0.09
	LobbyWaiting	0.04	0.03	0.03	0.03	0.03	0.05	0.11	0.16	0.35	0.47	0.54	0.56	0.51	0.47	0.51	0.53	0.50	0.30	0.18	0.12	0.10	0.07	0.05	0.05
	Conference	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.12	0.21	0.25	0.25	0.25	0.23	0.23	0.21	0.16	0.10	0.06	0.04	0.02	0.02	0.01	0.01
	Restroom	0.05	0.04	0.04	0.04	0.04	0.04	0.06	0.08	0.12	0.16	0.17	0.18	0.18	0.18	0.18	0.17	0.17	0.15	0.12	0.10	0.08	0.07	0.06	0.06
	Break	0.03	0.03	0.03	0.04	0.06	0.09	0.15	0.22	0.31	0.33	0.35	0.37	0.39	0.36	0.34	0.33	0.28	0.21	0.15	0.12	0.08	0.06	0.05	0.04
	MechElecRoom	0.09	0.09	0.09	0.09	0.09	0.11	0.13	0.15	0.20	0.24	0.26	0.27	0.27	0.27	0.27	0.26	0.24	0.19	0.17	0.16	0.14	0.12	0.11	0.11
	CompRoomData	0.05	0.05	0.05	0.05	0.09	0.12	0.19	0.41	0.55	0.60	0.60	0.60	0.60	0.60	0.60	0.57	0.53	0.36	0.23	0.17	0.14	0.11	0.08	0.08
	CopyRoom	0.11	0.11	0.11	0.12	0.11	0.11	0.13	0.24	0.28	0.34	0.42	0.47	0.48	0.48	0.48	0.45	0.36	0.22	0.19	0.16	0.13	0.11	0.11	0.11
Restaurant	Dining	0.14	0.10	0.08	0.07	0.07	0.08	0.17	0.29	0.37	0.44	0.45	0.50	0.53	0.53	0.52	0.50	0.50	0.50	0.51	0.54	0.55	0.48	0.34	0.22
	Kitchen	0.16	0.08	0.05	0.05	0.07	0.21	0.39	0.50	0.64	0.69	0.71	0.72	0.73	0.73	0.70	0.69	0.68	0.59	0.58	0.58	0.59	0.49	0.36	0.26
	Restroom	0.21	0.17	0.13	0.11	0.13	0.14	0.15	0.17	0.21	0.28	0.33	0.37	0.41	0.43	0.43	0.43	0.43	0.43	0.44	0.45	0.43	0.40	0.32	0.25
	StockRoom	0.13	0.11	0.09	0.08	0.12	0.15	0.21	0.25	0.25	0.30	0.35	0.37	0.37	0.38	0.39	0.38	0.35	0.33	0.33	0.34	0.32	0.27	0.22	0.17
	OfficeGeneral	0.20	0.19	0.16	0.10	0.08	0.15	0.20	0.19	0.22	0.30	0.34	0.38	0.44	0.47	0.46	0.45	0.44	0.43	0.42	0.42	0.41	0.41	0.35	0.27
	LobbyWaiting	0.14	0.10	0.08	0.07	0.07	0.08	0.17	0.29	0.37	0.44	0.45	0.50	0.53	0.53	0.52	0.50	0.50	0.50	0.51	0.54	0.55	0.48	0.34	0.22
	CorridorStairway	0.33	0.28	0.25	0.23	0.22	0.24	0.33	0.40	0.47	0.54	0.59	0.62	0.63	0.64	0.63	0.63	0.65	0.67	0.67	0.68	0.67	0.61	0.49	0.40
Retail Large	RetailSales	0.04	0.04	0.04	0.04	0.04	0.08	0.28	0.47	0.57	0.70	0.76	0.79	0.79	0.79	0.79	0.77	0.74	0.47	0.29	0.25	0.17	0.10	0.04	0.04
	Corridor	0.04	0.04	0.04	0.04	0.04	0.08	0.28	0.47	0.57	0.70	0.76	0.79	0.79	0.79	0.79	0.77	0.74	0.47	0.29	0.25	0.17	0.10	0.04	0.04
	StockRoom	0.11	0.11	0.16	0.19	0.19	0.20	0.30	0.43	0.48	0.55	0.62	0.62	0.62	0.61	0.60	0.58	0.54	0.36	0.28	0.25	0.23	0.19	0.16	0.11
	Work	0.04	0.04	0.04	0.04	0.04	0.08	0.28	0.47	0.57	0.70	0.76	0.79	0.79	0.79	0.79	0.77	0.74	0.47	0.29	0.25	0.17	0.10	0.04	0.04
	OfficeGeneral	0.10	0.11	0.11	0.11	0.11	0.13	0.23	0.43	0.53	0.56	0.58	0.57	0.59	0.59	0.58	0.56	0.48	0.27	0.16	0.13	0.12	0.12	0.11	0.11
	OfficeSmall	0.10	0.11	0.11	0.11	0.11	0.13	0.23	0.43	0.53	0.56	0.58	0.57	0.59	0.59	0.58	0.56	0.48	0.27	0.16	0.13	0.12	0.12	0.11	0.11
	Restroom	0.29	0.29	0.38	0.39	0.39	0.39	0.40	0.42	0.45	0.46	0.47	0.47	0.46	0.46	0.46	0.45	0.44	0.40	0.39	0.39	0.39	0.39	0.39	0.34
	Break	0.22	0.22	0.24	0.24	0.24	0.24	0.26	0.42	0.43	0.42	0.42	0.43	0.42	0.42	0.43	0.42	0.39	0.25	0.24	0.24	0.24	0.24	0.24	0.23
	MechElecRoom	0.16	0.16	0.15	0.15	0.16	0.16	0.16	0.18	0.23	0.26	0.29	0.31	0.31	0.32	0.32	0.31	0.29	0.26	0.26	0.25	0.22	0.19	0.18	0.17
Retail Small	RetailSales	0.10	0.09	0.09	0.09	0.09	0.10	0.15	0.24	0.37	0.50	0.64	0.71	0.73	0.73	0.72	0.71	0.68	0.58	0.40	0.28	0.19	0.15	0.12	0.11
	StockRoom	0.05	0.05	0.05	0.05	0.05	0.06	0.10	0.18	0.27	0.35	0.42	0.45	0.45	0.46	0.45	0.44	0.41	0.32	0.23	0.15	0.11	0.09	0.07	0.06
	Hall	0.18	0.18	0.17	0.17	0.17	0.18	0.23	0.36	0.43	0.53	0.59	0.59	0.58	0.58	0.58	0.58	0.57	0.45	0.34	0.27	0.25	0.23	0.20	0.18
	OfficeGeneral	0.04	0.03	0.03	0.03	0.03	0.05	0.09	0.19	0.31	0.43	0.51	0.53	0.53	0.53	0.53	0.53	0.49	0.36	0.22	0.14	0.10	0.08	0.06	0.04
	Restroom	0.03	0.02	0.02	0.02	0.03	0.04	0.05	0.08	0.12	0.15	0.16	0.17	0.17	0.16	0.17	0.16	0.15	0.15	0.12	0.09	0.07	0.06	0.04	0.03
	Break	0.03	0.03	0.03	0.03	0.04	0.05	0.09	0.15	0.25	0.32	0.36	0.38	0.40	0.40	0.37	0.34	0.31	0.25	0.19	0.13	0.08	0.06	0.05	0.04
	MechElecRoom	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.18	0.23	0.26	0.29	0.31	0.32	0.33	0.33	0.31	0.29	0.27	0.26	0.25	0.22	0.20	0.18	0.17
School	Classroom	0.01	0.01	0.01	0.01	0.00	0.01	0.07	0.22	0.29	0.32	0.32	0.28	0.18	0.16	0.17	0.22	0.19	0.15	0.08	0.06	0.04	0.03	0.02	0.01
	Gymnasium	0.03	0.03	0.03	0.02	0.02	0.03	0.14	0.30	0.38	0.40	0.38	0.39	0.39	0.44	0.44	0.47	0.45	0.40	0.38	0.30	0.20	0.12	0.05	0.03
	OfficeGeneral	0.03	0.03	0.03	0.03	0.03	0.05	0.11	0.22	0.31	0.36	0.37	0.37	0.35	0.33	0.33	0.32	0.26	0.19	0.11	0.08	0.07	0.05	0.04	0.03
	Kitchen	0.03	0.03	0.03	0.03	0.03	0.06	0.18	0.30	0.33	0.35	0.38	0.39	0.35	0.30	0.29	0.26	0.23	0.20	0.16	0.12	0.09	0.06	0.05	0.03
	RestRoom	0.01	0.01	0.02	0.02	0.01	0.01	0.05	0.12	0.19	0.22	0.24	0.24	0.21	0.20	0.21	0.21	0.19	0.14	0.08	0.07	0.05	0.03	0.03	0.02
	LibraryReading	0.00	0.00	0.00	0.00	0.00	0.01	0.12	0.20	0.30	0.33	0.33	0.32	0.27	0.22	0.20	0.24	0.20	0.17	0.13	0.07	0.03	0.02	0.01	0.01
	StorageSmlCond	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.06	0.07	0.09	0.08	0.08	0.06	0.06	0.07	0.06	0.04	0.02	0.03	0.05	0.04	0.03	0.02	0.01
	CorridorStairway	0.08	0.08	0.09	0.08	0.07	0.07	0.16	0.34	0.38	0.38	0.39	0.39	0.35	0.34	0.35	0.37	0.35	0.29	0.20	0.17	0.13	0.10	0.09	0.08
	Dining	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.23	0.30	0.35	0.37	0.35	0.26	0.17	0.14	0.13	0.12	0.13	0.11	0.08	0.04	0.01	0.00	0.00
	CompRoomClassrm	0.01	0.01	0.01	0.01	0.00	0.01	0.07	0.22	0.29	0.32	0.32	0.28	0.18	0.16	0.17	0.22	0.19	0.15	0.08	0.06	0.04	0.03	0.02	0.01
	LobbyWaiting	0.10	0.10	0.11	0.11	0.11	0.10	0.16	0.30	0.34	0.38	0.40	0.41	0.35	0.34	0.34	0.37	0.35	0.31	0.26	0.24	0.19	0.14	0.12	0.11
Warehouse (Non-Skylit)	WarehouseUnCond	0.10	0.09	0.09	0.09	0.10	0.13	0.19	0.26	0.34	0.36	0.37	0.36	0.35	0.35	0.35	0.34	0.28	0.21	0.17	0.16	0.15	0.14	0.12	0.11
	OfficeGeneral	0.07	0.07	0.08	0.08	0.08	0.10	0.13	0.22	0.36	0.42	0.44	0.45	0.45	0.44	0.44	0.42	0.34	0.24	0.17	0.13	0.11	0.09	0.09	0.08
	RestRoom	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.07	0.14	0.16	0.17	0.17	0.16	0.16	0.17	0.16	0.11	0.06	0.03	0.02	0.02	0.02	0.02	0.02
Warehouse (Skylit)	WarehouseUnCond	0.10	0.09	0.09	0.09	0.10	0.13	0.19	0.26	0.34	0.36	0.37	0.36	0.35	0.35	0.35	0.34	0.28	0.21	0.17	0.16	0.15	0.14	0.12	0.11
	OfficeGeneral	0.07	0.07	0.08	0.08	0.08	0.10	0.13	0.22	0.36	0.42	0.44	0.45	0.45	0.44	0.44	0.42	0.34	0.24	0.17	0.13	0.11	0.09	0.09	0.08
	RestRoom	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.07	0.14	0.16	0.17	0.17	0.16	0.16	0.17	0.16	0.11	0.06	0.03	0.02	0.02	0.02	0.02	0.02

Figure 25: DEER2016 blended baseline lighting schedules.

Source: DEER2016 (California Public Utilities Commission 2015) and the Statewide CASE Team calculations.

Building Type	Space Type	Baseline Lighting Energy Use Profiles																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Hotel	Dining	0.22	0.22	0.22	0.22	0.22	0.22	0.25	0.29	0.36	0.44	0.53	0.54	0.57	0.62	0.60	0.57	0.53	0.45	0.36	0.33	0.28	0.27	0.24	0.23
	GuestRmCorrid	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
	GuestRmOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HotelLobby	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
	Kitchen	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.36	0.47	0.59	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.61	0.47	0.42	0.35	0.34	0.26	0.25
	Laundry	0.22	0.22	0.22	0.22	0.24	0.27	0.43	0.60	0.65	0.68	0.68	0.68	0.68	0.68	0.68	0.65	0.60	0.43	0.27	0.24	0.22	0.22	0.22	0.22
	BarCasino	0.22	0.22	0.22	0.22	0.22	0.22	0.25	0.29	0.36	0.44	0.53	0.54	0.57	0.62	0.60	0.57	0.53	0.45	0.36	0.33	0.28	0.27	0.24	0.23
	OfficeGeneral	0.23	0.23	0.23	0.23	0.23	0.23	0.25	0.33	0.50	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.48	0.41	0.32	0.25	0.23	0.23	0.23	0.23
	RestRoom	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
	StockRoom	0.23	0.23	0.23	0.23	0.23	0.23	0.25	0.33	0.50	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.48	0.41	0.32	0.25	0.23	0.23	0.23	0.23
	GuestRmUnOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Office Large	OfficeOpen	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	OfficeSmall	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	CorridorStairway	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	StorageSmlCond	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	LobbyWaiting	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	Conference	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	Restroom	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	Break	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	MechElecRoom	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
	CopyRoom	0.06	0.06	0.06	0.06	0.10	0.14	0.21	0.38	0.55	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.53	0.41	0.32	0.23	0.16	0.13	0.10	0.10
Office Small	OfficeOpen	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	OfficeSmall	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	StorageSmlCond	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	Hall	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	LobbyWaiting	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	Conference	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	Restroom	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	Break	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	MechElecRoom	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	CompRoomData	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
	CopyRoom	0.08	0.08	0.08	0.08	0.11	0.14	0.20	0.42	0.56	0.60	0.60	0.60	0.59	0.59	0.60	0.57	0.54	0.37	0.24	0.17	0.15	0.13	0.10	0.10
Restaurant	Dining	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.46	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.47	0.27
	Kitchen	0.05	0.05	0.05	0.05	0.05	0.05	0.50	0.50	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.50	0.29
	Restroom	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.46	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.47	0.27
	StockRoom	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.46	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.47	0.27
	OfficeGeneral	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.46	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.47	0.27
	LobbyWaiting	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.46	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.47	0.27
	CorridorStairway	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.46	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.67	0.47	0.27
Retail Large	RetailSales	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.11	0.11
	Corridor	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.11	0.11
	StockRoom	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.05	0.05
	Work	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.21	0.11
	OfficeGeneral	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.66	0.73	0.73	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.06	0.05	0.05	0.05	0.05	0.05
	OfficeSmall	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.66	0.73	0.73	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.06	0.05	0.05	0.05	0.05	0.05
	Restroom	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.66	0.73	0.73	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.06	0.05	0.05	0.05	0.05	0.05
	Break	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.66	0.73	0.73	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.06	0.05	0.05	0.05	0.05	0.05
	MechElecRoom	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.05	0.05
Retail Small	RetailSales	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
	StockRoom	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
	Hall	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
	OfficeGeneral	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
	Restroom	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
	Break	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
	MechElecRoom	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.66	0.75	0.80	0.80	0.80	0.80	0.80	0.78	0.65	0.55	0.52	0.19	0.10	0.10	0.10
School	Classroom	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	Gymnasium	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.45	0.77	0.77	0.77	0.77	0.69	0.77	0.77	0.56	0.56	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	OfficeGeneral	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	Kitchen	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.53	0.79	0.86	0.86	0.86	0.86	0.70	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	RestRoom	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	LibraryReading	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	StorageSmlCond	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	CorridorStairway	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	Dining	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.86	0.86	0.86	0.86	0.70	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	CompRoomClassrm	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
	LobbyWaiting	0.05	0.05	0.05	0.05	0.05	0.43	0.43	0.53	0.53	0.81	0.81	0.81	0.81	0.81	0.81	0.50	0.39	0.39	0.39	0.26	0.09	0.09	0.09	0.09
Warehouse (Non-Skylit)	WarehouseUnCond	0.06	0.06	0.06	0.06	0.06	0.06	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.06	0.06	0.06	0.06	0.06	0.06
	OfficeGeneral	0.06	0.06	0.06	0.06	0.06	0.06	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.06	0.06	0.06	0.06	0.06	0.06
	RestRoom	0.06	0.06	0.06	0.06	0.06	0.06	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.06	0.06	0.06	0.06	0.06	0.06
Warehouse (Skylit)	WarehouseUnCond	0.06	0.06	0.06	0.06	0.06	0.06	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.06	0.06	0.06	0.06	0.06	0.06
	OfficeGeneral	0.06	0.06	0.06	0.06	0.06	0.06	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.06	0.06	0.06	0.06	0.06	0.06
	RestRoom	0.06	0.06	0.06	0.06	0.06	0.06	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.06	0.06	0.06	0.06	0.06	0.06

Figure 26: DEER2014 blended baseline lighting schedules.

Source: DEER2014 (California Public Utilities Commission 2015) and the Statewide CASE Team calculations.

Blending by lighting technology type was based on the percent fraction of lighting technology per activity area. The fractions were provided in the DEER dataset. Figure 27 depicts blending of lighting schedules graphically.

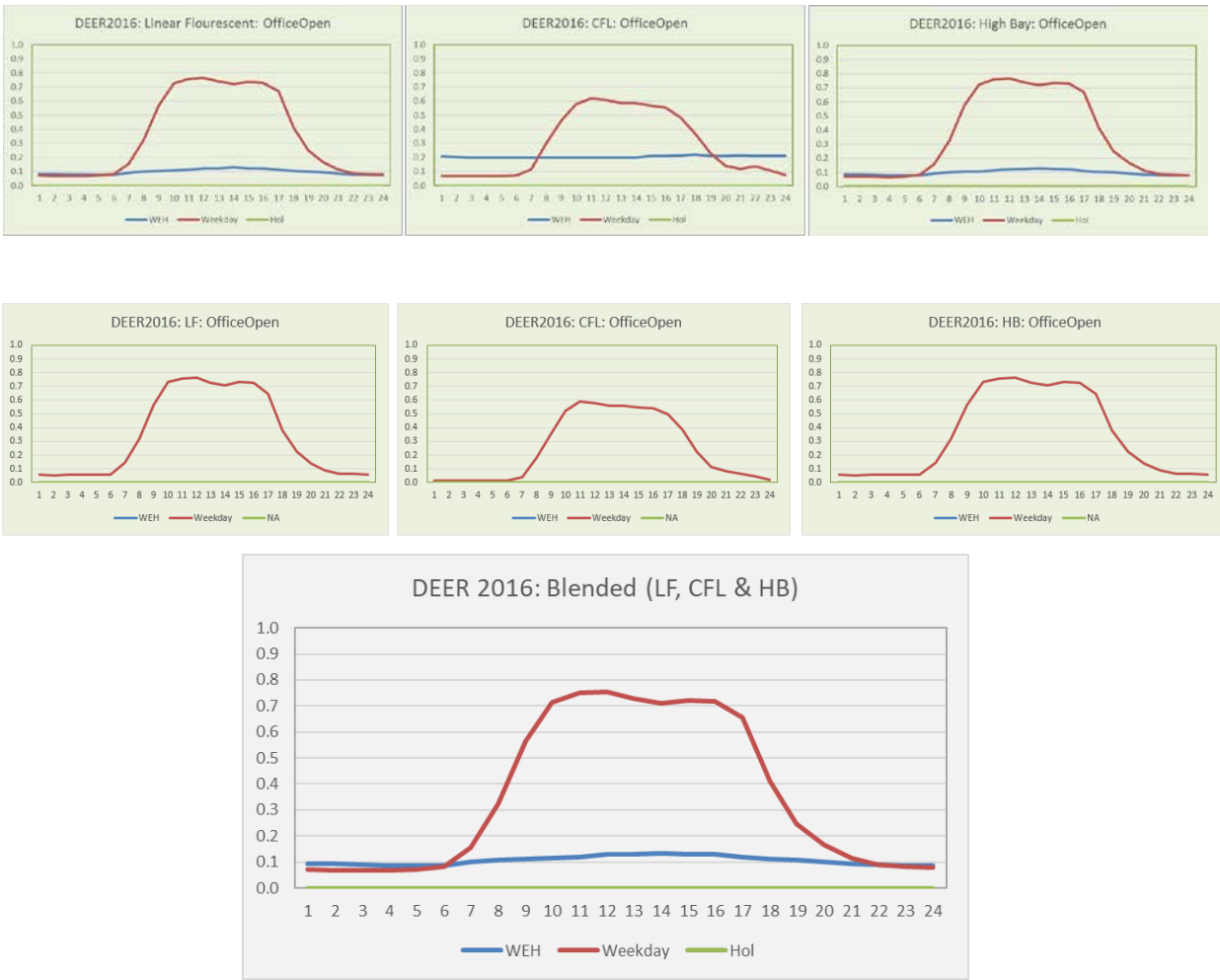

Figure 27: DEER lighting schedules for compact fluorescent lamps, linear fluorescent, and high bay metal halides (top) and blended schedule (bottom).

The lighting fractions used to blend lighting schedules by lighting technology type are provided in Figure 28.

		Lighting fraction by ActArea		
		LF	CFL	HB
Hotel	Dining	0.13	0.74	0.13
	GuestRmCorrid	0.13	0.74	0.13
	GuestRmOcc	0.26	0.74	0.00
	HotelLobby	0.13	0.74	0.13
	Kitchen	0.26	0.74	0.00
	Laundry	0.13	0.74	0.13
	BarCasino	0.26	0.74	0.00
	OfficeGeneral	0.13	0.74	0.13
	RestRoom	0.26	0.74	0.00
	StockRoom	0.26	0.74	0.00
	GuestRmUnOcc	0.26	0.74	0.00
Office Large	OfficeOpen	0.62	0.07	0.31
	OfficeSmall	0.93	0.07	0.00
	CorridorStairway	0.93	0.07	0.00
	StorageSmlCond	0.93	0.07	0.00
	LobbyWaiting	0.62	0.07	0.31
	Conference	0.93	0.07	0.00
	Restroom	0.93	0.07	0.00
	Break	0.93	0.07	0.00
	MechElecRoom	0.93	0.07	0.00
	CopyRoom	0.93	0.07	0.00
Office Small	OfficeOpen	0.56	0.17	0.27
	OfficeSmall	0.83	0.17	0.00
	StorageSmlCond	0.83	0.17	0.00
	Hall	0.83	0.17	0.00
	LobbyWaiting	0.56	0.17	0.27
	Conference	0.83	0.17	0.00
	Restroom	0.83	0.17	0.00
	Break	0.83	0.17	0.00
	MechElecRoom	0.83	0.17	0.00
	CompRoomData	0.83	0.17	0.00
	CopyRoom	0.83	0.17	0.00
Restaurant	Dining	0.29	0.56	0.14
	Kitchen	0.86	0.14	0.00
	Restroom	0.44	0.56	0.00
	StockRoom	0.44	0.56	0.00
	OfficeGeneral	0.44	0.56	0.00
	LobbyWaiting	0.29	0.56	0.14
	CorridorStairway	0.44	0.56	0.00
Retail Large	RetailSales	0.52	0.23	0.25
	Corridor	0.52	0.23	0.25
	StockRoom	0.52	0.23	0.25
	Work	0.77	0.23	0.00
	OfficeGeneral	0.77	0.23	0.00
	OfficeSmall	0.77	0.23	0.00
	Restroom	0.77	0.23	0.00
	Break	0.52	0.23	0.25
	MechElecRoom	0.52	0.23	0.25
Retail Small	RetailSales	0.52	0.23	0.25
	StockRoom	0.52	0.23	0.25
	Hall	0.52	0.23	0.25
	OfficeGeneral	0.52	0.23	0.25
	Restroom	0.52	0.23	0.25
	Break	0.52	0.23	0.25
	MechElecRoom	0.52	0.23	0.25
School	Classroom	0.93	0.07	0.00
	Gymnasium	0.47	0.07	0.47
	OfficeGeneral	0.93	0.07	0.00
	Kitchen	0.93	0.07	0.00
	RestRoom	0.93	0.07	0.00
	LibraryReading	0.93	0.07	0.00
	StorageSmlCond	0.93	0.07	0.00
	CorridorStairway	0.62	0.07	0.31
	Dining	0.62	0.07	0.31
	CompRoomClassrm	0.93	0.07	0.00
	LobbyWaiting	0.93	0.07	0.00
Warehouse	WarehouseUnCond	0.42	0.15	0.42
(Non-Skylit)	OfficeGeneral	0.85	0.15	0.00
	RestRoom	0.85	0.15	0.00
Warehouse	WarehouseUnCond	0.42	0.15	0.42
(Skylit)	OfficeGeneral	0.85	0.15	0.00
	RestRoom	0.85	0.15	0.00

Figure 28: Lighting fractions by building activity area for linear fluorescent, compact fluorescent lamps, and high bay metal halides lighting schedules.

In addition to lighting schedules by lighting technology, DEER provides lighting schedules for the following day types for each activity area:

- Weekday (assumed to apply 251 days per year);
- Saturday/Sunday (assumed to apply 104 days per year); and
- Holiday (assumed to apply ten days per year).

The schedules by day type were combined by applying weights to represent the number of weekday, weekends, and holidays in a non-leap year (shown in parenthesis above). Blending these schedules resulted in a single 24-hour profile for each activity area in each considered prototype building.

Control Factors for Automatic Daylighting Controls

Daylighting control factors were developed using Radiance-based daylighting simulations and a daylighting template-based approach. This approach is described in the PIER study (Saxena 2011).

The study developed a set of 17,280 template spaces representing typical commercial spaces with windows (sidelit) such as offices, classrooms, and libraries, and 1,080 template spaces representing typical commercial spaces with skylights (toplit) such as warehouses and big box retail stores. These templates cover a number of variations including room size, window/skylight size, window orientation, window/skylight visible light transmittance, ceiling heights, furniture heights, and climate zones. Figure 29 and Figure 30 represent two room size variations in sidelit and toplit templates.

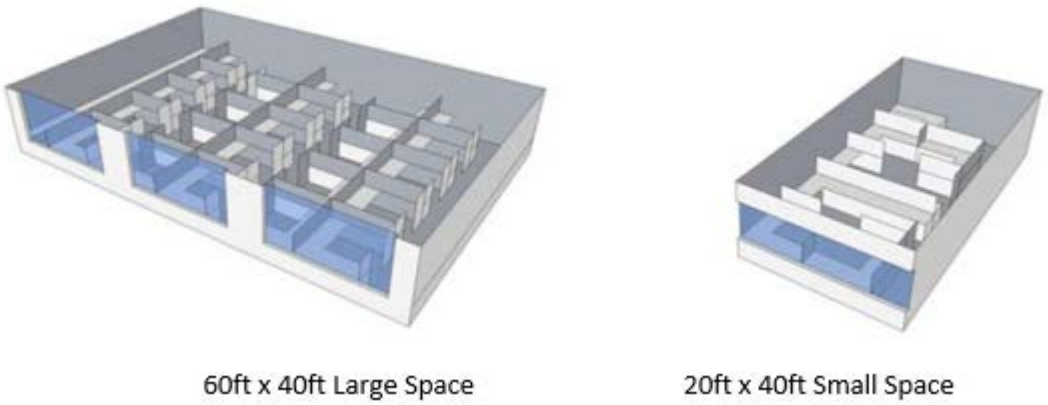

Figure 29: Sidelit template spaces.

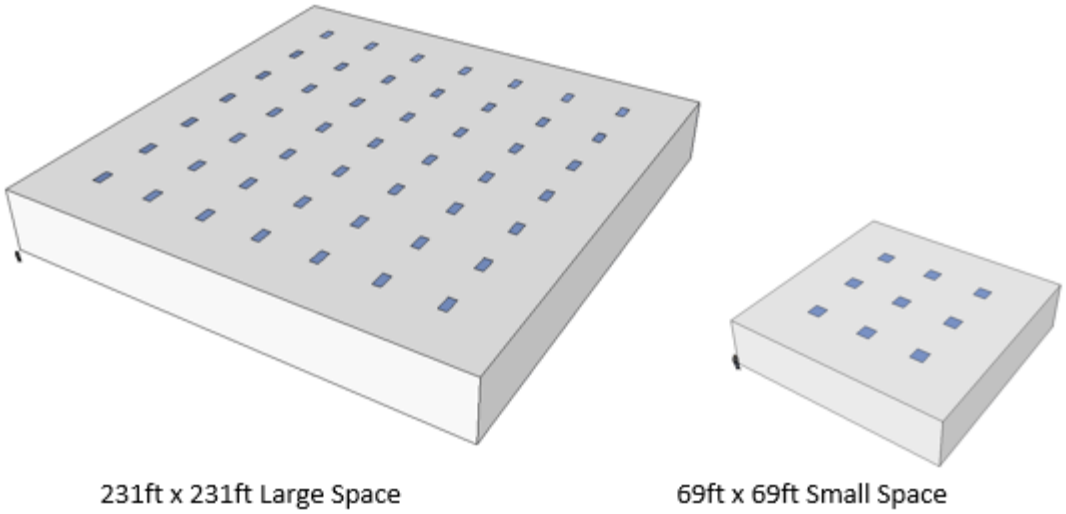

Figure 30: Toplit template spaces.

The advantage of using a template-based approach for this CASE Report is that the Radiance simulations can be done in advance. By mapping a space in one of the considered prototype buildings to its closest template, results can be obtained quickly from the pre-run template.

To develop daylighting control factors, each space type in the considered prototype buildings was mapped to a pre-run daylighting template. Daylighting simulation results in the form of hourly (24-hour) illuminance values were then converted into lighting energy savings.

To be conservative, the Statewide CASE Team chose to run the simulations for Climate Zone 2, which has the lowest energy savings among the four California Climate Zones 2, 6, 12 and 13 considered in daylighting simulations in the PIER study.

Table 25 provides the assumptions for the lighting and daylighting controls used in the development of daylighting control factors.

Table 25: Assumptions for Control Factors for Daylighting Controls

Variable	Value
Lighting Technology Type	LED
Daylighting Setpoint	Varies by space type (typically ~300 lux)
Lighting Control Types	Available settings in the lighting alteration model include: • Continuous dimming to OFF and • Continuous dim to 10 percent.
Climate Zone	California Climate Zone 2

Figure 31 and Figure 32 provide calculated daylighting control factors developed for each space type of the considered prototype buildings. Note that for spaces with no windows or skylights, the control factor values are ones (no added energy savings). Also, note that for most building types except for the skylit warehouse, the control factor values are very high (little added energy savings), since only a small fraction of building area is in the daylit zone.

Building Type	Space Type	Daylighting Control Factors (Dim to OFF)																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Hotel	Dining	1	1	1	1	1	1	0.862	0.784	0.734	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.758	0.785	0.813	1	1	1	1
	GuestRmCorrid	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	GuestRmOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HotelLobby	1	1	1	1	1	1	0.77	0.64	0.557	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.551	0.597	0.641	0.689	1	1	1	1
	Kitchen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Laundry	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BarCasino	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.98	0.94	0.901	0.878	0.871	0.868	0.867	0.867	0.872	0.875	0.893	0.914	0.946	0.977	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	GuestRmUnOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Office Large	OfficeOpen	1	1	1	1	1	1	0.992	0.976	0.96	0.951	0.948	0.947	0.947	0.947	0.949	0.95	0.957	0.966	0.978	0.991	1	1	1	1
	OfficeSmall	1	1	1	1	1	1	0.961	0.879	0.802	0.755	0.742	0.736	0.735	0.733	0.744	0.75	0.785	0.829	0.892	0.953	1	1	1	1
	CorridorStairway	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StorageSmlCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	0.969	0.889	0.843	0.838	0.832	0.828	0.828	0.829	0.83	0.835	0.843	0.867	0.895	0.944	1	1	1	1
	Conference	1	1	1	1	1	1	0.992	0.976	0.96	0.951	0.948	0.947	0.947	0.947	0.949	0.95	0.957	0.966	0.978	0.991	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.941	0.882	0.862	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.856	0.864	0.882	0.917	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CopyRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Office Small	OfficeOpen	1	1	1	1	1	1	0.986	0.951	0.912	0.883	0.872	0.868	0.867	0.868	0.87	0.875	0.902	0.925	0.956	0.983	1	1	1	1
	OfficeSmall	1	1	1	1	1	1	0.961	0.879	0.802	0.755	0.742	0.736	0.735	0.733	0.744	0.75	0.785	0.829	0.892	0.953	1	1	1	1
	StorageSmlCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Hall	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	0.954	0.883	0.866	0.856	0.844	0.837	0.836	0.837	0.841	0.849	0.865	0.874	0.883	0.917	1	1	1	1
	Conference	1	1	1	1	1	1	0.995	0.976	0.954	0.94	0.936	0.933	0.933	0.933	0.935	0.938	0.949	0.963	0.978	0.992	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.862	0.784	0.734	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.758	0.785	0.813	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CompRoomData	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CopyRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Restaurant	Dining	1	1	1	1	1	1	0.915	0.811	0.779	0.759	0.734	0.73	0.73	0.73	0.73	0.745	0.776	0.795	0.812	0.847	1	1	1	1
	Kitchen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.986	0.951	0.912	0.883	0.872	0.868	0.867	0.868	0.87	0.875	0.902	0.925	0.956	0.983	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	0.929	0.798	0.703	0.687	0.666	0.655	0.653	0.655	0.661	0.675	0.701	0.737	0.803	0.873	1	1	1	1
	CorridorStairway	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Retail Large	RetailSales	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Corridor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Work	1	1	1	1	1	1	0.992	0.968	0.924	0.896	0.877	0.865	0.863	0.864	0.871	0.888	0.913	0.95	0.97	0.985	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.989	0.953	0.908	0.88	0.871	0.866	0.865	0.865	0.87	0.877	0.899	0.926	0.957	0.984	1	1	1	1
	OfficeSmall	1	1	1	1	1	1	0.961	0.879	0.802	0.755	0.742	0.736	0.735	0.733	0.744	0.75	0.785	0.829	0.892	0.953	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.963	0.857	0.775	0.758	0.748	0.743	0.742	0.743	0.746	0.752	0.764	0.806	0.866	0.933	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Retail Small	RetailSales	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Hall	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.989	0.953	0.908	0.88	0.871	0.866	0.865	0.865	0.87	0.877	0.899	0.926	0.957	0.984	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.963	0.857	0.775	0.758	0.748	0.743	0.742	0.743	0.746	0.752	0.764	0.806	0.866	0.933	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
School	Classroom	1	1	1	1	1	1	0.986	0.958	0.928	0.911	0.899	0.895	0.895	0.893	0.899	0.911	0.929	0.946	0.968	0.987	1	1	1	1
	Gymnasium	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.984	0.961	0.946	0.937	0.935	0.935	0.935	0.934	0.935	0.938	0.952	0.965	0.979	0.992	1	1	1	1
	Kitchen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LibraryReading	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StorageSmlCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CorridorStairway	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Dining	1	1	1	1	1	1	0.915	0.811	0.779	0.759	0.734	0.73	0.73	0.73	0.73	0.745	0.776	0.795	0.812	0.847	1	1	1	1
	CompRoomClassrm	1	1	1	1	1	1	0.986	0.951	0.912	0.883	0.872	0.868	0.867	0.868	0.87	0.875	0.902	0.925	0.956	0.983	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warehouse (Non-Skylit)	WarehouseUnCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.976	0.932	0.895	0.875	0.87	0.868	0.868	0.866	0.87	0.876	0.901	0.929	0.958	0.985	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warehouse (Skylit)	WarehouseUnCond	1	1	1	1	1	1	0.975	0.826	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.796	0.953	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.976	0.932	0.895	0.875	0.87	0.868	0.868	0.866	0.87	0.876	0.901	0.929	0.958	0.985	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 31: Daylighting control factor profiles for dimming to OFF.

Building Type	Space Type	Daylighting Control Factors (Dim to 10%)																							
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Hotel	Dining	1	1	1	1	1	1	0.847	0.76	0.705	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.731	0.761	0.793	1	1	1	1
	GuestRmCorrid	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	GuestRmOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	HotelLobby	1	1	1	1	1	1	0.744	0.6	0.508	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.501	0.552	0.601	0.654	1	1	1	1
	Kitchen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Laundry	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BarCasino	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.978	0.933	0.89	0.864	0.856	0.853	0.853	0.852	0.858	0.861	0.881	0.905	0.94	0.974	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	GuestRmUnOcc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Office Large	OfficeOpen	1	1	1	1	1	1	0.991	0.973	0.956	0.946	0.943	0.941	0.941	0.941	0.943	0.944	0.952	0.962	0.976	0.99	1	1	1	1
	OfficeSmall	1	1	1	1	1	1	0.956	0.866	0.78	0.728	0.713	0.707	0.706	0.704	0.715	0.722	0.762	0.81	0.88	0.948	1	1	1	1
	CorridorStairway	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StorageSmlCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	0.966	0.876	0.826	0.82	0.813	0.809	0.809	0.809	0.812	0.816	0.825	0.852	0.883	0.938	1	1	1	1
	Conference	1	1	1	1	1	1	0.991	0.973	0.956	0.946	0.943	0.941	0.941	0.941	0.943	0.944	0.952	0.962	0.976	0.99	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.934	0.869	0.846	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.849	0.869	0.908	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CopyRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Office Small	OfficeOpen	1	1	1	1	1	1	0.984	0.945	0.902	0.87	0.858	0.853	0.852	0.853	0.856	0.862	0.891	0.917	0.951	0.981	1	1	1	1
	OfficeSmall	1	1	1	1	1	1	0.956	0.866	0.78	0.728	0.713	0.707	0.706	0.704	0.715	0.722	0.762	0.81	0.88	0.948	1	1	1	1
	StorageSmlCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Hall	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	0.949	0.87	0.852	0.84	0.826	0.819	0.818	0.819	0.823	0.832	0.85	0.86	0.87	0.908	1	1	1	1
	Conference	1	1	1	1	1	1	0.994	0.974	0.949	0.933	0.928	0.925	0.925	0.925	0.928	0.932	0.944	0.959	0.976	0.991	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.847	0.76	0.705	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.731	0.761	0.793	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CompRoomData	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CopyRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Restaurant	Dining	1	1	1	1	1	1	0.905	0.79	0.754	0.732	0.705	0.7	0.7	0.7	0.7	0.717	0.752	0.772	0.791	0.831	1	1	1	1
	Kitchen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	0.921	0.776	0.67	0.652	0.629	0.617	0.615	0.617	0.624	0.639	0.668	0.708	0.781	0.859	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	0.984	0.945	0.902	0.87	0.858	0.853	0.852	0.853	0.856	0.862	0.891	0.917	0.951	0.981	1	1	1	1
	CorridorStairway	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Retail Large	RetailSales	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Corridor	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Work	1	1	1	1	1	1	0.991	0.965	0.916	0.885	0.864	0.849	0.848	0.848	0.856	0.875	0.903	0.945	0.967	0.984	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.988	0.947	0.897	0.866	0.857	0.851	0.85	0.85	0.856	0.863	0.888	0.918	0.952	0.983	1	1	1	1
	OfficeSmall	1	1	1	1	1	1	0.956	0.866	0.78	0.728	0.713	0.707	0.706	0.704	0.715	0.722	0.762	0.81	0.88	0.948	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.959	0.841	0.75	0.731	0.72	0.715	0.714	0.715	0.718	0.725	0.738	0.785	0.851	0.926	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Retail Small	RetailSales	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StockRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Hall	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.988	0.947	0.897	0.866	0.857	0.851	0.85	0.85	0.856	0.863	0.888	0.918	0.952	0.983	1	1	1	1
	Restroom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Break	1	1	1	1	1	1	0.959	0.841	0.75	0.731	0.72	0.715	0.714	0.715	0.718	0.725	0.738	0.785	0.851	0.926	1	1	1	1
	MechElecRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
School	Classroom	1	1	1	1	1	1	0.984	0.954	0.92	0.901	0.887	0.883	0.883	0.881	0.888	0.901	0.921	0.941	0.964	0.986	1	1	1	1
	Gymnasium	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.982	0.956	0.94	0.93	0.928	0.928	0.928	0.926	0.928	0.931	0.946	0.961	0.977	0.991	1	1	1	1
	Kitchen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LibraryReading	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	StorageSmlCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	CorridorStairway	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Dining	1	1	1	1	1	1	0.905	0.79	0.754	0.732	0.705	0.7	0.7	0.7	0.7	0.717	0.752	0.772	0.791	0.831	1	1	1	1
	CompRoomClassrm	1	1	1	1	1	1	0.984	0.945	0.902	0.87	0.858	0.853	0.852	0.853	0.856	0.862	0.891	0.917	0.951	0.981	1	1	1	1
	LobbyWaiting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warehouse (Non-Skylit)	WarehouseUnCond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.974	0.925	0.884	0.861	0.856	0.853	0.853	0.851	0.856	0.863	0.89	0.921	0.953	0.983	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Warehouse (Skylit)	WarehouseUnCond	1	1	1	1	1	1	0.972	0.807	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.589	0.773	0.948	1	1	1	1
	OfficeGeneral	1	1	1	1	1	1	0.974	0.925	0.884	0.861	0.856	0.853	0.853	0.851	0.856	0.863	0.89	0.921	0.953	0.983	1	1	1	1
	RestRoom	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 32: Daylighting control factor profiles for dimming to 10 percent.

Control Factors for Occupant Sensing Controls

Control factors for occupant sensing controls are based on data collected from a meta-study on lighting controls published by LBNL (Williams, Atkinson, et al. 2012). This LBNL study is one of the most comprehensive studies on savings from lighting controls. The authors of the study analyzed and aggregated information from previous studies on lighting controls. Figure 33 shows the number of data points (studies) referenced for each control type by building type.

Building Type (Reported by Itself or in Combination with Other Building Types)	Percent Commercial Lighting Energy Usage (DOE, 2003)	Occupancy	Daylighting	Personal Tuning	Institutional Tuning
Office	25%	76	70	18	31
Warehouse	12%	10	4	1	-
Lodging	11%	7	-	-	-
Education	10%	22	33	13	-
Retail (other than mall)	10%	2	4	2	3
Healthcare inpatient	7%	2	2	1	1
Service	6%	-	-	-	-
Food service	4%	-	-	-	-
Food sales	4%	-	-	-	-
Public assembly	2%	2	1	-	-
Healthcare outpatient	2%	5	-	-	-
Public order and safety	2%	-	-	-	-
Religious	1%	-	-	-	-
Other	5%	8	3	-	-

Figure 33: Number of referenced studies for each control type by building type.

The authors then applied the following filters to the reviewed studies:

- Only single building types (the studies that reported savings for multiple building type were eliminated);
- Only peer reviewed (non-peer reviewed studies were eliminated);
- Only lighting controls savings (the studies that reported savings from controls together with lighting change were eliminated);
- Only lighting energy (studies that reported savings from lighting and HVAC energy were eliminated); and
- Only actual installations (the studies that had only simulated savings were eliminated).

Figure 34 provides the final count (in parentheses) for the number of studies that remained after all the above filters were applied. For occupancy sensors, the final number of studies was 38 studies across provided building types. The percent value reported in Figure 34 is the average of the savings from lighting controls from those studies.

Building Type	Occupancy	Daylighting	Personal Tuning	Institutional Tuning	Multiple Types
Office	22% (n=23)	27% (n=18)	35% (n=13)	36% (n=11)	40% (n=24)
Warehouse	31% (n= 4)	28% (n= 1)	-	-	-
Lodging	45% (n= 2)	-	-	-	-
Education	18% (n= 5)	29% (n= 7)	6% (n= 2)	-	34% (n= 7)
Retail (other than mall)	-	29% (n= 3)	-	60% (n= 1)	-
Healthcare inpatient	-	-	-	-	35% (n= 1)
Public assembly	36% (n= 2)	36% (n= 1)	-	-	-
Healthcare outpatient	23% (n= 1)	-	-	-	-
Other	7% (n= 1)	18% (n= 1)	-	-	-

Figure 34: Average savings by control type and building type after all filters applied.

The reported values with all filters applied were used as the basis for control factors in the lighting alteration model. The control factors were applied in accordance with the savings calculation methodology from the Advanced Lighting Control Systems Calculator (Saxena, Alexander and Arnold 2016). The detailed description of the methodology used in the lighting alteration model follows.

Consider a simplified presence graph as shown in Figure 35. This graph illustrates when an occupant is in a room (value 1) and away from the room (value 0).

Figure 35: An example of occupant presence graphed over a 24-hour day.

In Figure 36, the lighting energy use is overlaid in the presence graph. In this case, the baseline condition is described with lights turning ON at 6:00 am and OFF at 8:00 pm.

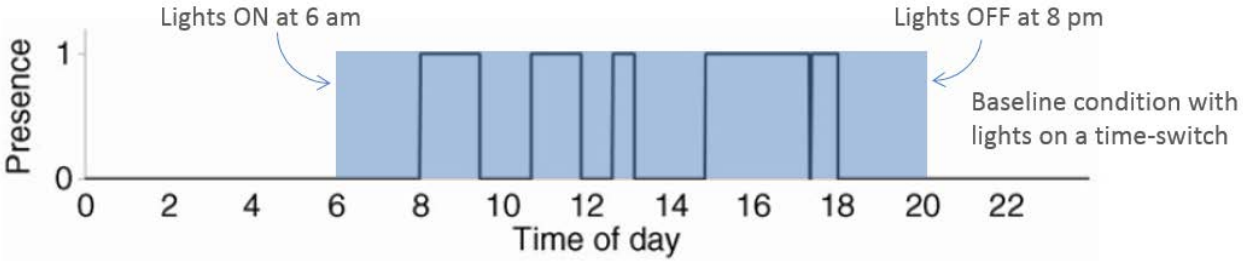

Figure 36: Baseline condition with lights being controlled by an automatic time-switch.

With an occupant sensing control, lights only turn ON when an occupant is present in the space and turn OFF after a set amount of time (delayed off time) after the occupant has left. Figure 37 shows an Auto ON – Auto OFF occupant sensing control with a 30-minute delay time. With Auto ON – Auto OFF setting, the occupant sensing control automatically turns lights ON when presence is detected and turns lights OFF when vacancy is detected after a set delay off time. In Figure 37, the blue shaded area represents time that lights are ON, and the brown shaded area represents savings compared to the baseline in Figure 36.

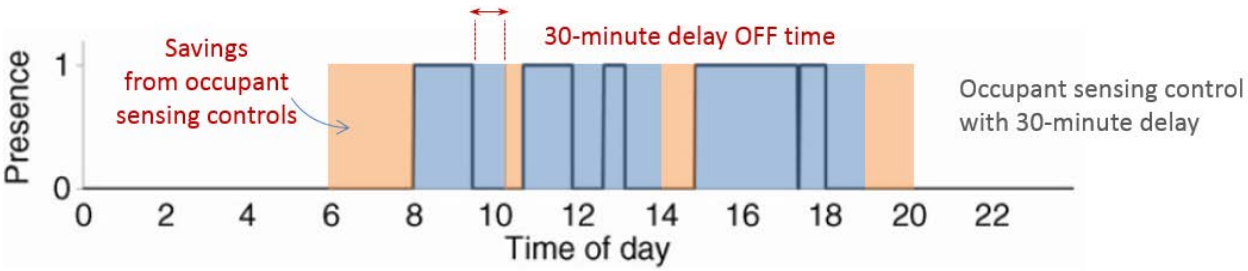

Figure 37: Occupant sensing controls with Auto ON – Auto OFF setting and 30-minute delay.

With Auto ON – Partial OFF setting, the occupant sensing control automatically turns lights ON when presence is detected, and turns lights OFF partially when vacancy is detected after a set delay OFF time. To estimate savings for this type of control, the savings calculated from Auto ON – Auto OFF can be adjusted by multiplying the value of savings from Auto ON – Auto OFF with the "partial OFF level" of the lighting system, as demonstrated by the equation below.

$$Occ\ Sensor\ Savings_{Auto\ ON-Partial\ OFF} = Occ\ Sensor\ Savings_{Auto\ ON-Auto\ OFF} \times Lighting\ Partial\ Off\ Level$$

Where

"Lighting partial OFF level" is a value from zero to one that indicates the level to which lights turn OFF partially. For example, for a partial OFF level of 50 percent of full lighting power, the multiplier is 0.5. In the lighting alteration model, the lighting partial OFF level of 0.5 was assumed.

Figure 38 illustrates reduced savings from Auto ON – Partial OFF setting. The blue shaded area represents time that lights are ON, and the brown shaded area represents savings compared the baseline in Figure 36.

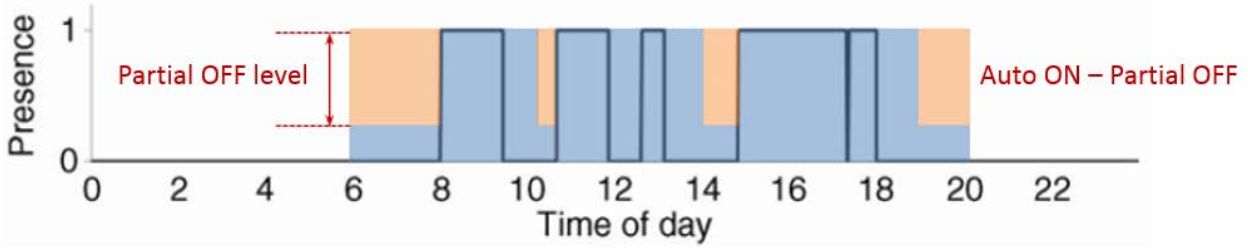

Figure 38: Occupant sensing controls with Auto ON – Partial OFF setting and 30-minute delay.

Appendix D: DEMAND SAVINGS CALCULATIONS

The Statewide CASE Team calculated demand savings using the time dependent valuation (TDV) coincident demand factors for nonresidential electricity on 15-year basis (McHugh 2016).

Demand factors were applied hourly to the final lighting schedules to develop final annual hours for demand (final lighting schedules are baseline schedules with appropriate control factor profiles applied). These final annual hours for demand were then multiplied by the appropriate LPD value (W/ft^2) for each area category to calculate per-unit demand for each considered building type (W/ft^2).

Finally, statewide demand savings (3.8 MW per year) were calculated by multiplying annual floor stock subject to the lighting alteration code (million ft^2) by per-unit demand savings (W/ft^2 per year) for each building type, as shown inFigure 39.

INCREMENTAL ENERGY SAVINGS

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Weights by Building Type Stock % of Considered Stock	Building Type	PER-UNIT ENERGY SAVINGS kWh/ft² per year	PER-UNIT DEMAND SAVINGS W/ft² per year	Annual Floor Stock Subject to Alteration Code million ft²	STATEWIDE ENERGY SAVINGS GWh per year	STATEWIDE DEMAND SAVINGS MW per year
1%	Hotel (excl. rooms)	0.09	0.010	7.4	0.65	0.07
28%	Office Large	0.02	0.003	159	3.78	0.44
8%	Office Small	0.03	0.003	42	1.28	0.12
4%	Restaurant	0.17	0.029	24	4.14	0.69
12%	Retail Large	0.03	0.005	77	2.23	0.37
12%	Retail Small	0.10	0.016	77	7.41	1.23
13%	School	0.10	0.010	57	5.88	0.56
22%	Warehouse Non-Refrigerated	0.05	0.003	98	4.56	0.32
100%					**29.9**	**3.8**

Figure 39: Statewide energy savings and demand reductions calculations.

Source: Lighting Alteration Model v2.0.

Appendix E: Energy Savings for Measure that Requires Occupant Sensing Controls in Stairwells Under Option 3

This appendix provides an overview of the methodology used to estimate energy savings from the measure requiring occupant sensing controls in stairwells under Option 3. Energy and demand savings resulting from the measure were calculated for the year 2020.

First, the total area of stairwells (as percent of total building area) was estimated from DEER prototypes with the CorridorStairway activity type. The DEER prototypes do not specify stairwells as a stand-alone activity type; instead, stairwells are part of a combined activity type called CorridorStairway. Twelve DEER prototype buildings have CorridorStairway activity type. Those DEER building types were mapped to six building type categories in the Energy Commission's Construction Forecast, as shown in Figure 40.

For each corresponding Energy Commission construction forecast category (see Table 18), appropriate DEER values for CorridorStairway activity type were averaged. For example, for schools, the DEER percent area in primary schools of 3.7 percent and the DEER percent area in secondary schools of 6.2 percent were averaged to 5.0 percent.

A further assumption was made that the CorridorStairway activity area was 45 percent stairwell and 55 percent corridor, based on a study of a few hundred buildings that found that tenants lost about six percent of their rented space to vertical penetrations (Miller 2012). This was roughly applied to the Large Office DEER prototype, which has 13.4 percent CorridorStairway area to get a 55 percent to 45 percent split between corridors and stairwells. This 45-percent estimate was applied to the six building types to get percent area for stairwells.

DEER Building Prototype	DEER Activity Type	DEER Percent Area - CorridorStairway
Education - Primary School	CorridorStairway	3.7%
Education - Secondary School	CorridorStairway	6.2%
Education - Community College	CorridorStairway	11.0%
Education - University	CorridorStairway	1.5%
Grocery	CorridorStairway	0.7%
Retail - 3-Story Large	CorridorStairway	1.6%
Health/Medical - Nursing Home	CorridorStairway	15.4%
Manufacturing - Bio/Tech	CorridorStairway	5.0%
Manufacturing - Light Industrial	CorridorStairway	5.8%
Office - Large	CorridorStairway	13.4%
Restaurant - Sit-Down	CorridorStairway	1.5%
Restaurant - Fast-Food	CorridorStairway	2.3%

CEC Construction Forecast Category	Avg. Percent Area - CorridorStairway	Percent Area - Stairway (@45%)
SCHOOL	5.0%	2.2%
COLLEGE	6.2%	2.8%
RETAIL	1.1%	0.5%
HOSP	15.4%	6.9%
N/A	N/A	N/A
OFF-LRG	13.4%	6.0%
REST	1.9%	0.9%

Figure 40: DEER building prototypes with CorridorStairway activity type and corresponding Energy Commission's Construction Forecast categories.

Next, the Energy Commission construction forecast (see Appendix A) was used to estimate the total area (million square feet) of existing floor space that will be impacted by the proposed code change. Figure 41 summarizes the assumptions that are based on the Statewide CASE Team's best judgement. The construction forecast categories were multiplied by percent area of stairwells to get the total area of stairwells in California, as shown in Figure 42. The rate of lighting alteration was assumed to be once in

15 years for all considered building types. The annual stairwell floor stock was multiplied by the market share of Option 3 of 23 percent (since occupant sensing controls are already required under Option 1 and 2).

Construction Forecast Building Type *Building sub-type (prototype)**	Weighting of Sub-Types to Construction Forecast Building Type**	Percent of existing floor space that will be altered during the first year the 2019 Standards are in effect.
Small office		25%
Restaurant		50%
Retail	100%	43%
Stand-Alone Retail	*10%*	50%
Large Retail	*75%*	50%
Strip Mall	*5%*	0%
Mixed-Use Retail	*10%*	0%
Food		0%
Non-refrigerated warehouse		0%
Refrigerated warehouse		0%
Schools	100%	55%
small school	*60%*	25%
large school	*40%*	100%
College	100%	94%
Small Office	*5%*	25%
Medium Office	*15%*	100%
Medium Office/Lab	*20%*	100%
Public Assembly	*5%*	50%
Large School	*30%*	100%
High Rise Apartment	*25%*	100%
Hospital		50%
Hotel/motel		50%
Large offices	100%	100%
Medium office	50%	100%
Large office	50%	100%

Figure 41: Assumptions on the existing floor space impacted by the measure that requires occupant sensing controls in stairwells under Option 3.

Using the Lighting Alteration Model v2.0, per-unit energy savings from partial OFF occupant sensing controls in stairwells under Option 3 were calculated using the Large Office building prototype. Under Option 3, 2019 LPD value for stairwells was reduced by 50 percent (0.6 W/ft^2 x 50% = 0.3 W/ft^2). The per-unit energy use with and without partial OFF occupant sensing controls was compared to get per-unit energy savings (kWh/ft^2 of stairwell area per year) and demand savings (W/ft^2 of stairwell area per year). The values for per-unit energy and demand savings were assumed to apply to other considered building types.

The per-unit energy and demand savings were scaled to statewide savings using calculated stairwell floor stock subject to the proposed measure.

Million Square Feet of Alterations Impacted By Proposed Code Change in		2020

Climate Zone	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	OFF-LRG	TOTAL
1	0	0.44	2.0	0	0	0	1.9	1.7	1.0	0.84	2.8	**11**
2	0	2.3	15	0	0	0	11	10	6.7	6.4	42	**94**
3	0	9.1	64	0	0	0	42	42	27	30	254	**468**
4	0	5.1	37	0	0	0	25	23	16	15	99	**220**
5	0	1.0	7.2	0	0	0	4.8	4.5	3.1	2.9	19	**43**
6	0	13	64	0	0	0	37	35	20	21	186	**376**
7	0	6.6	39	0	0	0	24	22	16	20	101	**229**
8	0	18	92	0	0	0	52	49	29	30	270	**540**
9	0	19	89	0	0	0	46	52	36	29	325	**596**
10	0	18	77	0	0	0	48	33	21	21	97	**316**
11	0	2.1	14	0	0	0	12	8.4	6.5	3.6	16	**62**
12	0	11	76	0	0	0	51	39	31	23	176	**408**
13	0	4.8	30	0	0	0	27	17	14	7.6	28	**127**
14	0	3.5	15	0	0	0	9.0	6.0	4.2	3.6	23	**64**
15	0	2.3	12	0	0	0	7.6	3.8	2.8	3.6	11	**43**
16	0	3.6	18	0	0	0	9.7	10	6.2	4.4	47	**98**
Total	**0**	**120**	**651**	**0**	**0**	**0**	**408**	**358**	**241**	**222**	**1695**	**3695**

Percent Area for Stairwells	0%	0.85%	0.51%	0%	0%	0%	2.2%	2.8%	6.9%	0.51%	6.0%	3.9%
Total Area for Stairwells (million ft²)	0	1.0	3.4	0	0	0	9.1	10.0	16.7	1.1	102	**143**
Annual Floor Stock Subject to Lighting Alterations (million ft²)	0	0.068	0.22	0	0	0	0.61	0.67	1.1	0.076	6.8	**9.6**
OPTION 3 Annual Floor Stock Subject to the Measure (million ft²)	**0**	**0.016**	**0.051**	**0**	**0**	**0**	**0.14**	**0.15**	**0.26**	**0.017**	**1.6**	**2.2**

The annual rate of lighting alterations	0.067
The market share of Option 3	23%
TOTAL Energy Savings:	**0.29 GWh**
(@ 0.13 kWh/ft²)	
TOTAL Demand Savings:	**0.035 MW**
(@ 0.016 W/ft²)	

Figure 42: Statewide energy savings for the measure that requires occupant sensing controls in stairwells under Option 3.

Appendix F: Detailed Per-Unit Energy Use and Demand Model Inputs and Results

For demonstration purposes, the detailed model inputs for Office Large and the results are included in this appendix. The results are from the Lighting Alteration Model v2.0 with wattage reduction of 35/50 percent in accordance with 2016 Title 24, Part 6 Standards. The detailed results for other considered building types are available upon request.

Color coding used in the screenshots of the lighting alteration model is as follows:
Red font color in control selection indicates a proposed lighting control requirement for 2019 Title 24, Part 6 code cycle.

Grey fill color means that a lighting control does not apply.

Green fill color highlights calculated values of annual FLE hours based on DEER lighting schedules and selected controls.

Orange fill color highlights values relevant to calculations of demand savings.

SUMMARY		OFFICE LARGE
Baseline (Existing Building Stock) Per-Unit Energy Use	**2.2 kWh/ft² per year**	**Distribution of the age of lighting systems**
2001 Title 24, Part 6	3.2 kWh/ft² per year	22%
2005 Title 24, Part 6	3.0 kWh/ft² per year	4%
2008 Title 24, Part 6	2.5 kWh/ft² per year	9%
2013 Title 24, Part 6	1.8 kWh/ft² per year	22%
2016 Title 24, Part 6	1.7 kWh/ft² per year	44%
2019 Standards Per-Unit Energy Use		
OPTION 1 | 85%-100% of 2019 LPA	1.5 kWh/ft² per year	
OPTION 2 | ≤ 85% of 2019 LPA	1.4 kWh/ft² per year	
OPTION 3 | Reduction of existing wattage (weighted)	1.2 kWh/ft² per year	**Distribution of the age of lighting systems**
Option 3 | 2001 Title 24, Part 6	1.5 kWh/ft² per year	22%
Option 3 | 2005 Title 24, Part 6	1.4 kWh/ft² per year	4%
Option 3 | 2008 Title 24, Part 6	1.2 kWh/ft² per year	9%
Option 3 | 2013 Title 24, Part 6	1.1 kWh/ft² per year	22%
Option 3 | 2016 Title 24, Part 6	1.0 kWh/ft² per year	44%

INPUTS			OFFICE LARGE					
DEER Building: Large Office (Ofl) modified to split "CorridorStairway" activity area into corridor (55% of "CorridorStairway) and stairway (45% of "CorridorStairway").								
Title 24, Part 6 Area Category	**DEER Activity Area**	**% of Total Area**	**2001 LPD, W/ft²**	**2005 LPD, W/ft²**	**2008 LPD, W/ft²**	**2013 LPD, W/ft²**	**2016, LPD W/ft²**	**2019 LPD, W/ft²**
Office Area > 250 ft²	OfficeOpen	46%	1.3	1.2	0.9	0.75	0.75	0.62
Office Area ≤ 250 ft²	OfficeSmall	20%	1.3	1.2	1.1	1.0	1.0	0.68
Corridors	Corridor-	7%	0.6	0.6	0.6	0.6	0.6	0.6
Corridors	Stairway-	6%	0.6	0.6	0.6	0.6	0.6	0.6
Commercial Storage	StorageSmlCond	5%	0.6	0.6	0.6	0.6	0.6	0.46
Lobby Area Main Entry	LobbyWaiting	4%	1.5	1.5	1.5	1.5	1.0	0.82
Convention, Conference, Multipurpose and Meeting Center Areas	Conference	3%	1.5	1.4	1.4	1.4	1.2	0.85
Restrooms	Restroom	3%	0.6	0.6	0.6	0.6	0.6	0.65
Dining Area	Break	2%	1.1	1.1	1.1	1.1	1.0	0.47
Electrical, Mechanical, Telephone Rooms	MechElecRoom	2%	0.7	0.7	0.7	0.7	0.55	0.39
Copy/Print Room	CopyRoom	1%	0.6	0.6	0.6	0.6	0.6	0.50
	TOTAL	**100%**						

Figure 43: Summary of model outputs and inputs for Office Large.

Source: Lighting Alteration Model v2.0.

BASELINE (Existing Building Stock) | kWh/ft² per year by AREA CATEGORY

	LIGHTING CONTROLS 2001					OUTPUT	DEMAND	
DEER Activity Area	Occupancy Controls	Auto Daylighting	2001 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	2001 kWh/ft² per year	Demand Intermediate Calculation	W/ft² per year
OfficeOpen			1.3	2,774	46%	3.61	0.325	0.42
OfficeSmall			1.3	2,774	20%	3.61	0.325	0.42
Corridor-			0.6	2,774	7%	1.66	0.325	0.20
Stairway-			0.6	2,774	6%	1.66	0.325	0.20
StorageSmlCond			0.6	2,774	5%	1.66	0.325	0.20
LobbyWaiting			1.5	2,774	4%	4.16	0.325	0.49
Conference			1.5	2,774	3%	4.16	0.325	0.49
Restroom			0.6	2,774	3%	1.66	0.325	0.20
Break			1.1	2,774	2%	3.05	0.325	0.36
MechElecRoom			0.7	2,774	2%	1.94	0.325	0.23
CopyRoom			0.6	2,774	1%	1.66	0.325	0.20
Weighted AVERAGE					100%	3.17		0.4

	LIGHTING CONTROLS 2005					OUTPUT	DEMAND	
DEER Activity Area	Occupancy Controls	Auto Daylighting	2005 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	2005 kWh/ft² per year	Demand Intermediate Calculation	W/ft² per year
OfficeOpen			1.2	2,774	46%	3.33	0.325	0.39
OfficeSmall			1.2	2,774	20%	3.33	0.325	0.39
Corridor-			0.6	2,774	7%	1.66	0.325	0.20
Stairway-			0.6	2,774	6%	1.66	0.325	0.20
StorageSmlCond			0.6	2,774	5%	1.66	0.325	0.20
LobbyWaiting			1.5	2,774	4%	4.16	0.325	0.49
Conference			1.4	2,774	3%	3.88	0.325	0.46
Restroom			0.6	2,774	3%	1.66	0.325	0.20
Break			1.1	2,774	2%	3.05	0.325	0.36
MechElecRoom			0.7	2,774	2%	1.94	0.325	0.23
CopyRoom			0.6	2,774	1%	1.66	0.325	0.20
Weighted AVERAGE					100%	2.98		0.3

	LIGHTING CONTROLS 2008					OUTPUT	DEMAND	
DEER Activity Area	Occupancy Controls	Auto Daylighting	2008 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	2008 kWh/ft² per year	Demand Intermediate Calculation	W/ft² per year
OfficeOpen			0.9	2,774	46%	2.50	0.325	0.29
OfficeSmall			1.1	2,774	20%	3.05	0.325	0.36
Corridor-			0.6	2,774	7%	1.66	0.325	0.20
Stairway-			0.6	2,774	6%	1.66	0.325	0.20
StorageSmlCond			0.6	2,774	5%	1.66	0.325	0.20
LobbyWaiting			1.5	2,774	4%	4.16	0.325	0.49
Conference			1.4	2,774	3%	3.88	0.325	0.46
Restroom			0.6	2,774	3%	1.66	0.325	0.20
Break			1.1	2,774	2%	3.05	0.325	0.36
MechElecRoom			0.7	2,774	2%	1.94	0.325	0.23
CopyRoom			0.6	2,774	1%	1.66	0.325	0.20
Weighted AVERAGE					100%	2.54		0.3

	LIGHTING CONTROLS 2013					OUTPUT	DEMAND	
DEER Activity Area	Occupancy Controls	Auto Daylighting	85% of 2013 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	2013 kWh/ft² per year	Demand Intermediate Calculation	W/ft² per year
OfficeOpen			0.6	2,774	46%	1.77	0.325	0.21
OfficeSmall	Yes		0.9	2,164	20%	1.84	0.254	0.22
Corridor-	Yes (partial)		0.5	2,469	7%	1.26	0.290	0.15
Stairway-	Yes (partial)		0.5	2,469	6%	1.26	0.290	0.15
StorageSmlCond			0.5	2,774	5%	1.41	0.325	0.17
LobbyWaiting			1.3	2,774	4%	3.54	0.325	0.41
Conference	Yes		1.2	2,164	3%	2.57	0.254	0.30
Restroom			0.5	2,774	3%	1.41	0.325	0.17
Break			0.9	2,774	2%	2.59	0.325	0.30
MechElecRoom			0.6	2,774	2%	1.65	0.325	0.19
CopyRoom			0.5	2,774	1%	1.41	0.325	0.17
Weighted AVERAGE					100%	1.80		0.2

DEER Activity Area	LIGHTING CONTROLS 2016 Occupancy Controls	Auto Daylighting	85% of 2016 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	OUTPUT 2016 kWh/ft² per year	Demand Intermediate Calculation	DEMAND W/ft² per year
OfficeOpen			0.6	2,774	46%	1.77	0.325	0.21
OfficeSmall	Yes		0.9	2,164	20%	1.84	0.254	0.22
Corridor-	Yes (partial)		0.5	2,469	7%	1.26	0.290	0.15
Stairway-	Yes (partial)		0.5	2,469	6%	1.26	0.290	0.15
StorageSmlCond			0.5	2,774	5%	1.41	0.325	0.17
LobbyWaiting			0.8	2,774	4%	2.24	0.325	0.26
Conference	Yes		1.0	2,164	3%	2.21	0.254	0.26
Restroom			0.5	2,774	3%	1.41	0.325	0.17
Break			0.9	2,774	2%	2.36	0.325	0.28
MechElecRoom			0.5	2,774	2%	1.30	0.325	0.15
CopyRoom			0.5	2,774	1%	1.41	0.325	0.17
Weighted AVERAGE					**100%**	**1.72**		**0.2**

Figure 44: Calculations of baseline (existing building stock) per-unit energy use and demand values for Office Large, comprising 2001, 2005, 2008, 2013, and 2016 code cycles.

Source: Lighting Alteration Model v2.0.

2019 STANDARDS | OPTION 1: 85%-100% of 2019 LPA | kWh/ft2 per year by AREA CATEGORY — **OFFICE LARGE**

DEER Activity Area	LIGHTING CONTROLS Occupancy Controls	Auto Daylighting	2019 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	OUTPUT kWh/ft² per year	Demand Intermediate Calculation	DEMAND W/ft² per year
OfficeOpen		Yes (plus OFF)	0.62	2,670	46%	1.66	0.317	0.20
OfficeSmall	Yes	Yes (plus OFF)	0.68	1,784	20%	1.21	0.225	0.15
Corridor-	Yes (partial)		0.6	2,484	7%	1.49	0.291	0.17
Stairway-	Yes (partial)		0.6	2,484	6%	1.49	0.291	0.17
StorageSmlCond			0.46	2,774	5%	1.28	0.325	0.15
LobbyWaiting		Yes (plus OFF)	0.82	2,412	4%	1.98	0.290	0.24
Conference	Yes	Yes (plus OFF)	0.85	2,112	3%	1.80	0.251	0.21
Restroom	Yes		0.65	1,878	3%	1.22	0.220	0.14
Break		Yes (plus OFF)	0.47	2,447	2%	1.14	0.287	0.13
MechElecRoom			0.39	2,774	2%	1.08	0.325	0.13
CopyRoom			0.5	2,774	1%	1.39	0.325	0.16
Weighted AVERAGE					**100%**	**1.50**		**0.2**

2019 STANDARDS | OPTION 2: ≤ 85% of 2019 LPA | kWh/ft2 per year by AREA CATEGORY — **OFFICE LARGE**

DEER Activity Area	LIGHTING CONTROLS Occupancy Controls	Auto Daylighting	85% of 2019 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	OUTPUT kWh/ft² per year	Demand Intermediate Calculation	DEMAND W/ft² per year
OfficeOpen			0.53	2,774	46%	1.46	0.325	0.17
OfficeSmall	Yes		0.58	2,194	20%	1.27	0.257	0.15
Corridor-	Yes (partial)		0.51	2,484	7%	1.27	0.291	0.15
Stairway-	Yes (partial)		0.51	2,484	6%	1.27	0.291	0.15
StorageSmlCond			0.39	2,774	5%	1.08	0.325	0.13
LobbyWaiting			0.70	2,774	4%	1.93	0.325	0.23
Conference	Yes		0.72	2,194	3%	1.59	0.257	0.19
Restroom	Yes		0.55	1,878	3%	1.04	0.220	0.12
Break			0.40	2,774	2%	1.10	0.325	0.13
MechElecRoom			0.33	2,774	2%	0.92	0.325	0.11
CopyRoom			0.43	2,774	1%	1.18	0.325	0.14
Weighted AVERAGE					**100%**	**1.37**		**0.2**

2019 STANDARDS | OPTION 3: reduction of existing wattage | kWh/ft² per year by AREA CATEGORY — OFFICE LARGE

DEER Activity Area	LIGHTING CONTROLS: Occupancy Controls	LIGHTING CONTROLS: Auto Daylighting	% of 2001 LPD, W/ft²	% of 2005 LPD, W/ft²	% of 2008 LPD, W/ft²	% of 2013 LPD, W/ft²	% of 2016 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	OUTPUT: 2001 kWh/ft² per year	2005 kWh/ft² per year	2008 kWh/ft² per year	2013 kWh/ft² per year	2016 kWh/ft² per year
OfficeOpen			0.65	0.60	0.45	0.38	0.38	2,774	46%	1.80	1.66	1.25	1.04	1.04
OfficeSmall	Yes		0.65	0.60	0.55	0.50	0.50	2,194	20%	1.43	1.32	1.21	1.10	1.10
CorridorStairway			0.39	0.39	0.39	0.39	0.39	2,774	13%	1.08	1.08	1.08	1.08	1.08
StorageSmlCond			0.39	0.39	0.39	0.39	0.39	2,774	5%	1.08	1.08	1.08	1.08	1.08
LobbyWaiting			0.98	0.98	0.98	0.98	0.62	2,774	4%	2.70	2.70	2.70	2.70	1.71
Conference	Yes		0.98	0.91	0.91	0.91	0.78	2,194	3%	2.14	2.00	2.00	2.00	1.71
Restroom	Yes		0.39	0.39	0.39	0.39	0.39	1,878	3%	0.73	0.73	0.73	0.73	0.73
Break			0.72	0.72	0.72	0.72	0.65	2,774	2%	1.98	1.98	1.98	1.98	1.80
MechElecRoom			0.46	0.46	0.46	0.46	0.36	2,774	2%	1.26	1.26	1.26	1.26	0.99
CopyRoom			0.39	0.39	0.39	0.39	0.39	2,774	1%	1.08	1.08	1.08	1.08	1.08
Weighted AVERAGE									**100%**	**1.60**	**1.51**	**1.29**	**1.17**	**1.12**
									Distribution of the age of lighting systems	22%	4%	9%	22%	44%
									Weighted Option 3					**1.26**

2019 STANDARDS | OPTION 3: Reduction of existing wattage | kWh/ft² per year by AREA CATEGORY — OFFICE LARGE

DEER Activity Area	LIGHTING CONTROLS: Occupancy Controls	LIGHTING CONTROLS: Auto Daylighting	% of 2001 LPD, W/ft²	% of 2005 LPD, W/ft²	% of 2008 LPD, W/ft²	% of 2013 LPD, W/ft²	% of 2016 LPD, W/ft²	Annual FLE Hours, hr	% of Total Area	OUTPUT: 2001 kWh/ft² per year	2005 kWh/ft² per year	2008 kWh/ft² per year	2013 kWh/ft² per year	2016 kWh/ft² per year
OfficeOpen			0.65	0.60	0.45	0.38	0.38	2,774	46%	1.80	1.66	1.25	1.04	1.04
OfficeSmall	Yes		0.65	0.60	0.55	0.50	0.50	2,194	20%	1.43	1.32	1.21	1.10	1.10
Corridor-			0.30	0.30	0.30	0.30	0.30	2,774	7%	0.83	0.83	0.83	0.83	0.83
Stairway-			0.30	0.30	0.30	0.30	0.30	2,774	6%	0.83	0.83	0.83	0.83	0.83
StorageSmlCond			0.30	0.30	0.30	0.30	0.30	2,774	5%	0.83	0.83	0.83	0.83	0.83
LobbyWaiting			0.75	0.75	0.75	0.75	0.48	2,774	4%	2.08	2.08	2.08	2.08	1.32
Conference	Yes		0.75	0.70	0.70	0.70	0.60	2,194	3%	1.65	1.54	1.54	1.54	1.32
Restroom	Yes		0.30	0.30	0.30	0.30	0.30	1,878	3%	0.56	0.56	0.56	0.56	0.56
Break			0.55	0.55	0.55	0.55	0.50	2,774	2%	1.53	1.53	1.53	1.53	1.39
MechElecRoom			0.35	0.35	0.35	0.35	0.28	2,774	2%	0.97	0.97	0.97	0.97	0.76
CopyRoom			0.30	0.30	0.30	0.30	0.30	2,774	1%	0.83	0.83	0.83	0.83	0.83
Weighted AVERAGE									**100%**	**1.49**	**1.40**	**1.18**	**1.06**	**1.02**
									Distribution of the age of lighting systems	22%	4%	9%	22%	44%
									Weighted Option 3					**1.16**

DEER Activity Area	DEMAND: Demand Intermediate Calculation	2001 W/ft² per year	2005 W/ft² per year	2008 W/ft² per year	2013 W/ft² per year	2016 W/ft² per year
OfficeOpen	0.325	0.21	0.20	0.15	0.12	0.12
OfficeSmall	0.257	0.17	0.15	0.14	0.13	0.13
Corridor-	0.325	0.10	0.10	0.10	0.10	0.10
Stairway-	0.325	0.10	0.10	0.10	0.10	0.10
StorageSmlCond	0.325	0.10	0.10	0.10	0.10	0.10
LobbyWaiting	0.325	0.24	0.24	0.24	0.24	0.15
Conference	0.257	0.19	0.18	0.18	0.18	0.15
Restroom	0.220	0.07	0.07	0.07	0.07	0.07
Break	0.325	0.18	0.18	0.18	0.18	0.16
MechElecRoom	0.325	0.11	0.11	0.11	0.11	0.09
CopyRoom	0.325	0.10	0.10	0.10	0.10	0.10
Weighted AVERAGE		**0.17**	**0.16**	**0.14**	**0.12**	**0.12**
		22%	4%	9%	22%	44%
						0.14

Figure 45: Calculations of 2019 Standards per-unit energy use values for Office Large (Options 1, 2, and 3) with wattage reduction of 35/50% under current Option 3 in accordance with 2016 Title 24, Part 6 code.

Source: Lighting Alteration Model v2.0.

Appendix G: Statewide Savings with Existing Building Stock as Baseline

The developed lighting alteration model serves two main purposes:

- Compares three compliance pathways in terms of potential energy savings using the existing building stock as baseline.
- Calculates incremental energy savings from the measure that requires the reduction of existing wattage by 50 percent (using proposed 2019 Standards with unchanged Option 3 as a baseline).

In this appendix, the model results are presented using the existing building stock as a baseline. Figure 46 and Figure 47 provide a high-level summary of per-unit energy use, per-unit energy savings, and statewide energy savings for the following two scenarios:

- Currently required reductions of existing wattage under Option 3 (i.e., reduction by 35 percent or 50 percent of existing wattage depending on space type).
- Revised reduction of existing wattage under Option 3 (i.e., reduction by 50 percent for all space types per proposed measure).

The Lighting Alteration Model v2.0 calculates three values for statewide energy savings, one corresponding to each compliance pathway. For each value, it is assumed that all regulated alterations are subject to the relevant compliance pathway. The market share of compliance pathways is used to blend the three values into one final value.

HIGH-LEVEL SUMMARY of MODEL OUPUTS			
Baseline (Existing Building Stock) Per-Unit Energy Use (based on 2001, 2005, 2008, 2013, and 2016 Title 24, Part 6 code vintages)	2.7	kWh/ft^2 per year	
2019 Standards Per-Unit Energy Use			
OPTION 1 | 85%-100% of 2019 LPA	1.8	kWh/ft^2 per year	
OPTION 2 | ≤ 85% of 2019 LPA	1.6	kWh/ft^2 per year	
OPTION 3 | Reduction of existing wattage	1.7	kWh/ft^2 per year	
2019 Standards Per-Unit Energy Savings			
OPTION 1 | 85%-100% of 2019 LPA	0.9	kWh/ft^2 per year	
OPTION 2 | ≤ 85% of 2019 LPA	1.0	kWh/ft^2 per year	
OPTION 3 | Reduction of existing wattage	1.0	kWh/ft^2 per year	
2019 Standards Statewide Energy Savings			Assuming that all regulated lighting alterations use:
OPTION 1 | 85%-100% of 2019 LPA	481	GWh per year	OPTION 1 for code compliance
OPTION 2 | ≤ 85% of 2019 LPA	581	GWh per year	OPTION 2 for code compliance
OPTION 3 | Reduction of existing wattage	557	GWh per year	OPTION 3 for code compliance
Weighted AVERAGE	**528**	**GWh per year**	Blended using data on market share of each compliance option

Figure 46: High-level summary of per-unit energy use and savings, and statewide energy savings, with wattage reduction of 35/50% under current Option 3.

Source: Lighting Alteration Model v2.0.

HIGH-LEVEL SUMMARY of MODEL OUPUTS			
Baseline (Existing Building Stock) Per-Unit Energy Use (based on 2001, 2005, 2008, 2013, and 2016 Title 24, Part 6 code vintages)	2.7	kWh/ft^2 per year	
2019 Standards Per-Unit Energy Use			
OPTION 1 | 85%-100% of 2019 LPA	1.8	kWh/ft^2 per year	
OPTION 2 | ≤ 85% of 2019 LPA	1.6	kWh/ft^2 per year	
OPTION 3 | Reduction of existing wattage	1.4	kWh/ft^2 per year	
2019 Standards Per-Unit Energy Savings			
OPTION 1 | 85%-100% of 2019 LPA	0.9	kWh/ft^2 per year	
OPTION 2 | ≤ 85% of 2019 LPA	1.0	kWh/ft^2 per year	
OPTION 3 | Reduction of existing wattage	1.2	kWh/ft^2 per year	
2019 Standards Statewide Energy Savings			Assuming that all regulated lighting alterations use:
OPTION 1 | 85%-100% of 2019 LPA	481	GWh per year	OPTION 1 for code compliance
OPTION 2 | ≤ 85% of 2019 LPA	581	GWh per year	OPTION 2 for code compliance
OPTION 3 | Reduction of existing wattage	688	GWh per year	OPTION 3 for code compliance
Weighted AVERAGE	**557**	**GWh per year**	Blended using data on market share of each compliance option

Figure 47: High-level summary of per-unit energy use and savings, and statewide energy savings, with wattage reduction of 50% under proposed Option 3.

Source: Lighting Alteration Model v2.0.

Figure 48 and Figure 49 provide the details of the model results for 2019 Standards statewide energy savings for two cases:

- Currently required reductions of existing wattage under Option 3 (i.e., reduction by 35 percent or 50 percent of existing wattage depending on space type).
- Revised reduction of existing wattage under Option 3 (i.e., reduction by 50 percent for all space types per proposed measure).

2019 STANDARDSStatewide Energy Savings

Weights by Building Type Stock % of Considered Stock	Building Type	Annual Floor Stock Subject to Alteration Code	OPTION 1 85-100% of 2019 LPA STATEWIDE ENERGY SAVINGS	OPTION 2 ≤ 85% of 2019 LPA STATEWIDE ENERGY SAVINGS	OPTION 3 Reduction of Existing Wattage STATEWIDE ENERGY SAVINGS	Weighted by Market Share of Compliance Options
		million ft²	GWh per year	GWh per year	GWh per year	GWh per year
1%	Hotel (excl. rooms)	7.4	6	8	10	
28%	Office Large	159	106	128	144	
8%	Office Small	42	33	37	39	
4%	Restaurant	24	50	55	34	
12%	Retail Large	77	96	127	138	
12%	Retail Small	77	72	97	84	
13%	School	57	73	84	60	
22%	Warehouse Non-Refrigerated	98	45	46	48	
100%	**Weighted AVERAGE (by Building Type Stock)**	**541**	**481**	**581**	**557**	**528**
	Weights by Market Share of Compliance Options	**100%**	48%	29%	23%	

Color coding:

USER Input to vary LPA threshold under Option 2 or allowed wattage under Option 3 in 2019 code cycle

Percentage of LPA used in the model for each compliance option

Assumed % of Lighting Power Allowance by Building Type	OPTION 1 "85-100% of LPA"	OPTION 2 ≤ 85% of LPA	Assumed % of Wattage Allowance by function area under Option 3	OPTION 3 Modeled Wattage Allowance	For REFERENCE ONLY OPTION 3 2016 Code Vintage
All Building Types	100%	85%	Office area category	50%	50%
			Retail area category	50%	50%
		2019 OPTION 2 Revised LPA			
		85%	Hotel function area	50%	50%
			All other area categories	65%	65%

Figure 48: 2019 Standards statewide energy savings with wattage reduction of 35/50% under current Option 3.

Source: Lighting Alteration Model v2.0.

2019 STANDARDSStatewide Energy Savings

Weights by Building Type Stock % of Considered Stock	Building Type	Annual Floor Stock Subject to Alteration Code	OPTION 1 85-100% of 2019 LPA STATEWIDE ENERGY SAVINGS	OPTION 2 ≤ 85% of 2019 LPA STATEWIDE ENERGY SAVINGS	OPTION 3 Reduction of Existing Wattage STATEWIDE ENERGY SAVINGS	Weighted by Market Share of Compliance Options
		million ft²	GWh per year	GWh per year	GWh per year	GWh per year
1%	Hotel (excl. rooms)	7.4	6	8	13	
28%	Office Large	159	106	128	161	
8%	Office Small	42	33	37	44	
4%	Restaurant	24	50	55	52	
12%	Retail Large	77	96	127	148	
12%	Retail Small	77	72	97	117	
13%	School	57	73	84	85	
22%	Warehouse Non-Refrigerated	98	45	46	67	
100%	**Weighted AVERAGE (by Building Type Stock)**	**541**	**481**	**581**	**688**	**557**
	Weights by Market Share of Compliance Options	**100%**	48%	29%	23%	

Color coding:

USER Input to vary LPA threshold under Option 2 or allowed wattage under Option 3 in 2019 code cycle

Percentage of LPA used in the model for each compliance option

Assumed % of Lighting Power Allowance by Building Type	OPTION 1 "85-100% of LPA"	OPTION 2 ≤ 85% of LPA
All Building Types	100%	85%

2019 OPTION 2 Revised LPA
85%

Assumed % of Wattage Allowance by function area under Option 3	OPTION 3 Modeled Wattage Allowance	For REFERENCE ONLY OPTION 3 2016 Code Vintage
Office area category	50%	50%
Retail area category	50%	50%
Hotel function area	50%	50%
All other area categories	50%	65%

Figure 49: 2019 Standards statewide energy savings with the revised wattage reduction of 50% under proposed Option 3.

Source: Lighting Alteration Model v2.0.

Appendix H: EXISTING BUILDING STOCK | SUMMARY OF LITERATURE REVIEW

The key findings from the studies that informed this CASE Report are presented in Table 26 in chronological order (by publishing date).

Table 26: Key Pertinent Points of Literature Review

Data Source (Year Published/Agency Commissioning Study/Title) and Citation	Key Pertinent Points and Relevance to this CASE Report
Multiple Years/CPUC/California Database of Energy Efficient Resources **(California Public Utilities Commission 2015)**	**Pertinent Points** • Includes 23 building types. For each building type, the DEER data specifies typical "activity" types. On average, each building type has five associated activity types. In total, the DEER data contains 110 building and activity type combinations, each with unique lighting schedules. • Information posted at http://www.deeresources.com/index.php/deer-versions/deer2016#LightingProfiles. **Relevance to this CASE Report** • Used as the source for lighting schedules and to ground truth LPD for the existing building stock in California.
2005/HMG/Sidelighting Photocontrols Field Study **(Heschong Mahone Group, Inc. 2005)**	**Pertinent Points** • The study found that as of 2004, there were only about 200 sidelit buildings with installed photocontrols in the West Coast. **Relevance to this CASE Report** • Used as the basis for simplifying assumptions related to automatic daylighting controls.

2006/The Energy Commission/California Commercial End Use Study **(Itron, Inc. 2006)**

Pertinent Points

- The study targeted 2,800 premises in California as a stratified random sample (by utility service area, climate zone, building type, and size class) in PG&E, SMUD, SCE, and SDG&E territories (e-page 32).
- 2,790 actual surveys were performed and accepted for inclusion into the DrCEUS database (e-page 94).
- PG&E, SCE, and SDG&E provided energy use data for 2000-2002; SMUD provided data for 2003 (e-page 100).
- The study presents the results for electric energy intensities (kWh/ft^2 per year) and electric usage (GWh) by building type for indoor lighting as summarized below (e-page 26).

Building Type	**Electric Energy Intensities (kWh/ft^2 per year) for Indoor Lighting**	**Electric Usage (GWh) for Indoor Lighting**
All Commercial	**3.92**	**19,265**
Lodging	3.50	945
Office Large (≥30,000 square feet)	4.46	2,945
Office Small (<30,000 square feet)	3.83	1,386
Restaurant	6.45	961
Retail	6.05	4,246
School	2.88	1,281
Warehouse Non-Refrigerated	2.21	1,223

- The study presents 16-day hourly shapes by building type (four day types – weekday, weekend, hot day (weekday), and cold day (weekday) – for four seasons (winter, spring, summer, and fall) (e-page 160).
- The study found that the primary electric end uses in the covered electric service areas are interior lighting (29%), cooling (15%), refrigeration (13%), and ventilation (12%) (e-page 21).

Relevance to this CASE Report

- Used reported electric energy intensities (kWh/ft^2 per year) to compare them with the per-unit energy use values presented in this CASE Report.

<table>
<tr>
<td>2011/Energy Commission/Office Daylighting Potential (Saxena 2011)</td>
<td>
Pertinent Points

The study used CEUS database as the basis for the analysis; the dataset with on-site surveys for 536 office premises was requested from Itron, which conducted the CEUS effort (e-page 19 and 24).
The study presented LPD values for surveyed premises as part of the CEUS effort as summarized below (e-page 25).

<table>
<tr><th></th><th>Office</th></tr>
<tr><td>LPD (W/ft^2), Average</td><td>1.28</td></tr>
<tr><td>LPD (W/ft^2), Median</td><td>1.15</td></tr>
<tr><td>LPD (W/ft^2), Min</td><td>0.04</td></tr>
<tr><td>LPD (W/ft^2), Max</td><td>7.70</td></tr>
<tr><td>LPD (W/ft^2), Standard Deviation</td><td>0.67</td></tr>
</table>

The study found that the percent of daylit areas with existing photocontrols was less than one percent (e-page 29).

Relevance to this CASE Report

Used the range in LPDs for office to ground truth the values used in the lighting alteration analysis for office.
Used as the basis for simplifying assumptions related to automatic daylighting controls.

</td>
</tr>
<tr>
<td>2012/DOE/2010 U.S. Lighting Market Characterization (Navigant Consulting, Inc. 2012)</td>
<td>
Pertinent Points

This study provides estimates of electric energy use by commercial indoor lighting in the United States for year 2010 as summarized below (CEUS was one of the data sources).

<table>
<tr><th>Building Type</th><th>Installed Wattage (W/ft^2)</th><th>Electric Energy Intensities (kWh/ft^2 per year) for Indoor Lighting</th></tr>
<tr><td>Lodging</td><td>0.6</td><td>2.4</td></tr>
<tr><td>Office</td><td>1.0</td><td>4.1</td></tr>
<tr><td>Food Service</td><td>1.3</td><td>5.4</td></tr>
<tr><td>Retail</td><td>1.5</td><td>6.3</td></tr>
<tr><td>School</td><td>0.6</td><td>2.5</td></tr>
<tr><td>Warehouse Non-Refrigerated</td><td>1.1</td><td>4.3</td></tr>
</table>
Relevance to this CASE Report

Used reported electric energy intensities (kWh/ft^2 per year) to compare them with the per-unit energy use values presented in this CASE Report.

</td>
</tr>
</table>

<table>
<tr>
<td>2012/LBNL/Lighting Controls in Commercial Buildings (Williams, Atkinson, et al. 2012)</td>
<td>
Pertinent Points

The study found that simulations significantly overestimate (by at least 10 percent) the average savings obtainable from daylighting controls in actual buildings (e-page 1).

Relevance to this CASE Report

Used as the basis to discount the contribution from automatic daylighting controls in the 2019 Standards per-unit energy calculations.

</td>
</tr>
<tr>
<td>2014/The Energy Commission/Lighting Electricity Use in California – Baseline Assessment to Support AB 1109 (California Lighting Technology Center, UC Davis 2014)</td>
<td>
Pertinent Points

The report presents electricity use intensity for indoor commercial lighting from 1995 to 2010 (kWh/ft^2 per year) as summarized below for the years that coincided with an updated Title 24, Part 6 code going into effect (e-page 30).
<table>
<tr><th>Year</th><th>kWh/ft^2 per year</th></tr>
<tr><td>1995</td><td>5.23</td></tr>
<tr><td>2001</td><td>4.85</td></tr>
<tr><td>2005
(Note: 2005 Title 24, Part 6 effective October 1, 2005)</td><td>4.40</td></tr>
<tr><td>2010
(Note: 2008 Title 24, Part 6 effective January 1, 2010)</td><td>3.72</td></tr>
</table>

The report estimates that the percent of total commercial electricity use for indoor commercial lighting decreased from 36.6 percent in 1995 to 25.7 percent in 2010; and that lighting use decreased from 28,400 GWh in 1995 to 25,769 GWh in 2010 (e-page 30).

Relevance to this CASE Report

Used reported electric energy intensities (kWh/ft^2 per year) to compare them with the per-unit energy use values presented in this CASE Report.

</td>
</tr>
</table>

2014/CPUC/California Commercial Saturation Survey **(Itron, Inc. 2014)**

Pertinent Points

- The study presents the results from a large-scale data collection effort to characterize the baseline information about energy consuming measures (including lighting) in commercial buildings in California (saturation, age, condition, and efficiency levels) in PG&E, SCE, and SDG&E territories (e-page 25).
- The study covered the period from November 2011 to May 2013 with 7,890 phone surveys completed and 1,439 on-site visits completed (e-page 25-26).
- On-site data collection covered eight commercial business types: food/liquor stores, health/medical clinics, miscellaneous businesses, offices, restaurants, retail, schools, and warehouses (e-page 28).
- The study provides the distribution of indoor lamps by control type as summarized below (relevant portion only) for the dominant linear lighting technology with over 90 percent of market share in the considered business types.

Control Type	**Percent of Sites**
Photocell / Motion Sensor	2.0%
Motion Sensor	9.1%
Photocell / Timeclock	1.4%
Daylighting / Other	0.3%
n (Number of Surveyed Sites)	**1,404**

Source: http://capabilities.itron.com/WO024/OtherPages/Results.aspx.

- The study provides the distribution of the age of lighting systems as summarized below (relevant portion only).

System Installation Year	**Office**	**Restaurant**	**Retail**	**School**	**Warehouse**
Unknown	49.4%	40.5%	36.4%	49.0%	40.5%
Pre-1990	13.2%	8.5%	7.1%	8.5%	2.8%
1990-1999	6.6%	5.5%	2.1%	8.0%	7.4%
2000-2003	5.5%	3.5%	9.5%	1.4%	5.3%
2004-2008	8.4%	16.8%	18.0%	9.7%	10.7%
2009-2012	16.8%	25.3%	26.9%	23.3%	33.4%
n	**238**	**166**	**227**	**160**	**124**

Source: http://capabilities.itron.com/WO024/OtherPages/Results.aspx.

- The data collected from on-site visits allowed to estimate average watt per square foot values for commercial spaces as summarized below (relevant portion only). Using self-reported lighting schedules, the authors developed kWh/ft^2 values (e-page 30 and 234-236).

Building Type	Aggregated Average (W/ft^2)	Linear Lighting Technology (W/ft^2)
Office	1.00	0.89
Restaurant	1.09	0.52
Retail	1.16	0.78
School	1.04	0.98
Warehouse	0.38	0.29

Source: http://capabilities.itron.com/WO024/OtherPages/Results.aspx.

Building Type	Mean Energy Intensity (kWh/ft^2 per year)	Percent Attributed to Lighting Load	Lighting Energy Intensity (kWh/ft^2 per year)	*n* (For Lighting Values)
Office	13.2	18%	2.4	**238**
Restaurant	40.9	11%	4.5	**170**
Retail	11.0	34%	3.7	**223**
School	6.1	24%	1.5	**157**
Warehouse	3.1	23%	0.71	**122**

Source: http://capabilities.itron.com/WO024/OtherPages/Overview.aspx (e-page 30 and e-pages 234 through 236 in CSS report).

Relevance to this CASE Report

- Used as the basis to support the assumption on the age of lighting systems in California.
- Used as a reference to ground truth the assumptions in baseline per-unit energy use calculations.
- Used reported electric energy intensities (kWh/ft^2 per year) to compare them with the per-unit energy use values presented in this CASE Report.

2014/NEEA/Commercial Building Stock Assessment (CBSA) **(Navigant Consulting, Inc. 2014)**

Pertinent Points

- The 2014 CBSA study collected primary on-site data for the largest random sample of commercial buildings in the history of the northwest. The study gathered primary data from 859 commercial sites across 12 building types in the states of Washington, Oregon, Idaho, and Montana. An additional 521 sites were surveyed as part of oversample studies performed at the request of some utilities (Appendix AAA, e-page 3).

Building Type	Number of Buildings Surveyed
Lodging	100
Office	171
Restaurant	159

Retail	152
School	117
Warehouse	105

- The report presents calculated LPD value for each building type as summarized below (only relevant portion). The report presents LPD values by space types as well (e-page 32).

Building Type	**Mean Indoor LPD (W/ft^2) 2009**	***n***	**Mean Indoor LPD (W/ft^2) 2014**	***n***
Lodging	1.18	54	1	185
Office	1.22	291	1.08	135
Restaurant	1.19	113	1.15	122
Retail	1.43	310	1.18	125
School	1.2	192	0.94	122
Warehouse	0.73	140	0.63	105

Source: 2014 CBSA, Appendix AAA, e-page 6 (http://neea.org/resource-center/regional-data-resources).

- The report presents data on percent of regional indoor lighting power controlled by lighting controls by building type as summarized below (relevant portion only).

Building Type	**Occupancy Sensor**	**Timeclock**	**Photocell**
All (*n*=791)	8% ±1%	3% ±1%	0% ±0%
Lodging (*n*=69)	1% ±1%	1% ±1%	0% ±0%
Office (*n*=113)	11% ±4%	5% ±3%	1% ±1%
Food Service (*n*=43)	0% ±0%	0% ±0%	0% ±1%
Retail (*n*=129)	2% ±1%	4% ±3%	1% ±1%
School (*n*=72)	15% ±5%	1% ±1%	0% ±0%
Warehouse (*n*=43)	17% ±7%	0% ±1%	0% ±0%

Source: 2014 CBSA, Appendix A, e-page 35 (http://neea.org/resource-center/regional-data-resources)

Relevance to this CASE Report

- Used as a reference for LPD values and uptake rates of lighting controls in the existing building floor stock outside of California.

2015/SMR Research Corporation/Commercial Property Database **(SMR Research Corp. 2015)**	**Pertinent Points** • The source reports that there are 774,292 commercial properties in California (including all building types). **Relevance to this CASE Report** • Used to characterize market. Note that F.W. Dodge Database provides up to 20 years of historical data and 25 years of forecast data on building construction for a fee.
2015/The Energy Commission/Existing Buildings EE Action Plan **(California Energy Commission 2015b)**	**Pertinent Points** • The document states that the CEUS update is currently under way at the Energy Commission (e-page 28). • Per the document, the McGraw-Hill survey estimates that the nonresidential retrofit market will triple by 2015, growing from 7-12 percent or $3 billion in 2010 to 25-33 percent of the market and $14 billion-$18 billion in 2015 (e-page 30). **Relevance to this CASE Report** • Used as a reference about future studies that characterize existing building stock in California.
2016/EIA/2012 Commercial Buildings Energy Consumption Survey **(U.S. Energy Information Administration 2016)**	**Pertinent Points** • Final sample size was just over 6,700 completed building interviews (over a 28 percent increase from the number of buildings in the 2003 CBECS). • The report provides findings on uptake rates of lighting controls by building type (floor space, number of buildings) for considered geographic regions. The most relevant geographic region is the West Pacific Region (WA, OR, CA, AK, HI). **Relevance to this CASE Report** • Used as a reference for uptake rates of lighting controls in the existing building floor stock in the West Pacific Region.

2016/DOE/Energy Savings Forecast of Solid-State (SSL) Lighting in General Illumination Applications **(Navigant Consulting, Inc. 2016)**

Pertinent Points

- The assumed rate of lighting alterations used in 2016 DOE Report on SSL Forecast was 10 percent per year or once every 10 years. According to the report, the renovation rate assumption has been increased from 5 percent to 10 percent compared to previous lighting market model iterations, due to increasing concerns regarding energy consumption, as well as the growing prevalence of utility and government incentive programs that compensate consumers who retrofit using LED lighting products (e-page 21 and 74).
- The report presents 2015 installed stock penetration for each control type (estimated based on over 140 sources of information (e-page 19, 34 and 99) as summarized below (relevant portion only).

Control Type	Installed Commercial Stock Penetration (%)
None	68%
Timer	4%
Occupancy Sensor	6%
Daylighting	<1%

- The report makes the following assumptions for energy savings for each control type by building type based on the literature review and stakeholder feedback (e-pages 106 through 108).

Building Type	Occupancy	Daylighting
Lodging	75%	9%
Office	56%	15%
Retail	21%	15%
Education	57%	14%
Warehouse	83%	14%

Source: 2016 DOE https://energy.gov/eere/ssl/downloads/2016-ssl-forecast-report.

Relevance to this CASE Report

- Used as a reference for the rate of lighting alterations and for the uptake rates of lighting controls.
- Evaluated for use as the basis for control factors for occupant sensing controls. In discussion with one of the study authors, the Statewide CASE Team learned that assumed national savings in the study for occupant sensing controls include savings from minimal lighting load during nighttime, weekend, and holidays that are otherwise captured by automatic time-clock controls in California.

Appendix I: LIGHTING ALTERATION SURVEY

The following core questions were asked in the 2017 Codes and Standards (C&S) Lighting Alteration Survey:

- Thinking of the projects completed in California since **May 2016,** approximately how often each of the four compliance pathways for nonresidential lighting retrofit projects was used to comply with Title 24, Part 6 code ("entire luminaire" or "component modification" as defined in Title 24, Part 6, Section 141.0(b)2I and J)?
- Thinking of projects completed by your firm in California since **January 2015**, on average how old were the lighting systems you replaced?
- Thinking of existing buildings in California, estimate the percentage of buildings with lighting systems of certain ages.

The survey was deployed using SurveyMonkey® and distributed using the following channels:

- The Energy Commission's listservs;
- Statewide CASE Team's distribution list;
- PG&E Trade Professional Alliance's distribution list;
- SCE distribution list of Trade Professionals; and
- California Energy Efficiency Alliance's distribution lists.

2017 C&S Lighting Alteration Survey Results

The survey responses were collected from February 18 through April 10, 2017. Figure 50, Figure 51, and Figure 52 summarize the survey results.

SUMMARY for MARKET SHARE of COMPLIANCE OPTIONS for REGULATED LIGHTING ALTERATIONS (entire luminaire and component modification type of retrofits)

Compliance option for lighting retrofit projects	Number of retrofit projects since May 2016	Percent of total number of projects	Percent of total EXCLUDING Performance Approach
85-100% of LPD allowance	1507	37%	42%
≤85% of LPD allowance	1168	29%	32%
Reduction of existing wattage by 35/50%	919	23%	26%
Performance Approach	467	11%	
TOTAL	**4061**	**100%**	**100%**

Distribution of respondents' role in the lighting industry	Number of respondents	
Electrical contractors	82	79%
Lighting retrofit contractors	12	12%
Building officials	3	3%
Commissioning providers and/or acceptance testers	3	3%
TOTAL number of respondents	**104**	**96%**

Distribution of respondents' geography	Number of respondents
National	11
Western US	3
All or Most of California	14
Northern California	13
Southern California	29
Central California	2
Sacramento Metro Area	2
San Francisco Bay Area Metro Area	13
Los Angeles Metro Area	10
San Diego Metro Area	5

Reported number of retrofit projects since May 2016 by respondent	
Max	800
Min	1
Average	39
Median	15

Figure 50: Survey results for market share of compliance pathways for regulated lighting alterations.

Source: 2017 C&S Lighting Alteration Survey and the Statewide CASE Team calculations.

Note: Survey responses without reported number of lighting retrofit projects completed since May 2016 were not included in the dataset. For each included survey response, to arrive at the project count by compliance pathway, reported percentages of market share by compliance pathway were applied to the reported number of retrofit projects. After summing the number of projects by compliance pathway for all survey responses, the final percentages of market share by compliance pathway were calculated.

SUMMARY for the AVERAGE AGE of LIGHTING SYSTEMS by BUILDING TYPE

	Age of lighting system AVERAGE of SUBSET of responses	Age of lighting system STANDARD DEVIATION of SUBSET of responses	*n* (excluded responses IF provided response was 1, 2, or > 30 yrs)
Hotels	12	6.5	54
Large offices (larger than 30,000 sq ft)	11	6.7	107
Small offices (less than 30,000 sq ft)	12	7.2	142
Restaurants	10	5.1	57
Retail stores	10	5.5	75
Schools	15	7.0	83
Warehouses (excluding refrigerated warehouses)	14	7.2	87

	Average age of lighting system AVERAGE of ALL	Average age of lighting system MEDIAN of ALL	Average age of lighting system MAX Reported Value	Average age of lighting system MIN Reported Value	*n*
Hotels	12	10	50	2	56
Large offices (larger than 30,000 sq ft)	13	10	75	2	115
Small offices (less than 30,000 sq ft)	13	10	75	2	150
Restaurants	11	9	75	1	64
Retail stores	12	10	50	1	84
Schools	17	15	60	2	92
Warehouses (excluding refrigerated warehouses)	16	12	90	1	95

	Age of lighting system AVERAGE of SUBSET of responses	Age of lighting system AVERAGE of SUBSET of responses	*n* (included responses ONLY if the number of projects was provided)	Number of total reported projects (since May 2016)
Hotels	10	8	23	1,407
Large offices (larger than 30,000 sq ft)	11	12	70	2,586
Small offices (less than 30,000 sq ft)	13	11	96	3,024
Restaurants	11	8	31	1,618
Retail stores	10	9	45	1,934
Schools	15	16	56	1,466
Warehouses (excluding refrigerated warehouses)	14	12	54	2,129

Figure 51: Survey results for the average age of lighting systems.

Source: 2017 C&S Lighting Alteration Survey and the Statewide CASE Team calculations.

SUMMARY for the DISTRIBUTION of the AGE of LIGHTING SYSTEMS by BUILDING TYPE

	More than 12 years	7 to 12 years old	3 to 7 years old	Less than 3 years	Total
Hotels	41%	25%	29%	16%	**112%**
Large offices (larger than 30,000 sq ft)	34%	28%	33%	18%	**112%**
Small offices (less than 30,000 sq ft)	36%	28%	32%	18%	**114%**
Restaurants	32%	28%	34%	21%	**114%**
Retail stores	30%	29%	32%	22%	**114%**
Schools	43%	28%	24%	18%	**114%**
Warehouses (excluding refrigerated warehouses)	43%	25%	27%	17%	**113%**

NORMALIZED to add to 100%

	More than 12 years ~2001 Title 24, Part 6 or earlier	7 to 12 years old ~2005 Title 24, Part 6	3 to 7 years old ~2008 Title 24, Part 6	Less than 3 years ~2013 Title 24, Part 6	Total	*n*
Hotels	37%	23%	26%	14%	**100%**	89
Large offices (larger than 30,000 sq ft)	30%	25%	29%	16%	**100%**	99
Small offices (less than 30,000 sq ft)	32%	24%	28%	16%	**100%**	108
Restaurants	28%	24%	30%	18%	**100%**	87
Retail stores	27%	26%	28%	19%	**100%**	91
Schools	38%	25%	21%	16%	**100%**	90
Warehouses (excluding refrigerated warehouses)	38%	22%	24%	15%	**100%**	86
Average	**33%**	**24%**	**27%**	**16%**	**100%**	

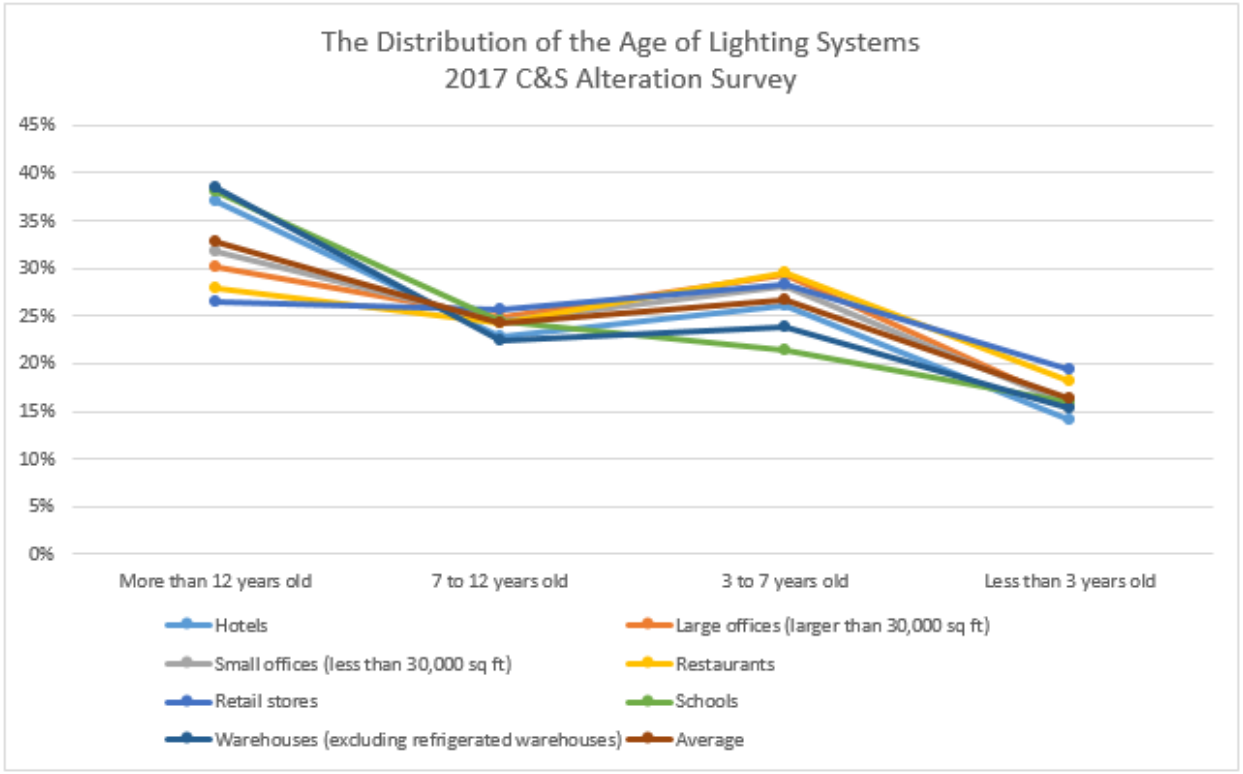

Figure 52: Survey results for the distribution of the age of lighting systems.

Source: 2017 C&S Lighting Alteration Survey and the Statewide CASE Team calculations.

Content of the Lighting Alteration Survey

The 2017 C&S Lighting Alteration Survey had four custom tracks depending on the selected industry role. The custom tracks were:

- Building official;
- Lighting retrofit installer;
- Lighting supplier; and
- General (for all others).

The core questions were asked in all tracks. The full survey is reproduced below.

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

2019 Title 24, Part 6 Lighting Alterations

Scope and Purpose of the Survey

The California Statewide Utility Codes and Standards Team actively supports the California Energy Commission in developing revisions to the 2019 California Building Energy Efficiency Standards (Title 24, Part 6).

The aggregated survey results will inform the lighting alterations analysis and will be provided to the Energy Commission to support its rulemaking process related to lighting alterations.

- **Your name and contact information will be kept confidential.**
- **You may skip questions not relevant to your area of expertise.**
- **If you started this survey and need to finish it later, just open the survey link using the same device and web browser (the answers are saved in a browser cookie when you click the Next button).**
- **If you have any questions or comments, email us at info@title24stakeholders.com**

For more information about the California Statewide Utility Codes and Standards Team's 2019 Title 24, Part 6 advocacy efforts, please visit: www.title24stakeholders.com

Thank you for your participation,
The Statewide Utility Codes and Standards Team

The Statewide Utility Codes and Standards Team is comprised of Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), Southern California Gas Company (SoCalGas), Los Angeles Department of Water and Power (LADWP), and Sacramento Municipal Utility District (SMUD).

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2019 Title 24, Part 6 Lighting Alterations

Firm Background Questions

1. How long have you been working in the lighting industry? Please enter your response as a number of years (a response of "5" would mean five years).

* 2. What is your role in the lighting industry? Please select the answer that best describes your role.

- ○ Building official
- ○ Lighting retrofit contractor
- ○ Electrical contractor
- ○ Manufacturer of lighting products
- ○ Distributor of lighting products
- ○ Other (please specify)

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2019 Title 24, Part 6 Lighting Alterations

Lighting Installer Firmographic Questions

3. About how many nonresidential lighting retrofit projects has your company completed in California since May 2016? Please enter your response as a number of projects (a response of "50" would mean fifty projects).

4. Since January 2015, in California, has your company conducted lighting retrofits in one or more of the following business types? Please check all that apply.

- [ ] Hotels
- [ ] Small offices (less than 30,000 sq ft)
- [ ] Large offices (larger than 30,000 sq ft)
- [ ] Restaurants
- [ ] Retail stores
- [ ] Schools
- [ ] Warehouses (excluding refrigerated warehouses)

5. Please select the answer that best describes the geography covered by your firm.

- ○ National
- ○ Western US
- ○ All or Most of California
- ○ Northern California
- ○ Southern California
- ○ Los Angeles Metro Area
- ○ San Francisco Bay Area Metro Area
- ○ San Diego Metro Area
- ○ Sacramento Metro Area
- ○ Other (please specify)

CALIFORNIA ENERGY CODES & STANDARDS
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2019 Title 24, Part 6 Lighting Alterations

Lighting Retrofit Installer Survey Questions

6. Thinking of the {{ Q3 }} projects your company has completed in California since **May 2016***...

...Approximately how often each of the four compliance pathways for nonresidential lighting retrofit projects was used to comply with Title 24, Part 6 code ("entire luminaire" or "component modification" as defined in Title 24, Part 6, Section 141.0(b)2I and J).

The percentages must add up to 100%.

* Note that the 50/35% wattage reduction compliance pathway became available as of April 13, 2016. The 50/35% wattage reduction pathway is based on reducing the replaced luminaire wattage by 50% or 35% depending on the building's occupancy type. Submitting Form NRCC-LTI-06 Indoor Lighting Existing Conditions is required for the 50/35% wattage reduction pathway.

Prescriptive Approach: 85-100% of LPD allowance

Prescriptive Approach: ≤85% of LPD allowance

Prescriptive Approach: 50/35% wattage reduction pathway *

Performance Approach

7. Thinking of projects completed by your firm in California since **January 2015**, on average how old were the lighting systems you replaced? Please provide your best estimates for each business type.

Hotels

Small offices (less than 30,000 sq ft)

Large offices (larger than 30,000 sq ft)

Restaurants

Retail stores

Schools

Warehouses (excluding refrigerated warehouses)

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Building Official Firmographic Questions

8. About how many nonresidential lighting retrofit projects have you overseen in California since May 2016? Please enter your response as a number of projects (a response of "50" would mean fifty projects).

9. Since January 2015, in California, which building / space types have you overseen? Please check all that apply.

- [ ] Hotels
- [ ] Small offices (less than 30,000 sq ft)
- [ ] Large offices (larger than 30,000 sq ft)
- [ ] Restaurants
- [ ] Retail stores
- [ ] Schools
- [ ] Warehouses (excluding refrigerated warehouses)

10. Please select the answer that best describes the geography that you cover.

- ○ National
- ○ Western US
- ○ All or Most of California
- ○ Northern California
- ○ Southern California
- ○ Los Angeles Metro Area
- ○ San Francisco Bay Area Metro Area
- ○ San Diego Metro Area
- ○ Sacramento Metro Area
- ○ Other (please specify)

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Building Official Survey Questions

11. Thinking of lighting projects completed in California since **May 2016**...

...Approximately how often each of the four compliance pathways for nonresidential lighting retrofit projects was used to comply with Title 24, Part 6 code ("entire luminaire" or "component modification" as defined in Title 24, Part 6, Section 141.0(b)2I and J).

The percentages should add up to 100%.

* Note that the 50/35% wattage reduction compliance pathway became available as of April 13, 2016. The 50/35% wattage reduction pathway is based on reducing the replaced luminaire wattage by 50% or 35% depending on the building's occupancy type. Submitting Form NRCC-LTI-06 Indoor Lighting Existing Conditions is required for the 50/35% wattage reduction pathway.

Prescriptive Approach: 85-100% of LPD allowance

Prescriptive Approach: ≤85% of LPD allowance

Prescriptive Approach: 50/35% wattage reduction pathway *

Performance Approach

12. Thinking of projects completed in California since **January 2015**, on average how old were the lighting systems being replaced? Please provide your best estimates for each business type.

Hotels

Small offices (less than 30,000 sq ft)

Large offices (larger than 30,000 sq ft)

Restaurants

Retail stores

Schools

Warehouses (excluding refrigerated warehouses)

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2019 Title 24, Part 6 Lighting Alterations

Lighting Supplier Firmographic Questions

13. Please select the answer that best describes where your products are sold.

- ◯ National / International
- ◯ Western US
- ◯ All or Most of California
- ◯ Northern California
- ◯ Southern California
- ◯ Los Angeles Metro Area
- ◯ San Francisco Bay Area Metro Area
- ◯ San Diego Metro Area
- ◯ Sacramento Metro Area
- ◯ Other (please specify)

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Lighting Supplier Survey Questions

14. Thinking of lighting projects completed in California since **May 2016**...

...Approximately how often each of the four compliance pathways for nonresidential lighting retrofit projects was used to comply with Title 24, Part 6 code ("entire luminaire" or "component modification" as defined in Title 24, Part 6, Section 141.0(b)2I and J).

The percentages should add up to 100%.

* Note that the 50/35% wattage reduction compliance pathway became available as of April 13, 2016. The 50/35% wattage reduction pathway is based on reducing the replaced luminaire wattage by 50% or 35% depending on the building's occupancy type. Submitting Form NRCC-LTI-06 Indoor Lighting Existing Conditions is required for the 50/35% wattage reduction pathway.

Prescriptive Approach: 85-100% of LPD allowance

Prescriptive Approach: ≤85% of LPD allowance

Prescriptive Approach: 50/35% wattage reduction pathway *

Performance Approach

15. Thinking of projects completed in California since **January 2015**, on average how old were the lighting systems being replaced? Please provide your best estimates for each business type.

Hotels

Small offices (less than 30,000 sq ft)

Large offices (larger than 30,000 sq ft)

Restaurants

Retail stores

Schools

Warehouses (excluding refrigerated warehouses)

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2019 Title 24, Part 6 Lighting Alterations

General Firmographic Questions

16. Please select the answer that best describes what region you are familiar with, in terms of lighting-related building codes.

- ◯ National
- ◯ Western US
- ◯ All or Most of California
- ◯ Northern California
- ◯ Southern California
- ◯ Los Angeles Metro Area
- ◯ San Francisco Bay Area Metro Area
- ◯ San Diego Metro Area
- ◯ Sacramento Metro Area
- ◯ Other (please specify)

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2019 Title 24, Part 6 Lighting Alterations

General Survey Questions

17. Thinking of lighting projects completed in California since**May 2016**...

...Approximately how often each of the four compliance pathways for nonresidential lighting retrofit projects was used to comply with Title 24, Part 6 code ("entire luminaire" or "component modification" as defined in Title 24, Part 6, Section 141.0(b)2I and J).

The percentages should add up to 100%.

* Note that the 50/35% wattage reduction compliance pathway became available as of April 13, 2016. The 50/35% wattage reduction pathway is based on reducing the replaced luminaire wattage by 50% or 35% depending on the building's occupancy type. Submitting Form NRCC-LTI-06 Indoor Lighting Existing Conditions is required for the 50/35% wattage reduction pathway.

Prescriptive Approach: 85-100% of LPD allowance

Prescriptive Approach: ≤85% of LPD allowance

Prescriptive Approach: 50/35% wattage reduction pathway *

Performance Approach

18. Thinking of projects completed in California since **January 2015**, on average how old were the lighting systems being replaced? Please provide your best estimates for each business type.

Hotels

Small offices (less than 30,000 sq ft)

Large offices (larger than 30,000 sq ft)

Restaurants

Retail stores

Schools

Warehouses (excluding refrigerated warehouses)

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2019 Title 24, Part 6 Lighting Alterations

Existing Lighting Equipment Age Survey Questions (California Statewide)

19. Thinking of existing buildings in California...

... Please estimate the percentage of buildings with lighting systems of certain ages.

From left to right (rows), the percentages for each building type should add up to 100%.

	More than 12 years old	7 to 12 years old	3 to 7 years old	Less than 3 years old
Hotels				
Small offices (less than 30,000 sq ft)				
Large offices (larger than 30,000 sq ft)				
Restaurants				
Retail stores				
Schools				
Warehouses (excluding refrigerated warehouses)				

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Finish and Submit

20. Please provide your contact information.

Name	
Organization/Affiliation	
City/Town	
State/Province	
Email Address	
Phone Number	

21. May a researcher from our team contact you to follow-up on the provided answers?

- ◯ Yes
- ◯ No

22. If you have further comments to any of the survey questions, please provide below.

23. If you have further supporting information, please submit as an attachment.

Choose File No file chosen

Appendix J: MEASURES CONSIDERED IN DRAFT CASE REPORT AND STAKEHOLDER FEEDBACK

Table 27 lists all the measures proposed in the Draft CASE Report (June 2017 version) and explanations for measure modifications in the Final CASE Report.

Table 27: Measures Proposed in the Draft CASE Report (June 2017 Version) and Explanation for Measure Modifications in the Final CASE Report

Measure ID	Measure Type	Measure Description	Change from Draft CASE Report to Final CASE Report
A	Code Cleanup	Restate the existing requirements for "entire luminaire alterations," "luminaire component modifications," and "lighting wiring alterations" more clearly, by organizing key information in three tables within the code language.	In the Final CASE Report, the Statewide CASE Team is using language provided by the Energy Commission. The Statewide CASE Team proposed some modifications to the provided language.
B	Code Cleanup	Clarify that "entire luminaire alterations" or "luminaire component modifications" projects that increase lighting power must meet all LPA and control requirements.	Kept the measure in the Final CASE Report.
C	Code Cleanup	Modify the exception for "entire luminaire alterations" and for "lighting wiring alterations" from two or fewer luminaires in an enclosed space to one luminaire in an enclosed space.	Kept the measure in the Final CASE Report.
D	Code Cleanup	Remove the exception for "luminaire component modifications" for two or fewer luminaires in an enclosed space, while keeping the code trigger of 70 or more luminaires per floor per tenant per year.	Modified the measure in the Final CASE Report to make the measure consistent with Measure C based on stakeholder feedback and for the sake of keeping the code language simpler.
E	Substantive Change (Option 3)	Require Option 3 to be applied to an entire enclosed space to reduce the ability for partial retrofits in the enclosed space (as already in place for Option 1 and 2).	Based on the stakeholder feedback, the Statewide CASE Team dropped the measure in the Final CASE Report.
F	Substantive Change (Option 3)	Require partial OFF occupant sensing controls for stairwells under Option 3, including stairwells in high-rise residential buildings, hotels, and motels (while keeping the exception for the requirement to have partial OFF occupant sensing controls in corridors).	Kept the measure in the Final CASE Report.
G	Substantive Change (Option 3)	Require a reduction of total existing lighting wattage in altered enclosed spaces by 50% of the rated wattage under Option 3 for all space types (rather than 50% for office, retail, and hotel and 35% for all other occupancies).	Kept the measure in the Final CASE Report.

Table 28: Results of Stakeholder Outreach by Measure (as Proposed in Draft CASE Report Dated June 2017)

Measure ID	Measure Type	Measure Description (as proposed in Draft CASE Report of June 2017)	Summary of Stakeholder Outreach
A	Code Cleanup	Restate the existing requirements for "entire luminaire alterations," "luminaire component modifications," and "lighting wiring alterations" more clearly, by organizing key information in three tables within the code language.	All interviewed stakeholders noted the need for simplification. The tally of stakeholder feedback regarding reorganization of code language in tables as proposed in CASE Draft Report, June 2017 version: 6 out of 9 interviewees support the measure and liked proposed tables. 2 out of 9 neutral about proposed tables. 1 out of 9 found table organization confusing.
B	Code Cleanup	Clarify that "entire luminaire alterations" or "luminaire component modifications" projects that increase lighting power must meet all LPA and control requirements.	This measure was kept in the Final CASE Report. The results of stakeholder outreach suggest that retrofit projects do not increase lighting power for the vast majority of projects. The results of stakeholder outreach are summarized in Section 2.5.
C	Code Cleanup	Modify the exception for "entire luminaire alterations" and for "lighting wiring alterations" from two or fewer luminaires in an enclosed space to one luminaire in an enclosed space.	This measure was kept in the Final CASE Report. The results of stakeholder outreach are summarized in Section 2.5.
D	Code Cleanup	Remove the exception for "luminaire component modifications" for two or fewer luminaires in an enclosed space, while keeping the code trigger of 70 or more luminaires per floor per tenant per year.	The tally of stakeholder feedback on the measure from the interviews is as follows: 1 out of 6 interviewees support the measure. 2 out of 6 neutral. 2 out of 6 concerned. 1 out of 6 opposes. Raised Concerns • Stranding energy savings due to higher cost to comply with the code is of great concern (e.g., it will be more expensive to retrofit private offices with stricter exemptions). • The code should be consistent for all types of retrofit projects (entire luminaire or component modification).
E	Substantive Change (Option 3)	Require Option 3 to be applied to an entire enclosed space to reduce the ability for partial retrofits in the enclosed space (as already in place for Option 1 and 2).	The tally of stakeholder feedback on the measure from the interviews is as follows: 3 out of 11 interviewees support the measure. 1 out of 11 neutral. 4 out of 11 concerned.

			3 out of 11 oppose. Raised Concerns • If some layers of lighting are already efficient in a space, projects will not be able to use Option 3. • Stranding energy saving in open plan offices is of great concern since projects in open plan offices may involve only a portion of the space due to, for example, multiple-tenant situation and/or budget constraints.
F	Substantive Change (Option 3)	Require partial OFF occupant sensing controls for stairwells under Option 3, including stairwells in high-rise residential buildings, hotels, and motels (while keeping the exception for the requirement to have partial OFF occupant sensing controls in corridors).	This measure was kept in the Final CASE Report. The results of stakeholder outreach are summarized in Section 2.5.
G	Substantive Change (Option 3)	Require a reduction of total existing lighting wattage in altered enclosed spaces by 50% of the rated wattage under Option 3 for all space types (rather than 50% for office, retail, and hotel and 35% for all other occupancies).	This measure was kept in the Final CASE Report. The results of stakeholder outreach are summarized in Section 2.5.

Appendix K: Overview of 2013 and 2016 Title 24, Part 6 Lighting Alteration Standards

Table 29 provides a detailed overview of the requirements for 2013 and 2016 Title 24, Part 6 Lighting Alteration Standards.

Table 29: Detailed Overview of 2013 and 2016 Title 24, Part 6 Lighting Alteration Requirements

Lighting Alterations Quick Reference	Lighting Power	Wattage Compared to Existing Wattage	area switch	area switch	not overriding controls	separate switch display	dimming	bi-level switching	auto shut-OFF	auto shut-OFF, separate display	countdown switches	time-switch timed override	time-switch holiday feature	occupancy sensor – classrooms, multipurpose and conference rooms	motion partial OFF – warehouse	motion partial OFF – library	motion partial OFF – corridors, stairwells	motion partial OFF – hotel corridors	motion partial OFF – garage	guestroom key card/occupancy sensor	auto daylighting controls – primary sidelit and skylit	auto daylighting – parking garage	demand response > 10,000 ft^2
	140.6		130.1(a)1	130.1(a)2	130.1(a)3	130.1(a)4	130.1(b)	Multi-level	130.1(c)1A-C	130.1(c)1D	130.1(c)2	130.1(c)3	130.1(c)4	130.1(c)5	130.1(c)6A	130.1(c)6B	130.1(c)6C	130.1(c)7A	130.1(c)7B	130.1(c)8	130.1(d)2	130.1(d)3	130.1(e)
2016 Title 24, Part 6 Standards																							
Entire Luminaire 141.0(b)2Ii	85-100% of LPA	NA	Y	Y	Y		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	120 W	60 W	Y
Entire Luminaire 141.0(b)2Ii	≤85% of LPA	NA	Y	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			
Entire Luminaire 141.0(b)2Iii	NA	Reduction by 50% for office, retail, hotel; by 35% for other	Y	Y	Y				Y		Y	Y	Y	Y	Y				Y				
Component Modification 141.0(b)2Ji: ≥ 70 existing luminaires per floor per tenant per year	85-100% of LPA		Y	Y	Y		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	120 W	60 W	Y

Component Modification 141.0(b)2Ji: ≥ 70 existing luminaires per floor per tenant per year	≤85% of LPA		Y	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			
Component Modification 141.0(b)2Jii: ≥ 70 existing luminaires per floor per tenant per year	NA	Reduction by 50% for office, retail, hotel; by 35% for other	Y	Y	Y				Y		Y	Y	Y	Y	Y					Y			
Lighting Wiring Alterations 141.0(b)2K	≤100%		Y	Y	Y			Y	Y			Y	Y									10+ L	10+ L	
2013 Title 24, Part 6 Standards																								
Luminaire Alterations 141.0(b)2Iii: ≥ 10% of existing luminaires/space	85-100%		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	120 W	60 W	
Luminaire Alterations 141.0(b)2Iii: ≥ 10% of existing luminaires/space	≤85%		Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			
Luminaire Alterations 141.0(b)2Iii: Increase wattage	≤100%		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	120 W	60 W	Y
Luminaire Modifications-in-Place and 1 for 1 replacement 141.0(b)2Iiii: ≥ 40 existing luminaires per floor per tenant per year	85-100%		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	120 W	60 W	
Luminaire Modifications-in-Place and 1 for 1 replacement 141.0(b)2Iiii: ≥ 40 existing luminaires per floor per tenant per year	≤85%		Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			
Lighting Wiring Alterations 141.0(b)2Iiv	NA		Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	120 W	60 W	Y

ATTACHMENT 2: PUBLIC COMMENTS SUBMITTED BY THE STATEWIDE CASE TEAM

Attachment 2 presents comments that the Statewide CASE Team submitted to the Energy Commission's docket that are relevant to this measure.

Hyperlinks for dockets submitted between publication of Final CASE Report and Results Report:

http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221679_20171103T170734_Statewide_Utility_Codes_and_Standards_Team_Comments_Statewide_U.pdf

http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221679_20171103T170734_Statewide_Utility_Codes_and_Standards_Team_Comments_Statewide_U.pdf

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Statewide Utility Codes and Standards Team Comments on Lighting Topics in 2019 Title 24, Part 6 Express Terms

Additional submitted attachment is included below.

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Comments on Lighting Topics in 2019 Title 24, Part 6 Express Terms

California Statewide Utility Codes and Standards Team

November 3, 2017

1. Introduction

The Statewide CASE Team appreciates the opportunity to participate in the rulemaking and the thoughtful feedback we have received from the California Energy Commission on the Codes and Standards Enhancement (CASE) proposals.

The CASE initiative presents recommendations to support the Energy Commission's efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and SoCalGas® – and several publicly Owned Utilities – Los Angeles Department of Water and Power, Sacramento Municipal Utility District, and Southern California Public Power Authority – sponsored this effort.

The California Statewide Utility Codes and Standards Team (Statewide CASE Team) actively supports the Energy Commission in developing revisions to Title 24, Part 6 by developing code change proposals that will result in feasible, enforceable, and cost-effective enhancements to the building energy efficiency standards. In developing these proposals, the Statewide CASE Team conducts research and market surveys, holds stakeholder meetings, and evaluates the energy savings and cost-effectiveness of considered measures. The CASE Reports, which present pertinent information that supports the code change proposals, are posted within each measure topic page on title24stakeholders.com.

The Statewide CASE Team encourages the Energy Commission to consider the following changes to the lighting measures.

Recommended revisions to the Express Terms are included in this document in purple. The Statewide CASE Team's recommended language insertions are single underlined and recommended language ~~deletions are single struck~~.

Recommended revisions to the Express Terms are summarized in Table 1.

Table 1: Summary of Recommended Revisions to the Express Terms

Measure Topic	Recommended Revision	Section of Standards
Lighting Alterations	• Clarify scope of the 70-luminaire exception so it only applies to component modifications. • Increase the stringency of the 70-luminaire exception by removing the per floor provision. For the "Reduction of Existing Wattage" compliance option: • Clarify that compliance must be demonstrated at the project level. • Eliminate the building size threshold.	EXCEPTION 6 to Section 141.0(b)2I Section 141.0(b)2I
Outdoor Lighting Controls	• Require motion sensing controls for luminaires that are primarily providing parking lot general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting. • Require that the controls reduce lighting power by at least 50 percent when vacant during normally occupied periods and that controls are *capable* of leaving at least 10 percent of power on when vacant. • Define a default normally unoccupied period of midnight to 6:00 am when the occupancy schedule is not known. • Require that the lighting system power be reduced by at least 75 percent power when unoccupied after-hours.	Section 130.2(c)
Indoor Lighting Sources	• If included, limit the 0.75 multiplier to small aperture tunable white and dim-to-warm luminaires. • Clarify that color tuning credit of 0.1 watt per square foot applies to any size aperture color changing luminaires in healthcare facilities.	Section 140.6 Table 140.6-C, footnote 10 for healthcare facility and hospitals
Indoor Lighting Controls	• Maintain the code stringency by keeping 20-minute time delay that is currently in Section 110.9(b)4F. • Require automatic shutoff controls to turn the lighting OFF no longer than 20 minutes after the guest room has been vacated rather than 30 minutes, which is currently required. For Daylighting controls: • Require daylighting dimming with OFF step in primary sidelit daylit zones in concourses and skylit daylit zones in all spaces. • Require dimming to no greater than the minimum dimmed state of the luminaire or the lowest setpoint in accordance to Table 130.1-A.	Section 130.1(c)4 (formerly 130.1(c)3) Section 130.1(c)7 (formerly 130.1(c)6) Section 130.1(d)3
Residential Lighting	• Maintain 2016 Title 24, Part 6 residential lighting requirements. In Joint Appendix JA8: • Use the more robust life test method that was designed for 2016 JA8 rather than the test methods described in Energy Star v2.1 Section 10. • Clarify the language for light sources with pre-programmed fade-in features. • Correct the error that exempts medium diameter (<2") ornamental lamps and small diameter (<1") other lamps. • Remove the option to use NEMA 77 as a test for flicker and retaining JA8 requirements and JA10 as the appropriate test method.	Section 150.0(k) Joint Appendix JA8

2. Lighting Alterations

2.1 Clarifying Scope of the 70-luminaire Exception

2.1.1 Recommendation and Justification

The Statewide CASE Team applauds the Energy Commission's effort to simplify the sections of the standards that apply to lighting alterations. Overall, the proposed language in the Express Terms is significantly less complex compared to the 2016 and 2013 code cycles.

To prevent misinterpretation and missed opportunities for energy use reduction, the Statewide CASE Team recommends that the code language clearly state that the 70-luminaire exception only applies to what are called "component modifications" in the 2016 code. For projects known as "entire luminaire alterations" in the 2016 code, only the threshold of 10 percent of affected luminaires should apply. The language in the Express Terms could be interpreted that the 70-luminaire exception applies to component modifications and entire luminaire alterations. The Statewide CASE Team estimates that about 28-35 percent of lighting alterations that are currently regulated under 2016 Title 24, Part 6 would not be subject to code if the scope of the 70-luminaire exception is not clarified.

2.1.2 Recommended Revisions to the Express Terms

Section 141.0(b)2I:

EXCEPTION 6 to Section 141.0(b)2I. For each building or tenant space, alteration of components in up to 70 luminaires ~~per floor of the space,~~ per annum without replacing the luminaire housings, and without increasing lighting power.

2.2 The "Reduction of Existing Wattage" Compliance Option

2.2.1 Recommendation and Justification

The Statewide CASE Team recommends that the code language specify that the compliance under Option 3 must be demonstrated at a project level not at a luminaire level. This revision will simplify the code compliance process significantly.

Further, the Statewide CASE Team recommends eliminating the building size limit for Option 3 for the following reasons:

- Using building size as a prerequisite would complicate the compliance process by requiring the applicant to produce additional documentation indicating building/tenant size and by requiring building departments to review the additional documentation.
- Given the proposed 70-luminaire exception and assuming each luminaire is serving approximately 100 square feet, the spaces that are about 7,000 square feet in size will not be subject to the lighting alteration requirements. In this case, Option 3 that is available for buildings or tenant spaces that are less than 5,000 square feet becomes irrelevant.

Instead of introducing a building size limit for Option 3, the Statewide CASE Team recommends increasing the stringency of the 70-luminaire exception by removing the per floor provision in Exception 6 to Section 141.0(b)2I.

2.2.2 Recommended Revisions to the Express Terms

Section 141.0(b)2I:

I. Altered Indoor Lighting Systems.

[…]

iii. The alteration type shall be a luminaire-for-luminaire alteration ~~within a building or tenant space of 5,000 square feet or less,~~ and the total wattage of the altered luminaires shall have at least 40% lower total rated ~~power~~ wattage compared to ~~the system~~ luminaires prior to the alteration. The rated wattage shall be calculated in accordance with Section 130.0. ~~and~~ The alteration shall comply with the lighting control requirements specified in Table 141.0-E.

3. Outdoor Lighting Controls

3.1 Motion Sensing Controls

3.1.1 Recommendation and Justification

The Energy Commission's proposed changes to Section 130.2(c) would require a control to turn lights off during the day and a control to reduce power by at least 50 percent during normally unoccupied periods by either a timeclock control with a two-hour override or a motion control. If the standards are adopted as proposed in the Express Terms, the Statewide CASE Team expects a decrease in the use of motion controls in favor of less expensive timeclock controls. This decrease in stringency of the outdoor lighting control standards would result in a loss of approximately 15 GWh/yr of energy savings as compared to the existing 2016 Title 24, Part 6 Standards.

Consistent with the Draft and Final CASE Reports on Outdoor Lighting Controls, the Statewide CASE Team recommends code language that would do the following:

- Require motion sensing controls for luminaires that are primarily providing lighting for general hardscape parking lots, outdoor sales lots, vehicle service station hardscapes, or vehicle service station canopies.
- Require that the controls reduce lighting power by at least 50 percent when vacant during normally occupied periods and that controls are *capable* of leaving at least 10 percent of power on when vacant.
- Define a default normally unoccupied period of midnight to 6:00 am when the occupancy schedule is not known.
- Require that the lighting system power be reduced by at least 75 percent when unoccupied after-hours. This additional level of control has a benefit-to-cost ratio in excess of four-to-one and saves an additional 6 GWh/yr statewide for new construction and retrofit projects.

3.1.2 Recommended Revisions to the Express Terms

Section 130.2(c):

(c) **Controls for Outdoor Lighting.** Outdoor lighting controls shall be installed that meet the following requirements for reducing lighting when daylight is available and during normally scheduled unoccupied periods:

EXCEPTION 1 to Section 130.2(c): Outdoor lighting not permitted by a health or life safety statute, ordinance, or regulation to be turned OFF or dimmed.

EXCEPTION 2 to Section 130.2(c): Lighting in tunnels required to be illuminated 24 hours per day and 365 days per year.

1. **Daylight Availability.** All installed outdoor lighting shall be controlled by a photo control, astronomical time-switch control, automatic scheduling control, or other control capable of automatically shutting OFF the outdoor lighting when daylight is available.
2. **Unoccupied Periods.** All installed outdoor lighting shall be controlled by ~~a control capable of reducing the outdoor lighting by at least 50 percent, or turning the lighting OFF, during normally~~

~~scheduled unoccupied periods. This control shall be either~~ an automatic scheduling control or an occupant sensing control, and shall include the following features:

A. ~~For a~~ Automatic scheduling controls shall reduce lighting power by at least 50 percent during normally unoccupied scheduled periods ~~the control shall provide an override function that turns the lighting ON during its scheduled dim or OFF period for no more than 2 hours when an override is initiated.~~

~~B. For occupant sensing controls, no more than 800 watts of lighting shall be controlled by any single sensor, and the control shall return the lighting to its dim or OFF state no later than 15 minutes after the area has been vacated.~~

B. Motion Sensing controls shall comply with Section 130.2(c)3. A through C.

3. **Bi-Level Motion Sensing**. Luminaires that are primarily providing parking lot general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting and where the bottom of the luminaire is mounted 24 feet or less above the ground, shall be controlled by automatic lighting controls that meet all of the following requirements:

   A. During normally scheduled occupied periods, the lighting power of each luminaire shall be automatically reduced by at least 50 percent or OFF when no activity has been detected in the area illuminated by the controlled luminaires for a time no longer than 15 minutes.

   B. During normally scheduled unoccupied periods, in addition to complying with the requirements of item A, total lighting power shall be automatically reduced by at least 75 percent including OFF when no activity has been detected in the area illuminated by the controlled luminaires for a time no longer than 60 minutes.

   C. No more than 800 watts of lighting power shall be controlled together.

   D. The lighting system shall be capable of being configured to automatically reduce power of each luminaire by at least 75 percent, but not exceeding 90 percent without turning the luminaires OFF if no activity is detected in the area illuminated by the controlled luminaires.

   EXCEPTION to Section 130.2(c)3: Luminaires controlled in accordance with Section 130.2(c)2A and located where trees or other obstructions block motion sensing between the luminaire and the area illuminated by the luminaire.

4. **Timed Manual Override**. Timed manual overrides are not required, but shall be allowed to override motion or scheduling controls for a duration not to exceed two hours. No more than 1,800 watts may be controlled per manual override control.

5. **Default Schedules**. Acceptance tests of outdoor lighting controls shall be conducted in accordance with Section 130.4(a)6. When scheduled operating hours are known, the acceptance tests shall confirm the time schedules are correctly applied. When scheduled operating hours are not known, acceptance tests shall be conducted to confirm the use of a default normally occupied scheduled period of 6:00 am to midnight and a default normally unoccupied scheduled period of midnight to 6:00 am.

4. Indoor Lighting Sources

4.1 Adder for Small Aperture Tunable White and Dim-to-Warm Luminaires

4.1.1 Recommendation and Justification

The Statewide CASE Team supports the Energy Commission's alignment with the Final CASE Report on Indoor Lighting Power Densities (LPDs) and supports the Energy Commission's decision to include a 0.75 multiplier for small aperture tunable white and dim-to-warm luminaires. The Statewide CASE Team's analysis in Appendix M of the Final CASE Report demonstrates that only small aperture color changing luminaires need a power adjustment factor. Large aperture tunable white systems do not need a power adjustment factor since those systems have efficacies that were within 10 percent of static lighting systems. The Statewide CASE Team is conducting additional research to compare a broader range of color tuning luminaires. The findings from this research will be added as an appendix to the posted Final CASE Report on http://title24stakeholders.com.

Pacific Northwest National Laboratory's (PNNL) September 2017 study ("Tuning the Light in Classrooms: Evaluating Trial LED Lighting Systems in Three Classrooms at the Carrollton-Farmers Branch Independent Schools District in Carrollton, TX") also supports the finding that the efficacies of large aperture tunable white lighting systems are comparable with static white lighting systems. PNNL's demonstration project used Lithonia tunable white luminaires and had LPDs between 0.54 and 0.63 watts per square foot, which are less than the 0.7 watts per square foot proposed for classrooms.

If the Energy Commission decides not to limit the 0.75 multiplier to small aperture tunable white and dim-to-warm luminaires, then the Statewide CASE Team recommends eliminating the 0.75 multiplier. This recommendation aligns with the comment from the International Association of Lighting Designers who also expressed support to remove the multiplier.

After considering input from other stakeholders, the Final CASE Report recommended a modest additional credit (0.1 watt per square foot) for all color tuning applications (including large aperture) in health care occupancies to accommodate lighting strategies that may benefit patient wellbeing. The Energy Commission's proposed language limits this additional credit to only small aperture luminaires. The Statewide CASE Team recommends updating this language to clarify that color tuning credit applies to any size aperture color changing luminaires in healthcare facilities.

4.1.2 Recommended Revisions to the Express Terms

Table 140.6-C, footnote 10 for healthcare facility and hospitals:

10. Tunable white or dim-to-warm luminaires as specified in Section 140.6(a)4Bii and iii. Large aperture color tuning or dim-to-warm luminaires qualify for this additional lighting power.

5. Indoor Lighting Controls

5.1 Delay Period for Occupant Sensing Controls

5.1.1 Recommendation and Justification

The Energy Commission suggested modifications to Section 110.9(b)4A of the code language that would require occupant sensing controls to turn OFF the lighting after 30 minutes. This change would increase energy usage from lighting applications where occupant sensing controls are required and, thus, result in a reduction of the stringency of the standards. The Statewide CASE Team recommends maintaining the code stringency by keeping 20-minute time delay that is currently in Section 110.9(b)4F. Keeping 20-minute time delay would be in alignment with ASHRAE 90.1-2016 requirements for occupancy sensing controls, in which all lighting must "automatically shut off within 20 minutes of all occupants leaving the space…" (ASHRAE 90.1-2016, Section 9.4.1(h)). Further, the Statewide CASE Team recommends including the 20-minute time out language for occupancy sensing controls in Section 130.1(c) for clarity.

The Statewide CASE Team supports the Energy Commission's intent stated during October 4, 2017, public workshop to include the language from 2016 Standards regarding manual ON or partial ON setting for occupant sensing controls in areas with multi-level controls.

5.1.2 Recommended Revisions to the Express Terms

Section 130.1(c)4 (formerly 130.1(c)3):

~~3~~4. Occupant sensing is required in office areas 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, classrooms, conference rooms, and restrooms. Occupant sensing is also required in corridors, stairwells, aisle ways in warehouses, open areas in warehouses, parking garages, parking areas, loading and unloading areas, library book stack aisles 10 feet or longer that are accessible from only one end, and library book stack aisles 20 feet or longer that are accessible from both ends. These controls shall provide the following in addition to the requirements of 130.1(c)1:

[…]

D. Occupant sensing controls shall be programmed to turn OFF all or part of the lighting no longer than 20 minutes after the space is vacant of occupants.

E. Occupant sensing controls shall function either as a:

i. Partial-ON Occupant Sensor capable of automatically activating between 50-70 percent of controlled lighting power, or

ii. Manual-ON Vacancy Sensor where all lighting responds to a manual ON input only.

EXCEPTION to 130.1(c)3E: In areas not required by Section 130.1(b) to have multi-level lighting controls, lighting is permitted to be controlled by an occupancy sensor that automatically turns ON all lighting when the room is occupied.

5.2 Delay Period for Automatic Shutoff Controls in Hotel Motel Guest Rooms

5.2.1 Recommendation and Justification

The Statewide CASE Team recommends requiring automatic shutoff controls to turn the lighting OFF no longer than 20 minutes after the guest room has been vacated rather than 30 minutes, which is currently required. This revision will simplify the code by aligning the requirement for guest rooms with the general requirement for 20-minute time delay in Section 110.9, 2016 Title 24, Part 6 and with Section 9.4.1.3(b) of ASHRAE 90.1-2016.

5.2.2 Recommended Revisions to the Express Terms

Section 130.1(c)7 (formerly 130.1(c)6):

~~6. In hotel motel guest rooms providing transient lodging, the automatic shutoff controls shall automatically turn the lighting off no longer than 30 minutes after the guest room has been vacated.~~

7. Hotel motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that, no longer than 20 minutes after the guest room has been vacated, lighting power is switched off.

EXCEPTION to Section 130.1(c)7: For hotel-motel guest rooms, one luminaire that is switched separately and where the switch is located within 6 feet of the entry door.

5.3 Daylighting Controls – Dimming to the Minimum of Dimmed State or Minimum Step in Table 130.1-A in Addition or as an Alternative to Dimming Plus OFF Controls

5.3.1 Recommendation and Justification

Additional energy savings could be achieved by adopting dimming plus OFF controls as presented in the Final CASE Report on Indoor Lighting Controls. However, stakeholders expressed concern about implementing daylight dimming plus OFF controls in office buildings, classrooms, and other areas where users expect to have more control over their electric lighting. Thus, the Statewide CASE Team recommends the Energy Commission adopt the OFF step in large space types in which the primary task is circulation and the space is saturated with daylight for most of the day. This requirement would apply to spaces such as airport and mall concourses, exterior corridors, and lobbies. The Statewide CASE Team proposes the OFF step be required in primary sidelit daylit zones in concourses and skylit daylit zones in all spaces. The Statewide CASE Team does not propose the OFF step be required in the secondary sidelit daylit zone.

In addition, when daylight in the daylit areas reaches 125 percent design illuminance the Statewide CASE Team recommends requiring dimming to no greater than the minimum dimmed state of the luminaire or the lowest setpoint in accordance to Table 130.1-A. The 2016 code language requires reducing lighting power to 35 percent of total light lighting power. Table 130.1-A requires LED fixtures to have the capability to dim to 10 percent of lighting power. Many LED luminaires are capable of dimming to five percent of lighting power, with some luminaires having a low set point of 0.1 to one percent of lighting power. Adjusting the required minimum setpoint to the lowest setting of the specific fixture required by Section 130.1(b) allows energy savings with no additional first cost.

If the Energy Commission decides not to introduce any requirements for dimming plus OFF controls, the Statewide CASE Team, recommends requiring dimming to no greater than the minimum dimmed state of the luminaire or the lowest setpoint in accordance to Table 130.1-A, when daylight in the daylit areas reaches 150 (versus 125) percent design illuminance.

5.3.2 Recommended Revisions to the Express Terms

Section 130.1(d)3:

(d) **Automatic Daylighting Controls.**

3. The automatic daylighting controls shall:

   […]

   C. For areas other than parking garages, ensure that when the daylight illuminance is greater than ~~150~~ 125 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be reduced ~~by a~~ to no greater than the minimum ~~of 65 percent~~ dimmed state or minimum step in Table 130.1-A;

   D. For the primary sidelit daylit zone in concourses and the skylit daylit zone in all spaces, when the daylight illuminance is greater than 150 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be shall be automatically turned OFF.

6. Residential Lighting

6.1 Correlated Color Temperature (CCT) and Dimmability Requirements

The Statewide CASE Team agrees with Acuity Brands that the proposed changes in the residential standards were substantive and that there was no prior public review opportunity of the proposal.[1] The current requirements in Section 150.0(k) and in Joint Appendix 8 (JA8) were developed carefully during the 2016 Standards development cycle with outreach to many stakeholders and detailed research. The Statewide CASE Team recommends that the Energy Commission not make substantive changes to the residential lighting requirements in this code cycle as the Statewide CASE Team has not received any compelling feedback that the basic structure of the residential requirements needs fixing. The residential lighting changes were one of the largest energy efficiency measures of the 2016 Standards, and several of the proposed changes would be disruptive to enforcement and compliance processes.

The Energy Commission's proposed changes may affect the enforceability of this section of the Standards as requirements differ depending upon whether lighting is "general lighting" or not, and whether it is in "habitable spaces" or not. This may provoke debate about which fixtures are providing general illumination versus those that are providing lighting for "decorative effect," and therefore exempt fixtures from requirements for color temperature and dimming.

In addition, the Energy Commission's proposal has moved lamp characteristics from the JA8 approval process to the building inspection process. The Express Terms require building inspectors to take time away from other enforcement activities to discern between 3200 Kelvin and 3600 Kelvin, which may not be realistic. Acuity Brands comments have also highlighted the disruptive nature of these changes, *"…manufacturers like Acuity Brands have committed considerable resources to update residential portfolios with JA8-2016 inseparable SSL luminaires at 4000K, and ask that the Commission evaluate the cost-effectiveness of making the change from 4000K to 3500K."*

The 2016 JA8 color temperature requirements were intentionally structured to be more stringent for removable lamps than for inseparable luminaires. It is much easier for the occupant of the home to replace a "daylight" blue LED removable lamp with an incandescent lamp than it is to replace inseparable LED luminaire with an incandescent luminaire.

The rationale for the low CCT requirements for LED replacement lamps is portrayed in Table 2. The table examines the possible outcomes from different lamp CCT selections initially installed by the home builder. This table considers occupant options if the installed lamp selection does not match their CCT preference. The table assumes that the lamp is retained if the lamp CCT matches the home occupant's preference. Additionally, incandescent lamps are only available in low color temperatures. LEDs, CFLs and other high-efficacy sources can produce high correlated color temperatures because these sources do not rely on the heating of a filament to produce a given color temperature.

In the table, there is only one scenario that could result in the occupant installing a low-efficacy incandescent lamp; when the initial lamp installed by the builder is a high color temperature (bluish) LED, and the occupant prefers low color temperatures (reddish) for the lighting in their home. If the occupant prefers a high color temperature (bluish) but the builder installed a high quality, high efficacy low color temperature LED, the homeowner could replace this lamp with a high efficacy, higher color temperature lamp with energy efficiency objectives maintained.

[1] http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221581_20171023T083232_Acuity_Brands_Comments_On_Draft_Express_Terms.pdf

The intent of the 3000 Kelvin maximum color temperature and other quality requirements in JA8 for long-lived, efficacious LED screw-in lamps is that they have comparable amenities to the incandescent lamps they displace and will be less likely to be replaced by incandescent lamps.

Table 2: Logic Model for the Color Temperature Requirements in the 2016 Standards

Initial Lamp	**Initial lamp: 3000 K LED (reddish)**		**Initial lamp: 4000 K LED (bluish)**	
Homeowner Preference	Likes reddish color lamps	Likes bluish color lamps	Likes reddish color lamps	Likes bluish color lamps
Outcome	Keeps initial LED lamp	Purchases bluish LED, CFL or induction	Purchases **inefficient incandescent** or reddish LED	Keeps initial LED lamp

Some high efficacy lamps emit an audible buzz, fail early when they are operated on a dimmer or in enclosed luminaires, flicker, exhibit pinkish-green color shifts or have dissimilar colors from lamp to lamp. The JA8 lamp specification is designed to prevent consumer rejection of high efficacy lamps by providing a testing and certification procedure to help to prevent poor quality products from being installed as part of the compliance process. For example, a lamp marked "JA8-2016-E" has been life-tested at elevated temperature so that it will not fail early if installed in an enclosed or recessed luminaire.

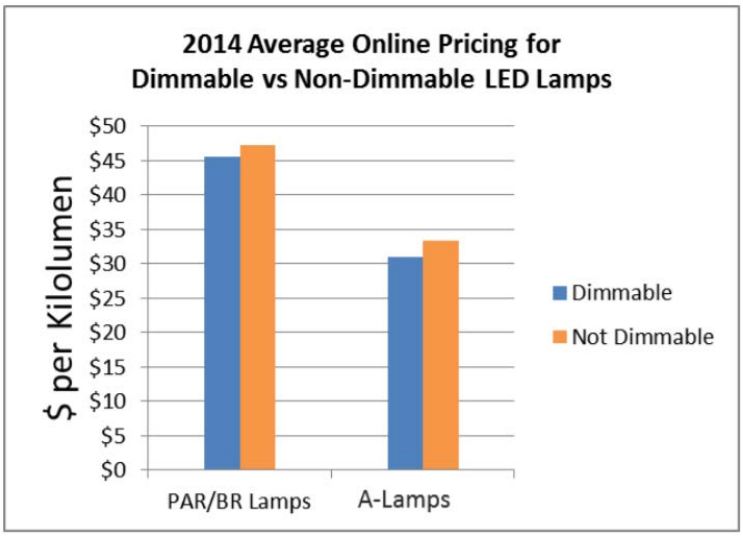

Figure 1: 2014 average online pricing for dimmable vs. non-dimmable LED lamps, based on hundreds of price points collected from nine online retailers.

Further, 2016 JA8 requires dimmability, a requirement which was demonstrated to be cost-effective when the 2016 Standards were adopted. Dimmability does not result in a cost adder for LED lamps, and most LED lamps are dimmable. This is consistent with comments the Statewide CASE Team has heard from industry contacts who are either in the driver manufacturer community or who have conducted research into dimming driver incremental costs. These stakeholders suggested that the incremental cost for an LED driver to be dimmable is small and shrinking. Estimates in 2014 ranged from $0.15 to $0.20 incremental manufacturer cost, but were expected to drop to $0.05 or less within three years. To verify that the incremental manufacturer cost to add dimmability is indeed small, the Statewide CASE Team has conducted an analysis of thousands of retail prices collected from 9 online retailers. As shown in

Figure 1, online prices for dimmable LED replacement lamp products (based on price points from hundreds of products collected throughout 2014, and prices have dropped since then) are actually slightly lower on average than prices for non-dimmable products. This suggests that any incremental manufacturer cost associated with making a product dimmable is negligible. It also stands in stark contrast to the linear fluorescent / compact fluorescent lighting market, where historically few products were dimmable and they carried significant incremental retail prices.

2016 Title 24, Part 6 residential lighting standard is easy to enforce (simply need to look for the marking on the light source) and does not require having to define general lighting or asking the building inspector to determine CCT. The Statewide CASE Team agrees with Lutron Electronics that for Section 150.0(k) the preferred solution is to keep 2016 language without changes. [2]

6.2 Joint Appendix JA8 Updates

JA8.3.5 & 6: The Statewide CASE Team recommends using the more robust life test method that was designed for 2016 JA8 rather than the test methods described in Energy Star v2.1 Section 10. The test methods developed for 2016 JA8 were based on Energy Star, but expanded upon it. Specifically, the Energy Star elevated temperature test does not apply to luminaires or light engines, so the 2016 JA8 language provided guidance for testing ICAT luminaire and air leakage specification. The Statewide CASE Team also recommends that language is adjusted to explicitly state that products be tested at 6,000 hours.

JA8.3.3: The Statewide CASE Team supports the additional clarifying language for light sources with pre-programmed fade-in features.

Table JA-8: The Statewide CASE Team recommends correcting the error that exempts medium diameter (<2") ornamental lamps and small diameter (<1") other lamps. This exception was written in JA8.5 when the initial 2016 proposal included a requirement for multiple criteria marked on the lamp. When the marking was simplified to "JA8-2016" or "JA8-2016-E," this exception was no longer needed; it was removed from the body of JA8, but the compliance threshold criteria in Table JA-8 was accidentally left in. In addition, the requirements in Table 150.0-A required that lamps be marked as meeting "JA8" to be considered high efficacy. Thus, it is desirable to remove this conflicting language from Table JA-8.

6.3 NEMA 77 as Flicker Test for Light Sources (JA8)

In Section JA8.3.7, the Energy Commission is proposing to allow flicker testing to be done using either JA10 or NEMA77, and allowing sources to meet the flicker requirements in JA8 or NEMA77 (Pst and SVM of less than 1). The Statewide CASE Team recommends removing the option to use NEMA 77 as a test for flicker and retaining JA8 requirements and JA10 as the appropriate test method, for two reasons: 1) the Energy Commission's proposal is a weakening of the existing flicker requirements at a key frequency range, and 2) the Energy Commission's proposal would eliminate one of the primary benefits of the current requirements which is a data stream for all products in a format that can be compared to other flicker standards such as IEEE PAR1789 (i.e., percent amplitude modulation at specific cut-off frequencies). These two issues are explained in more detail below.

Weakening of current standards in the 120-200 Hz range

While the NEMA 77 flicker requirements are stricter in the low frequency (more visible) range, the proposed limit of SVM = 1 actually allows *more* flicker at higher frequencies (up to 35 percent at 200 Hz) than the existing Title 24, Part 6 limit, and it is therefore a weakening of the flicker requirements in

[2] http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221547_20171019T161544_Lutron_Electronics_Co_Inc_Comments_On_2019_Building_Energy_Effi.pdf

this range. Low frequency flicker is extremely noticeable and likely to inspire home builder and consumer rejection. Flicker occurring at frequencies in the range of 120-200 Hz can have serious negative impacts on specific segments of the population (such as migraines, headaches, and reduced visual performance) despite being less perceptible.

Products with flicker in this range could be designed, marketed, and installed by builders in new homes, without anyone immediately recognizing the problematic levels of flicker. This represents a significant risk for consumer dissatisfaction with high efficacy lighting. The role of standards may be even more important to prevent flicker from occurring in this frequency range.

Removing the benefit of data availability from current standards (test and list)

The ANSI standard for flicker, IEEE PAR 1789-2015, "Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers," is the best currently available standard for minimizing the health risks from flicker. The IEEE Standard has a recommended relationship of Percent Modulation (same as percent amplitude modulation, modulation depth or percent flicker) to frequency. The JA10 formatted test data summarizes its results with regards to modulation percentage and frequency, rendering it easy to compare the performance of light sources to the recommendations in the IEEE Standard. Since the NEMA 77 method does not require publishing the JA10 filtered amplitude modulation results, it cannot be directly applied to the IEEE recommendations. Thus, users would not have data in the format used by the IEEE standard, and California would not have the market benefits that result from test and list standards. This data will help maintain better-than-minimum flicker quality lamps as incandescent sources are phased out. The Statewide Team recommends that the flicker data for JA8 compliant products continue to be collected using the JA10 test method and recording of summary amplitude modulation data for the various cut-off frequencies specified in JA10 and continue to populate the JA8 database. This information could be used over the next several years to inform the discussions that determine the reasonable levels of directly perceptible and imperceptible flicker and associated costs.

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Statewide Utility Codes and Standards Team Comments on Lighting Topics in 2019 Title 24, Part 6 Express Terms

Additional submitted attachment is included below.

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Comments on Lighting Topics in 2019 Title 24, Part 6 Express Terms

California Statewide Utility Codes and Standards Team

November 3, 2017

1. Introduction

The Statewide CASE Team appreciates the opportunity to participate in the rulemaking and the thoughtful feedback we have received from the California Energy Commission on the Codes and Standards Enhancement (CASE) proposals.

The CASE initiative presents recommendations to support the Energy Commission's efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and SoCalGas® – and several publicly Owned Utilities – Los Angeles Department of Water and Power, Sacramento Municipal Utility District, and Southern California Public Power Authority – sponsored this effort.

The California Statewide Utility Codes and Standards Team (Statewide CASE Team) actively supports the Energy Commission in developing revisions to Title 24, Part 6 by developing code change proposals that will result in feasible, enforceable, and cost-effective enhancements to the building energy efficiency standards. In developing these proposals, the Statewide CASE Team conducts research and market surveys, holds stakeholder meetings, and evaluates the energy savings and cost-effectiveness of considered measures. The CASE Reports, which present pertinent information that supports the code change proposals, are posted within each measure topic page on title24stakeholders.com.

The Statewide CASE Team encourages the Energy Commission to consider the following changes to the lighting measures.

Recommended revisions to the Express Terms are included in this document in purple. The Statewide CASE Team's recommended language insertions are single underlined and recommended language ~~deletions are single struck~~.

Recommended revisions to the Express Terms are summarized in Table 1.

Table 1: Summary of Recommended Revisions to the Express Terms

Measure Topic	Recommended Revision	Section of Standards
Lighting Alterations	• Clarify scope of the 70-luminaire exception so it only applies to component modifications. • Increase the stringency of the 70-luminaire exception by removing the per floor provision. For the "Reduction of Existing Wattage" compliance option: • Clarify that compliance must be demonstrated at the project level. • Eliminate the building size threshold.	EXCEPTION 6 to Section 141.0(b)2I Section 141.0(b)2I
Outdoor Lighting Controls	• Require motion sensing controls for luminaires that are primarily providing parking lot general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting. • Require that the controls reduce lighting power by at least 50 percent when vacant during normally occupied periods and that controls are *capable* of leaving at least 10 percent of power on when vacant. • Define a default normally unoccupied period of midnight to 6:00 am when the occupancy schedule is not known. • Require that the lighting system power be reduced by at least 75 percent power when unoccupied after-hours.	Section 130.2(c)
Indoor Lighting Sources	• If included, limit the 0.75 multiplier to small aperture tunable white and dim-to-warm luminaires. • Clarify that color tuning credit of 0.1 watt per square foot applies to any size aperture color changing luminaires in healthcare facilities.	Section 140.6 Table 140.6-C, footnote 10 for healthcare facility and hospitals
Indoor Lighting Controls	• Maintain the code stringency by keeping 20-minute time delay that is currently in Section 110.9(b)4F. • Require automatic shutoff controls to turn the lighting OFF no longer than 20 minutes after the guest room has been vacated rather than 30 minutes, which is currently required. For Daylighting controls: • Require daylighting dimming with OFF step in primary sidelit daylit zones in concourses and skylit daylit zones in all spaces. • Require dimming to no greater than the minimum dimmed state of the luminaire or the lowest setpoint in accordance to Table 130.1-A.	Section 130.1(c)4 (formerly 130.1(c)3) Section 130.1(c)7 (formerly 130.1(c)6) Section 130.1(d)3
Residential Lighting	• Maintain 2016 Title 24, Part 6 residential lighting requirements. In Joint Appendix JA8: • Use the more robust life test method that was designed for 2016 JA8 rather than the test methods described in Energy Star v2.1 Section 10. • Clarify the language for light sources with pre-programmed fade-in features. • Correct the error that exempts medium diameter (<2") ornamental lamps and small diameter (<1") other lamps. • Remove the option to use NEMA 77 as a test for flicker and retaining JA8 requirements and JA10 as the appropriate test method.	Section 150.0(k) Joint Appendix JA8

2. Lighting Alterations

2.1 Clarifying Scope of the 70-luminaire Exception

2.1.1 Recommendation and Justification

The Statewide CASE Team applauds the Energy Commission's effort to simplify the sections of the standards that apply to lighting alterations. Overall, the proposed language in the Express Terms is significantly less complex compared to the 2016 and 2013 code cycles.

To prevent misinterpretation and missed opportunities for energy use reduction, the Statewide CASE Team recommends that the code language clearly state that the 70-luminaire exception only applies to what are called "component modifications" in the 2016 code. For projects known as "entire luminaire alterations" in the 2016 code, only the threshold of 10 percent of affected luminaires should apply. The language in the Express Terms could be interpreted that the 70-luminaire exception applies to component modifications and entire luminaire alterations. The Statewide CASE Team estimates that about 28-35 percent of lighting alterations that are currently regulated under 2016 Title 24, Part 6 would not be subject to code if the scope of the 70-luminaire exception is not clarified.

2.1.2 Recommended Revisions to the Express Terms

Section 141.0(b)2I:

EXCEPTION 6 to Section 141.0(b)2I. For each building or tenant space, alteration of components in up to 70 luminaires ~~per floor of the space,~~ per annum without replacing the luminaire housings, and without increasing lighting power.

2.2 The "Reduction of Existing Wattage" Compliance Option

2.2.1 Recommendation and Justification

The Statewide CASE Team recommends that the code language specify that the compliance under Option 3 must be demonstrated at a project level not at a luminaire level. This revision will simplify the code compliance process significantly.

Further, the Statewide CASE Team recommends eliminating the building size limit for Option 3 for the following reasons:

- Using building size as a prerequisite would complicate the compliance process by requiring the applicant to produce additional documentation indicating building/tenant size and by requiring building departments to review the additional documentation.
- Given the proposed 70-luminaire exception and assuming each luminaire is serving approximately 100 square feet, the spaces that are about 7,000 square feet in size will not be subject to the lighting alteration requirements. In this case, Option 3 that is available for buildings or tenant spaces that are less than 5,000 square feet becomes irrelevant.

Instead of introducing a building size limit for Option 3, the Statewide CASE Team recommends increasing the stringency of the 70-luminaire exception by removing the per floor provision in Exception 6 to Section 141.0(b)2I.

2.2.2 Recommended Revisions to the Express Terms

Section 141.0(b)2I:

I. Altered Indoor Lighting Systems.

[…]

iii. The alteration type shall be a luminaire-for-luminaire alteration ~~within a building or tenant space of 5,000 square feet or less,~~ and the total wattage of the altered luminaires shall have at least 40% lower total rated ~~power~~ wattage compared to ~~the system~~ luminaires prior to the alteration. The rated wattage shall be calculated in accordance with Section 130.0. ~~and~~ The alteration shall comply with the lighting control requirements specified in Table 141.0-E.

3. Outdoor Lighting Controls

3.1 Motion Sensing Controls

3.1.1 Recommendation and Justification

The Energy Commission's proposed changes to Section 130.2(c) would require a control to turn lights off during the day and a control to reduce power by at least 50 percent during normally unoccupied periods by either a timeclock control with a two-hour override or a motion control. If the standards are adopted as proposed in the Express Terms, the Statewide CASE Team expects a decrease in the use of motion controls in favor of less expensive timeclock controls. This decrease in stringency of the outdoor lighting control standards would result in a loss of approximately 15 GWh/yr of energy savings as compared to the existing 2016 Title 24, Part 6 Standards.

Consistent with the Draft and Final CASE Reports on Outdoor Lighting Controls, the Statewide CASE Team recommends code language that would do the following:

- Require motion sensing controls for luminaires that are primarily providing lighting for general hardscape parking lots, outdoor sales lots, vehicle service station hardscapes, or vehicle service station canopies.
- Require that the controls reduce lighting power by at least 50 percent when vacant during normally occupied periods and that controls are *capable* of leaving at least 10 percent of power on when vacant.
- Define a default normally unoccupied period of midnight to 6:00 am when the occupancy schedule is not known.
- Require that the lighting system power be reduced by at least 75 percent when unoccupied after-hours. This additional level of control has a benefit-to-cost ratio in excess of four-to-one and saves an additional 6 GWh/yr statewide for new construction and retrofit projects.

3.1.2 Recommended Revisions to the Express Terms

Section 130.2(c):

(c) **Controls for Outdoor Lighting.** Outdoor lighting controls shall be installed that meet the following requirements for reducing lighting when daylight is available and during normally scheduled unoccupied periods:

EXCEPTION 1 to Section 130.2(c): Outdoor lighting not permitted by a health or life safety statute, ordinance, or regulation to be turned OFF or dimmed.

EXCEPTION 2 to Section 130.2(c): Lighting in tunnels required to be illuminated 24 hours per day and 365 days per year.

1. **Daylight Availability.** All installed outdoor lighting shall be controlled by a photo control, astronomical time-switch control, automatic scheduling control, or other control capable of automatically shutting OFF the outdoor lighting when daylight is available.
2. **Unoccupied Periods.** All installed outdoor lighting shall be controlled by ~~a control capable of reducing the outdoor lighting by at least 50 percent, or turning the lighting OFF, during normally~~

~~scheduled unoccupied periods. This control shall be either~~ an automatic scheduling control or an occupant sensing control, and shall include the following features:

A. ~~For a~~ Automatic scheduling controls shall reduce lighting power by at least 50 percent during normally unoccupied scheduled periods ~~the control shall provide an override function that turns the lighting ON during its scheduled dim or OFF period for no more than 2 hours when an override is initiated.~~

~~B. For occupant sensing controls, no more than 800 watts of lighting shall be controlled by any single sensor, and the control shall return the lighting to its dim or OFF state no later than 15 minutes after the area has been vacated.~~

B. Motion Sensing controls shall comply with Section 130.2(c)3. A through C.

3. **Bi-Level Motion Sensing**. Luminaires that are primarily providing parking lot general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting and where the bottom of the luminaire is mounted 24 feet or less above the ground, shall be controlled by automatic lighting controls that meet all of the following requirements:

   A. During normally scheduled occupied periods, the lighting power of each luminaire shall be automatically reduced by at least 50 percent or OFF when no activity has been detected in the area illuminated by the controlled luminaires for a time no longer than 15 minutes.

   B. During normally scheduled unoccupied periods, in addition to complying with the requirements of item A, total lighting power shall be automatically reduced by at least 75 percent including OFF when no activity has been detected in the area illuminated by the controlled luminaires for a time no longer than 60 minutes.

   C. No more than 800 watts of lighting power shall be controlled together.

   D. The lighting system shall be capable of being configured to automatically reduce power of each luminaire by at least 75 percent, but not exceeding 90 percent without turning the luminaires OFF if no activity is detected in the area illuminated by the controlled luminaires.

   EXCEPTION to Section 130.2(c)3: Luminaires controlled in accordance with Section 130.2(c)2A and located where trees or other obstructions block motion sensing between the luminaire and the area illuminated by the luminaire.

4. **Timed Manual Override**. Timed manual overrides are not required, but shall be allowed to override motion or scheduling controls for a duration not to exceed two hours. No more than 1,800 watts may be controlled per manual override control.

5. **Default Schedules**. Acceptance tests of outdoor lighting controls shall be conducted in accordance with Section 130.4(a)6. When scheduled operating hours are known, the acceptance tests shall confirm the time schedules are correctly applied. When scheduled operating hours are not known, acceptance tests shall be conducted to confirm the use of a default normally occupied scheduled period of 6:00 am to midnight and a default normally unoccupied scheduled period of midnight to 6:00 am.

4. Indoor Lighting Sources

4.1 Adder for Small Aperture Tunable White and Dim-to-Warm Luminaires

4.1.1 Recommendation and Justification

The Statewide CASE Team supports the Energy Commission's alignment with the Final CASE Report on Indoor Lighting Power Densities (LPDs) and supports the Energy Commission's decision to include a 0.75 multiplier for small aperture tunable white and dim-to-warm luminaires. The Statewide CASE Team's analysis in Appendix M of the Final CASE Report demonstrates that only small aperture color changing luminaires need a power adjustment factor. Large aperture tunable white systems do not need a power adjustment factor since those systems have efficacies that were within 10 percent of static lighting systems. The Statewide CASE Team is conducting additional research to compare a broader range of color tuning luminaires. The findings from this research will be added as an appendix to the posted Final CASE Report on http://title24stakeholders.com.

Pacific Northwest National Laboratory's (PNNL) September 2017 study ("Tuning the Light in Classrooms: Evaluating Trial LED Lighting Systems in Three Classrooms at the Carrollton-Farmers Branch Independent Schools District in Carrollton, TX") also supports the finding that the efficacies of large aperture tunable white lighting systems are comparable with static white lighting systems. PNNL's demonstration project used Lithonia tunable white luminaires and had LPDs between 0.54 and 0.63 watts per square foot, which are less than the 0.7 watts per square foot proposed for classrooms.

If the Energy Commission decides not to limit the 0.75 multiplier to small aperture tunable white and dim-to-warm luminaires, then the Statewide CASE Team recommends eliminating the 0.75 multiplier. This recommendation aligns with the comment from the International Association of Lighting Designers who also expressed support to remove the multiplier.

After considering input from other stakeholders, the Final CASE Report recommended a modest additional credit (0.1 watt per square foot) for all color tuning applications (including large aperture) in health care occupancies to accommodate lighting strategies that may benefit patient wellbeing. The Energy Commission's proposed language limits this additional credit to only small aperture luminaires. The Statewide CASE Team recommends updating this language to clarify that color tuning credit applies to any size aperture color changing luminaires in healthcare facilities.

4.1.2 Recommended Revisions to the Express Terms

Table 140.6-C, footnote 10 for healthcare facility and hospitals:

10. Tunable white or dim-to-warm luminaires as specified in Section 140.6(a)4Bii and iii. Large aperture color tuning or dim-to-warm luminaires qualify for this additional lighting power.

5. Indoor Lighting Controls

5.1 Delay Period for Occupant Sensing Controls

5.1.1 Recommendation and Justification

The Energy Commission suggested modifications to Section 110.9(b)4A of the code language that would require occupant sensing controls to turn OFF the lighting after 30 minutes. This change would increase energy usage from lighting applications where occupant sensing controls are required and, thus, result in a reduction of the stringency of the standards. The Statewide CASE Team recommends maintaining the code stringency by keeping 20-minute time delay that is currently in Section 110.9(b)4F. Keeping 20-minute time delay would be in alignment with ASHRAE 90.1-2016 requirements for occupancy sensing controls, in which all lighting must "automatically shut off within 20 minutes of all occupants leaving the space…" (ASHRAE 90.1-2016, Section 9.4.1(h)). Further, the Statewide CASE Team recommends including the 20-minute time out language for occupancy sensing controls in Section 130.1(c) for clarity.

The Statewide CASE Team supports the Energy Commission's intent stated during October 4, 2017, public workshop to include the language from 2016 Standards regarding manual ON or partial ON setting for occupant sensing controls in areas with multi-level controls.

5.1.2 Recommended Revisions to the Express Terms

Section 130.1(c)4 (formerly 130.1(c)3):

~~3~~4. Occupant sensing is required in office areas 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, classrooms, conference rooms, and restrooms. Occupant sensing is also required in corridors, stairwells, aisle ways in warehouses, open areas in warehouses, parking garages, parking areas, loading and unloading areas, library book stack aisles 10 feet or longer that are accessible from only one end, and library book stack aisles 20 feet or longer that are accessible from both ends. These controls shall provide the following in addition to the requirements of 130.1(c)1:

[…]

D. Occupant sensing controls shall be programmed to turn OFF all or part of the lighting no longer than 20 minutes after the space is vacant of occupants.

E. Occupant sensing controls shall function either as a:

i. Partial-ON Occupant Sensor capable of automatically activating between 50-70 percent of controlled lighting power, or

ii. Manual-ON Vacancy Sensor where all lighting responds to a manual ON input only.

EXCEPTION to 130.1(c)3E: In areas not required by Section 130.1(b) to have multi-level lighting controls, lighting is permitted to be controlled by an occupancy sensor that automatically turns ON all lighting when the room is occupied.

5.2 Delay Period for Automatic Shutoff Controls in Hotel Motel Guest Rooms

5.2.1 Recommendation and Justification

The Statewide CASE Team recommends requiring automatic shutoff controls to turn the lighting OFF no longer than 20 minutes after the guest room has been vacated rather than 30 minutes, which is currently required. This revision will simplify the code by aligning the requirement for guest rooms with the general requirement for 20-minute time delay in Section 110.9, 2016 Title 24, Part 6 and with Section 9.4.1.3(b) of ASHRAE 90.1-2016.

5.2.2 Recommended Revisions to the Express Terms

Section 130.1(c)7 (formerly 130.1(c)6):

~~6. In hotel motel guest rooms providing transient lodging, the automatic shutoff controls shall automatically turn the lighting off no longer than 30 minutes after the guest room has been vacated.~~

7. Hotel motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that, no longer than 20 minutes after the guest room has been vacated, lighting power is switched off.

EXCEPTION to Section 130.1(c)7: For hotel-motel guest rooms, one luminaire that is switched separately and where the switch is located within 6 feet of the entry door.

5.3 Daylighting Controls – Dimming to the Minimum of Dimmed State or Minimum Step in Table 130.1-A in Addition or as an Alternative to Dimming Plus OFF Controls

5.3.1 Recommendation and Justification

Additional energy savings could be achieved by adopting dimming plus OFF controls as presented in the Final CASE Report on Indoor Lighting Controls. However, stakeholders expressed concern about implementing daylight dimming plus OFF controls in office buildings, classrooms, and other areas where users expect to have more control over their electric lighting. Thus, the Statewide CASE Team recommends the Energy Commission adopt the OFF step in large space types in which the primary task is circulation and the space is saturated with daylight for most of the day. This requirement would apply to spaces such as airport and mall concourses, exterior corridors, and lobbies. The Statewide CASE Team proposes the OFF step be required in primary sidelit daylit zones in concourses and skylit daylit zones in all spaces. The Statewide CASE Team does not propose the OFF step be required in the secondary sidelit daylit zone.

In addition, when daylight in the daylit areas reaches 125 percent design illuminance the Statewide CASE Team recommends requiring dimming to no greater than the minimum dimmed state of the luminaire or the lowest setpoint in accordance to Table 130.1-A. The 2016 code language requires reducing lighting power to 35 percent of total light lighting power. Table 130.1-A requires LED fixtures to have the capability to dim to 10 percent of lighting power. Many LED luminaires are capable of dimming to five percent of lighting power, with some luminaires having a low set point of 0.1 to one percent of lighting power. Adjusting the required minimum setpoint to the lowest setting of the specific fixture required by Section 130.1(b) allows energy savings with no additional first cost.

If the Energy Commission decides not to introduce any requirements for dimming plus OFF controls, the Statewide CASE Team, recommends requiring dimming to no greater than the minimum dimmed state of the luminaire or the lowest setpoint in accordance to Table 130.1-A, when daylight in the daylit areas reaches 150 (versus 125) percent design illuminance.

5.3.2 Recommended Revisions to the Express Terms

Section 130.1(d)3:

(d) **Automatic Daylighting Controls.**

3. The automatic daylighting controls shall:

   […]

   C. For areas other than parking garages, ensure that when the daylight illuminance is greater than ~~150~~ 125 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be reduced ~~by a~~ to no greater than the minimum ~~of 65 percent~~ dimmed state or minimum step in Table 130.1-A;

   D. For the primary sidelit daylit zone in concourses and the skylit daylit zone in all spaces, when the daylight illuminance is greater than 150 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be shall be automatically turned OFF.

6. Residential Lighting

6.1 Correlated Color Temperature (CCT) and Dimmability Requirements

The Statewide CASE Team agrees with Acuity Brands that the proposed changes in the residential standards were substantive and that there was no prior public review opportunity of the proposal.[1] The current requirements in Section 150.0(k) and in Joint Appendix 8 (JA8) were developed carefully during the 2016 Standards development cycle with outreach to many stakeholders and detailed research. The Statewide CASE Team recommends that the Energy Commission not make substantive changes to the residential lighting requirements in this code cycle as the Statewide CASE Team has not received any compelling feedback that the basic structure of the residential requirements needs fixing. The residential lighting changes were one of the largest energy efficiency measures of the 2016 Standards, and several of the proposed changes would be disruptive to enforcement and compliance processes.

The Energy Commission's proposed changes may affect the enforceability of this section of the Standards as requirements differ depending upon whether lighting is "general lighting" or not, and whether it is in "habitable spaces" or not. This may provoke debate about which fixtures are providing general illumination versus those that are providing lighting for "decorative effect," and therefore exempt fixtures from requirements for color temperature and dimming.

In addition, the Energy Commission's proposal has moved lamp characteristics from the JA8 approval process to the building inspection process. The Express Terms require building inspectors to take time away from other enforcement activities to discern between 3200 Kelvin and 3600 Kelvin, which may not be realistic. Acuity Brands comments have also highlighted the disruptive nature of these changes, *"…manufacturers like Acuity Brands have committed considerable resources to update residential portfolios with JA8-2016 inseparable SSL luminaires at 4000K, and ask that the Commission evaluate the cost-effectiveness of making the change from 4000K to 3500K."*

The 2016 JA8 color temperature requirements were intentionally structured to be more stringent for removable lamps than for inseparable luminaires. It is much easier for the occupant of the home to replace a "daylight" blue LED removable lamp with an incandescent lamp than it is to replace inseparable LED luminaire with an incandescent luminaire.

The rationale for the low CCT requirements for LED replacement lamps is portrayed in Table 2. The table examines the possible outcomes from different lamp CCT selections initially installed by the home builder. This table considers occupant options if the installed lamp selection does not match their CCT preference. The table assumes that the lamp is retained if the lamp CCT matches the home occupant's preference. Additionally, incandescent lamps are only available in low color temperatures. LEDs, CFLs and other high-efficacy sources can produce high correlated color temperatures because these sources do not rely on the heating of a filament to produce a given color temperature.

In the table, there is only one scenario that could result in the occupant installing a low-efficacy incandescent lamp; when the initial lamp installed by the builder is a high color temperature (bluish) LED, and the occupant prefers low color temperatures (reddish) for the lighting in their home. If the occupant prefers a high color temperature (bluish) but the builder installed a high quality, high efficacy low color temperature LED, the homeowner could replace this lamp with a high efficacy, higher color temperature lamp with energy efficiency objectives maintained.

[1] http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221581_20171023T083232_Acuity_Brands_Comments_On_Draft_Express_Terms.pdf

The intent of the 3000 Kelvin maximum color temperature and other quality requirements in JA8 for long-lived, efficacious LED screw-in lamps is that they have comparable amenities to the incandescent lamps they displace and will be less likely to be replaced by incandescent lamps.

Table 2: Logic Model for the Color Temperature Requirements in the 2016 Standards

Initial Lamp	**Initial lamp: 3000 K LED (reddish)**		**Initial lamp: 4000 K LED (bluish)**	
Homeowner Preference	Likes reddish color lamps	Likes bluish color lamps	Likes reddish color lamps	Likes bluish color lamps
Outcome	Keeps initial LED lamp	Purchases bluish LED, CFL or induction	Purchases **inefficient incandescent** or reddish LED	Keeps initial LED lamp

Some high efficacy lamps emit an audible buzz, fail early when they are operated on a dimmer or in enclosed luminaires, flicker, exhibit pinkish-green color shifts or have dissimilar colors from lamp to lamp. The JA8 lamp specification is designed to prevent consumer rejection of high efficacy lamps by providing a testing and certification procedure to help to prevent poor quality products from being installed as part of the compliance process. For example, a lamp marked "JA8-2016-E" has been life-tested at elevated temperature so that it will not fail early if installed in an enclosed or recessed luminaire.

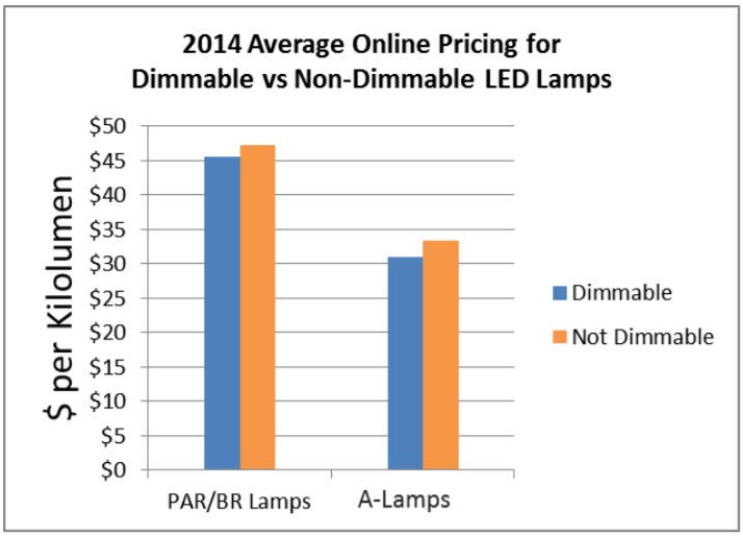

Figure 1: 2014 average online pricing for dimmable vs. non-dimmable LED lamps, based on hundreds of price points collected from nine online retailers.

Further, 2016 JA8 requires dimmability, a requirement which was demonstrated to be cost-effective when the 2016 Standards were adopted. Dimmability does not result in a cost adder for LED lamps, and most LED lamps are dimmable. This is consistent with comments the Statewide CASE Team has heard from industry contacts who are either in the driver manufacturer community or who have conducted research into dimming driver incremental costs. These stakeholders suggested that the incremental cost for an LED driver to be dimmable is small and shrinking. Estimates in 2014 ranged from $0.15 to $0.20 incremental manufacturer cost, but were expected to drop to $0.05 or less within three years. To verify that the incremental manufacturer cost to add dimmability is indeed small, the Statewide CASE Team has conducted an analysis of thousands of retail prices collected from 9 online retailers. As shown in

Figure 1, online prices for dimmable LED replacement lamp products (based on price points from hundreds of products collected throughout 2014, and prices have dropped since then) are actually slightly lower on average than prices for non-dimmable products. This suggests that any incremental manufacturer cost associated with making a product dimmable is negligible. It also stands in stark contrast to the linear fluorescent / compact fluorescent lighting market, where historically few products were dimmable and they carried significant incremental retail prices.

2016 Title 24, Part 6 residential lighting standard is easy to enforce (simply need to look for the marking on the light source) and does not require having to define general lighting or asking the building inspector to determine CCT. The Statewide CASE Team agrees with Lutron Electronics that for Section 150.0(k) the preferred solution is to keep 2016 language without changes. [2]

6.2 Joint Appendix JA8 Updates

JA8.3.5 & 6: The Statewide CASE Team recommends using the more robust life test method that was designed for 2016 JA8 rather than the test methods described in Energy Star v2.1 Section 10. The test methods developed for 2016 JA8 were based on Energy Star, but expanded upon it. Specifically, the Energy Star elevated temperature test does not apply to luminaires or light engines, so the 2016 JA8 language provided guidance for testing ICAT luminaire and air leakage specification. The Statewide CASE Team also recommends that language is adjusted to explicitly state that products be tested at 6,000 hours.

JA8.3.3: The Statewide CASE Team supports the additional clarifying language for light sources with pre-programmed fade-in features.

Table JA-8: The Statewide CASE Team recommends correcting the error that exempts medium diameter (<2") ornamental lamps and small diameter (<1") other lamps. This exception was written in JA8.5 when the initial 2016 proposal included a requirement for multiple criteria marked on the lamp. When the marking was simplified to "JA8-2016" or "JA8-2016-E," this exception was no longer needed; it was removed from the body of JA8, but the compliance threshold criteria in Table JA-8 was accidentally left in. In addition, the requirements in Table 150.0-A required that lamps be marked as meeting "JA8" to be considered high efficacy. Thus, it is desirable to remove this conflicting language from Table JA-8.

6.3 NEMA 77 as Flicker Test for Light Sources (JA8)

In Section JA8.3.7, the Energy Commission is proposing to allow flicker testing to be done using either JA10 or NEMA77, and allowing sources to meet the flicker requirements in JA8 or NEMA77 (Pst and SVM of less than 1). The Statewide CASE Team recommends removing the option to use NEMA 77 as a test for flicker and retaining JA8 requirements and JA10 as the appropriate test method, for two reasons: 1) the Energy Commission's proposal is a weakening of the existing flicker requirements at a key frequency range, and 2) the Energy Commission's proposal would eliminate one of the primary benefits of the current requirements which is a data stream for all products in a format that can be compared to other flicker standards such as IEEE PAR1789 (i.e., percent amplitude modulation at specific cut-off frequencies). These two issues are explained in more detail below.

Weakening of current standards in the 120-200 Hz range

While the NEMA 77 flicker requirements are stricter in the low frequency (more visible) range, the proposed limit of SVM = 1 actually allows *more* flicker at higher frequencies (up to 35 percent at 200 Hz) than the existing Title 24, Part 6 limit, and it is therefore a weakening of the flicker requirements in

[2] http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN221547_20171019T161544_Lutron_Electronics_Co_Inc_Comments_On_2019_Building_Energy_Effi.pdf

this range. Low frequency flicker is extremely noticeable and likely to inspire home builder and consumer rejection. Flicker occurring at frequencies in the range of 120-200 Hz can have serious negative impacts on specific segments of the population (such as migraines, headaches, and reduced visual performance) despite being less perceptible.

Products with flicker in this range could be designed, marketed, and installed by builders in new homes, without anyone immediately recognizing the problematic levels of flicker. This represents a significant risk for consumer dissatisfaction with high efficacy lighting. The role of standards may be even more important to prevent flicker from occurring in this frequency range.

Removing the benefit of data availability from current standards (test and list)

The ANSI standard for flicker, IEEE PAR 1789-2015, "Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers," is the best currently available standard for minimizing the health risks from flicker. The IEEE Standard has a recommended relationship of Percent Modulation (same as percent amplitude modulation, modulation depth or percent flicker) to frequency. The JA10 formatted test data summarizes its results with regards to modulation percentage and frequency, rendering it easy to compare the performance of light sources to the recommendations in the IEEE Standard. Since the NEMA 77 method does not require publishing the JA10 filtered amplitude modulation results, it cannot be directly applied to the IEEE recommendations. Thus, users would not have data in the format used by the IEEE standard, and California would not have the market benefits that result from test and list standards. This data will help maintain better-than-minimum flicker quality lamps as incandescent sources are phased out. The Statewide Team recommends that the flicker data for JA8 compliant products continue to be collected using the JA10 test method and recording of summary amplitude modulation data for the various cut-off frequencies specified in JA10 and continue to populate the JA8 database. This information could be used over the next several years to inform the discussions that determine the reasonable levels of directly perceptible and imperceptible flicker and associated costs.