CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Nonresidential Lighting Alterations

Draft Analysis Methodology

Last Updated: 3/21/2017

1. INTRODUCTION

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). Our joint intent is to achieve significant energy savings through the development of reasonable, responsible, and cost-effective code change proposals for the 2019 Title 24 code change cycle.

The scope of 2019 Title 24, Part 6 alteration analysis includes the assessment of the relative energy savings for three prescriptive options to comply with Title 24, Part 6 nonresidential lighting alteration requirements. Specifically, the analysis focuses on quantifying the effect of lower 2019 LPD levels on energy savings from nonresidential lighting alterations for entire luminaire and component modification type of retrofits.

Furthermore, the analysis aims to present scenarios of potential modifications to the lighting alteration code with the goal of demonstrating the changes needed, if any, for the "2019 wattage reduction" compliance option to be at least as energy efficient as the "≤ 85% of 2019 LPD allowance" compliance option for each considered code vintage and each considered building type on kWh/sf per-unit energy use basis.

The goal of this effort is to provide a transparent analysis of the savings resulting from LPD changes and control changes, so that all stakeholders can compare the energy impacts of different lighting alteration compliance options.

The Statewide Utility Team is requesting feedback on the draft analysis methodology presented in this document. Input we receive will inform the code change proposal that the Statewide Utility Team will be proposing to the California Energy Commission in April 2017.

To provide feedback, please email us at info@title24stakeholders.com or contact the measure lead at:

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

2. KEY ASSUMPTIONS AND STEP-BY-STEP METHODOLOGY TO ASSESS ENERGY IMPACTS

Note that information that is incomplete or may change is highlighted in yellow.

2.1 Key Assumptions for Energy Savings Analysis

The per-unit analysis considers the following building types: office (small and large), restaurant, retail (large), warehouse (non-refrigerated), school, and hotel. Collectively these building types account for approximately seventy percent of existing building stock in 2020.

For considered building types, the table below lists floor areas and percentages of total existing building stock in 2020 (Energy Commission).

Table 1: Estimated floor areas by building type in 2020

Building Type	Building Stock (million square feet	Percent of Total	Percent of Considered Stock
Hotel	362	5%	7%
Office Large	1,384	18%	26%
Office Small	395	5%	7%
Restaurant	196	2%	4%
Retail	1,248	16%	24%
School	604	8%	11%
Warehouse Non-Refrigerated	1,117	14%	21%
All Other Building Types (Food, Warehouse Refrigerated, College, Hospital, Miscellaneous)	2,544	32%	N/A
TOTAL	7,850	100%	N/A
TOTAL Considered Stock	5,306	68%	100%

2.1.1 Assumptions Related to Retrofit Market

The table below summarizes the market related assumptions used in the per-unit analysis. The assumption on the rate of alterations is applicable to extrapolating the per-unit results to statewide level.

Table 2: Assumptions for market related variables in the analysis

Key Variable	Assumption	Sources to Inform the Assumption
Market share of lighting systems at each vintage of historical Title 24, Part 6 codes in existing building stock in 2020 (LPD levels and lighting controls)	2001 Title 24, Part 6 – 0% 2005 Title 24, Part 6 – 45% 2008 Title 24, Part 6 – 40% 2013 Title 24, Part 6 – 15% 2016 Title 24, Part 6 – 0%	These percentages were shifted by one cycle forward compared to estimates used in 2016 Title 24, Part 6 alteration analysis. This assumption will be further informed by field data gathered with the alteration survey.
Market share of regulated alterations (entire luminaire and component modification type of retrofits)	85-100% of LPD allowance – xx% ≤ 85% of LPD allowance – xx% 35/50% wattage reduction – xx% Performance approach – xx%	No readily available data was identified. As reference, 2016 Title 24, Part 6 alteration analysis used: 85-100% of LPD allowance – 13% ≤ 85% of LPD allowance – 29% 35/50% wattage reduction – 51% This assumption will be informed by field data gathered with the alteration survey.
Rate of alterations for building types of interest (this assumption is applicable for extrapolating "Per-Unit Energy" values to statewide savings)	Hotel – 10 years Office Large – 15 years Office Small – 15 years Restaurant – 10 years Retail Large – 7 years School – 15 years Warehouse – 15 years	IBEW comment letter dated 11/6/2015 states: "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." (CEC 15-BSTD-01 Docket, TN #76315). The assumed rate of alterations used in 2016 DOE Report on SSL Forecast was 10% per year or every 10 years (2016 DOE, e-page 21). This assumption will be further informed by field data gathered with the alteration survey.

2.1.2 Assumptions Related to LPDs

The table below provides a high-level summary of assumed LPDs as percentages of allowed LPDs and assumed control requirements for entire luminaire and component modification retrofit projects for three available prescriptive compliance options.

Table 3: Summary of assumed LPDs and control requirements in the analysis for available compliance options

	Assumed Percent of LPD Allowance for Restaurant, School, Warehouse	Assumed Percent of LPD Allowance for Hotel, Office, Retail	Manual Area Controls	Manual Multi-Level Control[1]	Auto Shut-off Control[2]	Auto Daylighting Controls	Demand Responsive Controls[4]
85-100% of LPD allowance	100%	100%	Yes	Yes	Yes	Yes	Yes
≤ 85% of LPD allowance [5]	85%	85%	Yes	Yes (or bi-level)	Yes	No	No
35/50% wattage reduction [6]	65%	50%	Yes	No	Partial Yes [3]	No	No

1. For each enclosed space (≥100 sf/enclosed space and lighting load >0.5 W/sf).
2. Note that auto shut-off controls for all three compliance options can be met with occupancy controls or automatic time-switch controls (Section 130.1 (c) 1A except for areas specified in 130.1 (c) 5).
3. Except 130.1(c)1D, separate shut-off controls for display/ornamental; 130.1(c)6B, full or partial off occupancy sensing in library stacks; 130.1(c)6C, full or partial off occupancy sensing in corridors and stairwells; 130.1(c)7A, partial off occupancy sensing in corridors and stairwells in hotels; 130.1(c)8, guest room card key/occupancy sensing.
4. > 10,000 sf/single building 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 DR controls are ignored in this analysis and listed in the table to provide a complete list of Title 24, Part 6 requirements around lighting controls.
5. Introduced in 2013 code cycle, effective July 1, 2014.
6. Introduced in 2016 code cycle, a new compliance option available as of April 13, 2016.

The analysis is performed at the area category level for considered building prototypes. 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).

The table below lists vintage, current, and expected 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. LPD values for 2019 Title 24, Part 6 are draft values and may be revised.

Color coding:
Area categories considered in 2019 T24 P6 NR Lighting Alteration Analysis

Area Category	2001 (effective June 2001)	2005 (effective Oct 2005)	2008 (effective Jan 2010)	2013 (effective July 2014)	2016 (effective Jan 2017)	2019 Estimates (MAY CHANGE)	For Reference Only ASHRAE 90.1 2016
Auditorium	2.0	1.5	1.5	1.5	1.4	0.67	0.6
Classroom, Lecture	1.6	1.2	1.2	1.2	1.2	0.90	1.1
Commercial Storage	0.6	0.6	0.6	0.6	0.6	0.46	0.5
Corridors, Restroom, Stair, and Support	0.6	0.6	0.6	0.6	0.6	0.54	0.7
Convention, Conference, Multipurpose and Meeting Center Areas	1.5	1.4	1.4	1.4	1.2	0.93	1.07
Dining Area	1.1	1.1	1.1	1.1	1.0	0.54	0.8
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	0.63	0.7
Exhibit, Museum	2.0	2.0	2.0	2.0	1.8	0.22	1.1
General Commercial High Bay	1.2	1.1	1.0	1.0	1.0	0.58	0.8
General Commercial Low Bay	1.0	1.0	0.9	0.9	0.9	0.61	1.0
General Commercial, Precision	1.5	1.3	1.2	1.2	1.2	0.86	0.9
Grocery	1.6	1.6	1.6	1.2	1.2	1.1	1.2
Hotel	2.2	1.5	1.5	1.5	1.4	0.62	0.9
Library Reading Areas	1.2	1.2	1.2	1.2	1.1	0.77	0.8
Library Stacks	1.5	1.5	1.5	1.5	1.5	1.1	1.2
Lobby Area Hotel	1.7	1.1	1.1	1.1	0.95	0.48	1.06
Lounge Area	1.1	1.1	1.1	1.1	0.9	0.44	0.62
Malls	1.2	1.2	1.2	1.2	1.0	0.79	0.9
Medical and Clinic	1.4	1.2	1.2	1.2	1.2	0.89	1.0
Office Area > 250 sf	1.3	1.2	0.9	0.75	0.75	0.68	0.87
Office Area ≤ 250 sf	1.3	1.2	1.1	1.0	1.0	0.85	0.93
Religious Worship	2.1	1.5	1.5	1.5	1.5	0.55	1.0
Retail	2.0	1.7	1.6	1.2	1.2	0.79	0.9
Theater Area	0.9	0.9	0.9	0.9	0.9	0.31	1.1
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
Waiting Area	1.1	1.1	1.1	1.1	0.8	0.72	1.0
AVERAGE LPD	**1.4**	**1.2**	**1.2**	**1.1**	**1.1**	**0.67**	**0.89**

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

Figure 1: Vintage, current, and estimated future LPDs for considered area categories

The table below presents the area categories that have been considered for each building type. The Database for Energy Efficient Resources (DEER) is used as the source for typical activity areas found in the considered building types, as well as the percentages of activity areas of the total building area (the spreadsheet titled "DEER2016-ComLtgProfilesSummary-15May2015"). DEER activity areas were mapped to Title 24, Part 6 area categories as shown in the table below.

Color coding:
Area categories considered in 2019 T24 P6 NR Lighting Alteration Analysis

	Considered Building Prototypes						
Area Category	Hotel	Office Large	Office Small	Restaurant	Retail	School	Warehouse
Auditorium							
Classroom, Lecture						X	
Commercial Storage		X	X	X	X	X	X
Corridors, Restroom, Stair, and Support Areas	X	X	X	X	X	X	X
Convention, Conference, Multipurpose and Meeting Center Areas		X	X				
Dining Area	X	X	X	X	X	X	
Electrical, Mechanical, Telephone Rooms		X	X	X	X		
Exercise, Gym						X	
Exhibit, Museum							
General Commercial High Bay							
General Commercial Low Bay			X		X		
General Commercial, Precision							
Grocery							
Hotel							
Library Reading Areas						X	
Library Stacks							
Lobby Area Hotel	X						
Lounge Area	X						
Malls							
Medical and Clinic							
Office Area > 250 sf	X	X	X	X	X	X	X
Office Area ≤ 250 sf		X	X				
Religious Worship							
Retail					X		
Theater Area							
Kitchen, Food Preparation Areas	X			X		X	
Laundry Area	X						
Waiting Area		X	X	X		X	

Figure 2: Area categories in the considered building types

2.1.3 Assumptions Related to Lighting Controls

To account for the energy savings due to occupant sensing and automatic daylighting controls in the applicable area categories, reduction factors for occupant and daylighting controls were used.

Occupant control reduction factors were used for area categories that explicitly require an occupant sensing control. The meta-study conducted by LBNL was used as the source for reduction factors from occupant sensing controls in the considered building types.

Daylighting control reduction factors were developed using Radiance based daylighting simulations and a daylighting template based approach. This approach is described in the PIER Office Daylighting Research Study (see Publication No. CEC-500-2013-002 for more details).

2.1.4 Simplifications Made in the Analysis

The following simplifications are made in the analysis when calculating baseline Per-unit energy use values:

- LPD allowance for ornamental lighting for applicable area categories is ignored for all building types except for retail. Note that the presented per-unit energy use values for retail do not yet reflect LPD allowance for ornamental lighting. **Rationale**: Ornamental lighting could be a significant portion of lighting load in retail.
- LPD allowance for task lighting for applicable area categories is ignored for all building types. **Rationale**: The data is not readily available to estimate the task lighting portion of LPD allowance.
- The energy savings from automatic daylighting controls in baseline per-unit energy use calculations are ignored since the uptake rate of automatic daylighting controls has been reported to be very low in the existing building stock.

The following simplifications are made in the analysis when calculating 2019 Standards per-unit energy use values:

- LPD allowance for ornamental lighting for applicable area categories is ignored for all building types except for retail. Note that the presented per-unit energy use values for retail do not yet reflect LPD allowance for ornamental lighting. **Rationale**: Ornamental lighting could be a significant portion of lighting load in retail.
- LPD allowance for task lighting for applicable area categories is ignored for all building types. **Rationale**: The data is not readily available to estimate the task lighting portion of LPD allowance.
- The savings from automatic daylighting controls were assessed for only one climate zone (Climate Zone 2 using the Energy Commission's nomenclature). **Rationale**: Modeled savings in Radiance were readily available for the considered scenarios for Climate Zone 2, 6, 12, and 13. The range in savings was approximately 2 percent. As a conservative approach, the most conservative climate zone was selected. Furthermore, the savings from automatic daylighting controls were discounted by 10 percent based on the findings from an LBNL study, reporting that modeled savings tend to overestimate actual savings from automatic daylighting controls by at least 10 percent (A. B. Williams 2012).
- Energy savings due to demand responsive controls are ignored. **Rationale**: Title 24, Part 6 mandates that certain buildings shall be demand response ready, 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 assumed to be incorporated in baseline DEER lighting schedules and are not considered separately like occupant sensing controls or automatic daylighting controls.

2.1.5 Rationale for Selecting DEER Lighting Schedules Over Alternative Calculation Method (ACM) Lighting Schedules Used in CBECC-Com

Lighting schedules available from DEER and CBECC-Com were evaluated to be used as baseline lighting schedules in this analysis. The Statewide CASE Team concluded that DEER lighting schedules are the most suitable for this analysis because:

- DEER provides lighting schedules for each function area (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 & Measurement Verification (EM&V) effort.

Furthermore, the Statewide CASE Team evaluated DEER2014 versus DEER2016 lighting profiles. The Statewide CASE Team concluded that for the purposes of this analysis, DEER2014 profiles are more appropriate than DEER2016 profiles. In a meeting between PG&E and CPUC Staff on 8/29/2014 discussing DEER2014 lighting profiles, CPUC staff stated that:

- The original DEER profiles date back to 1994 California Conservation Inventory Group (CCIG) 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; and
- DEER2014 lighting profiles have not changed since 2005.

Since the meeting, DEER2016 profiles were released. DEER2016 profiles were further updated 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 2004/2005 and 2015 (years when the field monitoring data was gathered). Since the analysis presented in this CASE Report explicitly accounts for reduction in energy use due to occupancy controls and daylighting controls and since 2005 is the earliest code vintage being considered for this analysis, DEER2014 was selected as the source for baseline lighting schedules.

Note that EM&V field monitoring data do not track absence/presence of lighting controls in the monitored buildings. The field data are 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. The contribution of lighting controls in reducing annual hours cannot be extracted from DEER profiles.

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 HVAC related analysis, but also for lighting related analysis. While for HVAC larger zones within a building provide sufficient detail, for lighting more granularity was needed. CPUC responded to this need by adding more area categories for 23 representative commercial buildings types. Some of the new area categories (e.g., corridors/stairwells, restrooms, conference rooms, etc.). are important for this analysis for accounting properly 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.

The table below summarizes the findings about the lighting schedules available through DEER and CBECC-Com.

Table 4: Descriptions of DEER and CBECC-Com lighting schedules

Characteristic	DEER Lighting Schedules	2016 ACM / CBECC-Com Lighting Schedules
Source	• The original DEER profiles date back to 1994 Final Report on Technology Energy Savings Prepared for The California Conservation Inventory Group (CCIG) by Neos Corporation. • DEER profiles are informed by field monitoring EM&V data collected for multiple buildings over many years.	• Lighting schedules currently used in CBECC-Com, referred to as 2016 ACM lighting schedules, are available as a supporting Excel file for 2016 Nonresidential Alternative Calculation Reference Manual (California Energy Commission 2016). • Current ACM lighting schedules were introduced in 2013 Title 24, Part 6 code

	• 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 further updated based on field monitoring data gathered in 2015. For most of building spaces, the annual hours for lighting load were reduced going from DEER2014 to DEER2016 lighting profiles. The Statewide CASE Team attributes the reduction to the higher uptake of lighting controls installed in the monitored buildings between 2004/2005 and 2015 (years when the field monitoring data was gathered).	cycle as part of the migration effort from DOE2.1E to EnergyPlus/CBECC-Com building energy modeling software. • 2013 and 2016 ACM lighting schedules come from 2010 ASHRAE 90.1 User Manual, Section G. • Note that 2010 ASHRAE 90.1 User Manual presents two values for percent of maximum load for some of the hours of a workday. The lower values of 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 2013 and 2016 ACM lighting schedules. • For reference, the higher values of percent of maximum load in lighting schedules in 2010 ASHRAE 90.1 were based on ASHRAE 90.1-1989 schedules, documented in 90.1-1989 ECB Compliance Supplement, Table 7.1C.
Building Types / Function Areas	• DEER2014 and DEER2016 data set describes 23 representative commercial buildings 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 education sector. • For each lighting schedule type (Standard, Break, Summer), 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 schedules for High Bay lighting in addition to lighting schedules for Compact Fluorescent and Linear Fluorescent Lighting. • In total, there are 164 unique 24-hr lighting schedules identified by their unique Profile IDs.	CBECC-Com 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, a small office building prototype uses only “Office” lighting schedule. A large office building prototype uses “Office” and “Assembly” lighting schedules.

2.2 Energy Savings Methodology

The table below summarizes the approach to calculate energy savings for the following scenarios:

- 2019 LPD values updated and the "35/50% wattage reduction" compliance option remaining unchanged (Scenario 1),
- 2019 LPD values updated and the "35/50% wattage reduction" compliance option removed (Scenario 2), and
- Other scenarios are TBD.

Table 5: Step-by-step methodology to calculate energy savings

Step	Key Details and Step Output
Step 1 Calculate **2005-2019 baseline per-unit energy use** for building types of interest (in kWh/sf per year)	• For each building type of interest, estimate per-unit energy use for building's lighting load for four code vintages (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 of an area category from the total building area, LPD is 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 full load equivalent hours is used in this analysis to account for reduction in operating hours as well as in LPDs 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 full load equivalent hours since for periods of time throughout a year the lights are only partially on in the room. • Use area category LPD for 2001, 2005, 2008, 2013, and 2016 Title 24, Part 6 code vintages and use appropriate DEER lighting schedules for annual hours. • Consider these building types: hotel, office small, office large, restaurant, retail large, school, and warehouse. The cumulative square footage for the considered building types equals to 68% of existing building stock. • When accounting for the savings from occupant sensing and daylighting controls in baseline per-unit energy use, discount the savings from controls using an assumed compliance rate. **Output** Baseline per-unit energy use for the building types of interest for four code vintages in kWh/sf per year

Step 2 Calculate **average baseline per-unit energy use (in kWh/sf per year) weighted by** market share of code vintage and by building type stock	• Use the assumed distribution of lighting systems by 2001-2016 Title 24, Part 6 code vintages (2001 – 0%, 2005 – 45%, 2008 – 40%, 2013 – 15%, 2016 – 0%; may be modified based on gathered field data). • To weigh by building type stock, use Energy Commission forecast of building stock by building type in 2020. As a refinement to the analysis, use historical Energy Commission forecast for 2001, 2005, 2008, 2013, and 2016 as weights for 2001, 2005, 2008, 2013, and 2016 baseline per-unit energy use values, respectively. **Output** Single baseline per-unit energy use value in kWh/sf per year
Step 3 Calculate **2019 Standards per-unit energy use** for building types of interest for each compliance option (in kWh/sf per year)	• For each building type of interest, estimate per-unit energy use for building's lighting load, 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 of an area category from the total building area, LPD is 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: $Annual\ FLE\ Hours[hr] = 251\times (\sum_{i=1}^{24} Baseline\ Weekday\ Hour\ Fraction_i\ [hr] \times Hour\ Control\ Factor_i) + 104\times (\sum_{i=1}^{24} Baseline\ Weekend\ Hour\ Fraction_i\ [hr]\times Hour\ Control\ Factor_i) + 10\times (\sum_{i=1}^{24} Baseline\ Holiday\ Hour\ Fraction_i\ [hr] \times Hour\ Control\ Factor_i)$ Where 251 is the number of workdays excluding 10 federal holidays in 2021 (a non-leap year), 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 LPD allowance" option, assume 100% 2019 LPD of area category LPD. For each function area in the considered building types, use appropriate DEER lighting schedule for annual hour profile as baseline lighting schedule. As applicable, modify the baseline weekday lighting schedules using control factor profiles for occupant sensing and automatic daylighting controls. • For the "≤ 85% of 2019 LPD allowance" option, assume 85% of area category 2019 LPD. For each function area in the considered building types,

	use appropriate DEER lighting schedule as baseline lighting schedule. As applicable, modify the baseline lighting schedules using applicable control factor profiles (i.e., occupant sensing controls). • For the "35/50% wattage reduction" option, assume 65% of area category LPD for restaurant, school, warehouse and assume 50% of area category LPD for hotel, office, retail. Use 2001, 2005, 2008, 2013 and 2016 code vintages as existing, "pre-retrofit" area category LPD values. For each area category in the considered building types, use an appropriate DEER lighting schedule for annual hour profile as baseline lighting schedule. As applicable, modify the baseline weekday 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 vintages as weights to calculate single per-unit energy use value for the "35/50% wattage reduction" option for each building type. Note that most likely the energy savings from Option 3 may not be realized on the same timescale compared to Option 1 or Option 2 for a building. Consider this example: if Option 1 or Option 2 is used to retrofit half the luminaires in an open office, to comply with an LPD provision, the area used in the LPD calculation would have to be the total area of the open office. Consequently, when Option 1 or Option 2 is used, it is much more likely that all the luminaires in the open office will be retrofitted to meet LPD provisions. On the other hand, Option 3 provides the flexibility to just retrofit half the luminaires (since LPD calculations are not applicable). That said, eventually, the other half of the luminaires will be due for replacement eventually, so the full savings will be realized at some point under Option 3 as well. **Output** 2019 Standards per-unit energy use values for the building types of interest (three values per each building type corresponding to three compliance options)
Step 4 Calculate **average 2019 Standards per-unit energy use weighted by** building type stock (in kWh/sf per year)	• To weigh 2019 Standards Per-Unit Energy values by building type stock, use Energy Commission forecast of building stock by building type in 2020. **Output** 2019 Standards per-unit energy use values for three compliance options in kWh/sf per year
Step 5 Calculate **expected per-unit energy use for Scenario 1,** 35/50% wattage reduction option remains unchanged (in kWh/sf per year)	• Use market share of regulated alterations (the percentages to be informed by field data gathered from building departments and lighting experts). **Output** Scenario 1 expected per-unit energy use value in kWh/sf per year
Step 6 Calculate **expected per-unit energy use for Scenario 2,** with removed 35/50% wattage reduction option (in kWh/sf per year)	• Use market share of regulated alterations, where the share of the "35/50% wattage reduction" path is 0. **Output** Scenario 2 expected per-unit energy use value in kWh/sf per year
Step 7 Calculate **expected energy savings for Scenario 1** (in kWh/sf per year)	• To calculate expected Energy Savings for Scenario 1, use the following formula: Scenario 1 Energy Savings [kWh/sf per year] = Baseline per-unit energy use (2001-2019) – Scenario 1 per-unit energy use

	Output Scenario 1 Energy Savings in kWh/sf per year
Step 8 Calculate **expected energy savings for Scenario 2** (in kWh/sf per year)	• To calculate Expected Energy Savings for Scenario 2, the following formula was used: Energy Savings [kWh/sf per year] = Baseline per-unit energy use (2001-2019) – Scenario 2 per-unit energy use **Output** Scenario 2 Energy Savings in kWh/sf per year
Step 9 Extrapolate **expected energy savings for Scenario 1 & 2 to statewide level** (in GWh per year)	• Use the rate of alterations by building type to determine the annual percentage of existing building stock that is being altered. The rate of alterations by building type to be informed by field data gathered from building departments and lighting experts. **Output** Scenario 1 & 2 Energy Savings in GWh per year

2.3 Per-Unit Energy Impacts Results

The results for per-unit energy use calculations in kilowatt-hours per square foot per year (kWh/sf per year) for the considered building types are presented in the tables below.

Table 6: Calculated 2019 Standards per-unit energy use values

Building Type	**OPTION 1 85-100% of 2019 LPD allowance** (kWh/sf per year)	**OPTION 2 ≤85% of 2019 LPD allowance** (kWh/sf per year)	**OPTION 3 Weighted 35/50% wattage reduction** (kWh/sf per year)	**Weights by Building Type Stock % of Considered Stock**
Hotel	2.6	2.3	2.1	7%
Office Large	1.7	1.5	1.3	26%
Office Small	1.6	1.5	1.3	7%
Restaurant	2.8	2.6	3.6	4%
Retail	2.7	2.3	2.6	24%
School	2.1	1.9	2.0	11%
Warehouse Non-Refrigerated	0.84	0.98	0.99	21%
Weighted AVERAGE (by Building Type Stock)	**1.89**	**1.74**	**1.75**	**100%**

Table 7: Calculated 2019 Standards per-unit energy use values for option 3, the 35/50% wattage reduction

Building Type	**2001 Title 24, Part 6** (kWh/sf per year)	**2005 Title 24, Part 6** (kWh/sf per year)	**2008 Title 24, Part 6** (kWh/sf per year)	**2013 Title 24, Part 6** (kWh/sf per year)	**2016 Title 24, Part 6** (kWh/sf per year)	**Weights by Building Type Stock % of Considered Stock**

Hotel	2.5	2.1	2.1	2.1	1.9	7%
Office Large	1.5	1.4	1.2	1.1	1.0	26%
Office Small	1.5	1.4	1.2	1.1	1.1	7%
Restaurant	3.7	3.6	3.6	3.6	3.0	4%
Retail	3.2	2.8	2.6	2.0	2.0	24%
School	2.5	2.1	2.0	2.0	1.9	11%
Warehouse Non-Refrigerated	1.0	1.0	0.98	0.96	0.96	21%
Weighted AVERAGE (by Building Type Stock)	**2.06**	**1.85**	**1.72**	**1.54**	**1.49**	**100%**
Weights by Code Vintage	0%	45%	40%	15%	0%	

For comparison, the table below summarizes per-unit energy use values obtained from the previous large-scale studies.

Table 8: Historical per-unit energy use values for comparison

	Per-unit energy use for Indoor Lighting (kWh/sf per year)		
Data Source	2006 03 / Energy Commission / California Commercial End Use Study (CEUS), data gathered 2000-2003	2012 01 / DOE / 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 square feet)	4.46	-	-
Office Small (<30,000 square feet)	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