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BUILDING ENERGY EFFICIENCY MEASURE PROPOSAL TO THE

CALIFORNIA ENERGY COMMISSION

FOR THE 2019 UPDATE TO THE

BUILDING ENERGY EFFICIENCY STANDARDS

NONRESIDENTIAL LIGHTING ALTERATIONS – SIMPLE COMPLIANCE METHODS

Nonresidential Lighting

Prepared by: California Energy Alliance

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EXECUTIVE SUMMARY

Introduction

This proposal presents recommendations to support California Energy Commission (Energy Commission) efforts to update or expand requirements for various technologies and strategies contained in California's Building Energy Efficiency Standards (Energy Standards). The California Energy Alliance (CEA) sponsored this effort. This report and the code change proposal presented herein supports the Energy Commission effort to develop technical and cost-effectiveness information for proposed regulations on energy efficient building design practices and technologies.

Scope of Code Change Proposal

The proposed measure, *Nonresidential Lighting Alterations – Simple Compliance Methods*, will affect the following code documents listed in Table 1.

Table 1: Scope of Code Change Proposal

Standards Requirements (see note below)	Compliance Option	Appendix	Modeling Algorithms	Simulation Engine	Forms
Section 100.1	Ps, Pm	N/A	N/A	N/A	NRCC-LTI-06-E
Section 141.0(b)2.I (M)	Ps, Pm	N/A	N/A	N/A	NRCC-LTI-06-E
Section 141.0(b)2.J (M)	Ps, Pm	N/A	N/A	N/A	NRCC-LTI-06-E

Note: An (M) indicates mandatory requirements, (Ps) Prescriptive, (Pm) Performance.

Measure Description

Within the last 15 years, thousands of labor-hours have been invested across the state to analyze, justify and document recommended updates to the lighting alterations provisions contained in the Energy Standards. The code requirements for lighting alterations have grown from two lines of text in the 2005 Standards to more than two pages of requirements in 2016. Understandably, many stakeholders have expressed frustration with the lengthy and often confusing language now governing the energy performance of lighting alterations in California. The intent of this proposal is to *reframe and simplify* the nonresidential lighting alterations code language to reflect a practical, easy-to-implement set of requirements while helping to transition California's existing building stock toward zero net energy (ZNE) readiness and increasing electricity savings for California ratepayers as compared to current practice.

The proposed measure simplifies the lighting alterations provisions contained in Section 141.0(b)2.I and 141.0(b)2.J of the Energy Standards by eliminating separate requirements for entire luminaire alterations and luminaire component modifications; creating a cost-sensitive

compliance option for small buildings and tenant spaces; and providing a universal compliance threshold and set of exemptions for all regulated alterations.

Nonresidential buildings in which 10 percent or more of the luminaires in an enclosed space are altered would be required to follow one of three methods for determining the extent of the alteration requirements.

Method 1. The first method applies to lighting alterations with a lighting power allowance (LPA) between 80 percent and 100 percent of that allowed under Section 140.6. These alterations would be required to meet the same lighting controls requirements (Section 130.1) as required for new construction. This approach is the same as that utilized under the 2016 Energy Standards except that the threshold for compliance has been lowered from 85 percent to 80 percent to align with changes proposed for Method 2.

Method 2. The second method would require compliance with LPAs for new construction and include installation of certain lighting control devices based on the resulting LPA. The LPA threshold that is used to trigger lighting controls requirements would be changed from 85 percent of the allowed lighting power per Section 140.6 to 80 percent of that allowed. This change is proposed to balance the overall energy impacts of the proposed measures ensuring that sufficient energy savings are achieved as compared to 2016 Energy Standards compliance methods.

Method 3. The third method would be applicable to buildings or tenant spaces 5,000 square feet or smaller. This approach consists of one-for-one luminaire replacements or one-for-one luminaire modifications that utilize replacement/modified luminaires with 40 percent lower rated input power at full output as compared to the luminaires they replace. It is combined with a smaller set of lighting control requirements. The building size criteria and universal 40 percent power reduction requirement represent the proposed changes. These changes are proposed in order to simplify requirements and maintain a cost-sensitive compliance option for small buildings while transitioning the majority of California's building stock considering a retrofit towards alterations that address both lighting power, advanced lighting controls and grid-responsiveness.

In addition to changes related to these compliance methods, the exemption for annual luminaire modifications would be reduced from 70 luminaries per building floor or single-story tenant space to 50 luminaires per building floor or single-story tenant space; and the exemption for alterations involving two or fewer luminaires per enclosed space would be replaced with a single exemption for any space with only one luminaire. These changes eliminate redundant layers of exemptions and continue to ensure that small spaces and spaces in need of a small lighting system change are not encumbered with lighting control requirements intended for larger alteration projects.

This change is a mandatory measure that will impact all regulated lighting alterations. The proposed change does not create new standards or address equipment that was previously unregulated. The proposed change impacts the following code sections:

- Section 100.1 Definitions and Rules of Construction
- Section 141.0(b)2.I Entire Luminaire Alterations
- Section 141.0(b)2.J Luminaire Component Modifications

Market Analysis and Regulatory Impact Assessment

Research shows that nonresidential remodeling and renovation projects occur approximately every six to 12 years depending on the building type. Lighting alterations represent a majority of these projects in California (ADM Associates, 2002). Electrical contractors report that approximately 27 percent of their revenue is generated from modernization/retrofit projects (Renaissance Research, 2016). These statistics show that lighting alterations represent a significant portion of the alterations projects completed in California and provide an excellent opportunity to implement more-efficient design practices and technology in California's existing buildings.

The current ability of the market to supply the measure in response to the possible Standards change is nothing if not robust. No market ramp-up to meet demand associated with the possible Standards change is required. The realities of the existing statutory environments in California and elsewhere, as well as an increasing sophistication of project specifications among ownership groups, has spurred a complementary response from manufacturers throughout the supply chain.

Given the current state of the market, the proposed measures should result in an overall increase in business and employment opportunities. The proposal simplifies the code requirements and thus should increase compliance and the overall number of retrofits. It should also create more work per retrofit by increasing the number of deeper retrofits by tightening exemptions. In addition, the proposal provides ancillary support for the demand response and renewable energy industries by increasing automated demand response capabilities in existing buildings.

Statewide Energy Impacts

CEA estimates the energy savings over the first twelve months of implementation of *Lighting Alterations – Simple Compliance Methods* to be 11 gigawatt-hours (GWh) as compared to current, code-compliant building practices for lighting alterations. CEA estimates the proposed measure will result in 2.1 MW of peak demand reduction. Section 4 discusses the methodology and Section 4.5 shows the results for the per unit energy impact analysis. Appendix F provides a second set of analyses utilizing alternate recommended LPDs issued by the Statewide Utility Codes and Standards team after the draft version of this report was issued. As important, CEA believes that the proposed simplified requirements will increase compliance rates and accelerate the overall rate of lighting alterations in existing buildings, which will more quickly move California towards realization of its energy and environmental savings goals.

Cost-effectiveness

Lighting Alterations – Simple Compliance Methods does not significantly alter the stringency of the existing Energy Standards. The code change proposal is based on simple modifications to the compliance methods currently contained in the Energy Standards. Therefore, measure cost-effectiveness was demonstrated when the original language was adopted.

In particular, a 2011 codes and standards enhancement (CASE) study completed to support changes to the nonresidential lighting alterations provisions being considered for the 2013

Energy Standards demonstrated the cost-effectiveness of two key elements included in the current measure proposal (California Statewide Utility Codes and Standards Team 2011). The study focused on the requirement for a 10 percent compliance threshold for regulated lighting alterations and the requirement to install area and automatic shut-OFF controls. These two elements were both new as compared to the Energy Standards in effect at the time (2008 Energy Standards). The analysis examined the retrofit of large and small office buildings, which did (and still do) represent the majority of lighting alterations completed in California, using multiple strategies (in terms of installed equipment) to achieve compliance.

The study showed that LPD requirements applied to retrofits consisting of 10 percent or more luminaires per enclosed space were cost-effective with a benefit cost ratio ranging from 1.0 to 2.9 depending on the type of luminaire used as part of the alteration. The study also showed that the requirement to add lighting controls was cost-effective in 15 of 16 scenarios examined. The benefit cost ratio across compliance scenarios ranged from 1.21 to 3.55. A summary of 2011 results are presented in Table 2.

Table 2: Cost-effectiveness Summary (2011$)

Strategy	Total Cost per Square Foot	Savings TDV$/Square Foot	Benefit Cost Ratio
Replacement Luminaires/Sources to meet LPD requirements	$1.44 – $4.04	$4.19	1.0-2.9
Occupancy Control in Enclosed Rooms	$0.53-$0.56	$1.90	3.38-3.55
Occupancy Control in Open Areas	$0.25-$0.53	$0.65	1.21-2.76
Occupancy Control – Whole Building	$0.32-$0.66	$1.02	1.55-3.55

Source: CASE Draft Measure – Lighting Retrofits, 2011

The above referenced study followed the Energy Commission's TDV methodology, which presents TDV Energy Costs Savings (present valued energy cost savings) over the 15 year period of analysis. For a detailed description of the Cost-effectiveness Methodology referenced in this report, please see *CASE Draft Measure – Lighting Retrofits* prepared in support of the 2013 California Building Energy Efficiency Standards.

The outcome of the referenced effort resulted in adoption of the same measures under consideration as part of this code change proposal. Accordingly, the 2011 analysis demonstrating cost-effectiveness remains applicable. In addition, the price of lighting technology has substantially decreased since 2011 when the study was issued, and product availability has increased. Therefore, the cost-benefit ratios cited above represent conservative estimates based on 2011-era technology and prices.

Looking at current technology, new wireless solutions are reducing the cost of retrofitting or adding controls in existing buildings. A recent industry survey reports that contractors saw a 16 percent decline in the cost of wireless lighting controls from 2014 to 2017 (CALCTP 2017). Wireless controls also install much more quickly than wired controls in building retrofits since

they do not require the same amount of new wiring. The same survey found, on average, wireless lighting control installation times are approximately 62 percent lower than installation times for wired solutions and that time is only about 20 percent higher than the time necessary to do a lamp and ballast retrofit alone. By 2020, lighting control contractors' estimate that the cost of wireless controls will drop by an additional 28 percent compared to today's prices as more products and new technology become available. As a result, the actual cost-effectiveness of the proposed measures is likely much higher than estimated in 2011 and much higher than assumed when the 2016 code changes were adopted.

Finally, CEA notes that the cost-effectiveness calculations do not take into account the additional savings and benefits that result from the installation of lighting controls that are demand-response capable. As automated demand response requirements expand across the state in order to support grid reliability and an increase in renewable energy capabilities, the ancillary savings and benefits from the installation of demand-response-capable controls will also increase.

Greenhouse Gas and Water Related Impacts

For more a detailed and extensive analysis of the possible environmental impacts from the implementation of the proposed measure, please refer to Section 6.2 of this report.

Greenhouse Gas Impacts

Avoided greenhouse gas (GHG) emissions of the proposed code change for the first year the standards are in effect are estimated at 3,918 metric tons of CO2e. Assumptions used in developing the GHG savings are provided in Section 6.2 of this report. The monetary value of avoided GHG emissions is included in TDV cost factors (TDV $) and is thus included in the Cost-effectiveness Analysis included in this report.

Water Use and Water Quality Impacts

The proposed measure is not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants.

Acceptance Testing

Acceptance testing requirements for the proposed measure will not change as compared to requirements contained in the 2016 Energy Standards. Acceptance test requirements for applicable lighting alterations, as is the case under the current Energy Standards, consist of tests for:

- Automatic Shut-OFF controls
- Automatic Daylighting controls
- Demand Responsive controls
- Institutional tuning controls used to earn a power adjustment factor

Lighting alterations that add lighting controls to control 20 or fewer luminaires are exempt from acceptance test requirements.

1. INTRODUCTION

The overall goal of this report is to propose a code change measure dedicated to simplification of the nonresidential lighting alterations requirements contained in California's Building Energy Efficiency Standards (Energy Standards). The proposal, *Lighting Alterations – Simple Compliance Methods*, contains pertinent information that justifies the code change. The California Energy Alliance (CEA) sponsored this effort, and it supports the California Energy Commission (Energy Commission) in its efforts to develop and promote cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficiency design practices and technologies.

Section 2 of this report provides a description of the measure, how the measure came about, and how the measure helps achieve California's energy efficiency, demand response and zero net energy (ZNE) goals. This section includes enforcement considerations and anticipated effects on compliance rates.

Section 3 presents the market analysis including a review of the current market structure. This section offers an overview of how the proposed standard will impact various stakeholders including builders, building designers, building occupants, equipment retailers (including manufacturers and distributors), energy consultants, and building inspectors. Finally, this section presents estimates of how the proposed change will impact statewide employment.

Section 4 describes the methodology and approach used to estimate energy use, demand, costs, and environmental impacts. Key assumptions used in the analyses can be also found in Section 4.

Results from the energy, demand, costs, and environmental impacts analysis are presented in Section 5. The authors calculated energy, demand, and environmental impacts using three metrics: (1) per unit, (2) statewide impacts during the first year for buildings complying with the 2019 Energy Standards, and (3) the cumulative statewide impacts for all lighting retrofits completed during the 15 year period of analysis. Time Dependent Valuation (TDV) energy impacts, which accounts for the higher value of peak savings, are presented per unit, first year statewide and cumulative statewide.

The report concludes with specific recommendations on Energy Standards language necessary to reflect the change including updates and/or changes to the Appendices, Alternate Calculation Manual (ACM), and Compliance Forms.

2. MEASURE DESCRIPTION

2.1 Measure Overview

Research shows that nonresidential remodeling and renovation projects occur approximately every six to 12 years depending on the building type. Lighting alterations represent a majority of these projects in California (ADM Associates, 2002). Electrical contractors report that approximately 27 percent of their revenue is generated from modernization/retrofit projects (Renaissance Research, 2016). These statistics show that lighting alterations represent a significant portion of the alterations projects completed in California and provide an excellent opportunity to implement more-efficient design practices and technology in California's existing buildings.

Within the last 15 years, because of this opportunity, thousands of labor-hours have been invested across the state to analyze, justify and document recommended updates to the lighting alterations provisions contained in the Energy Standards. This investment has been focused on maximizing the energy savings associated with nonresidential lighting alterations by applying specific regulations to individual building occupancies and space types. The code requirements for nonresidential lighting alterations have grown from two lines of text under the 2005 Standards to more than two pages of requirements in 2016. Understandably, many stakeholders have expressed frustration with the lengthy and often confusing language now governing the energy performance of lighting alterations in California.

In light of these concerns, CEA proposes to *reframe and simplify* the lighting alterations code language to reflect a practical, easy-to-implement set of requirements that significantly reduce the current complexity of lighting alterations requirements contained in the 2016 Energy Standards. In addition, this proposal will increase electricity savings for California ratepayers as compared to current practice, increase the migration of existing buildings toward ZNE readiness, improve understanding of the nonresidential lighting alterations sections within the Energy Standards and lead to a higher overall compliance rate.

CEA's code change proposal has three primary goals:

1. Improve the adoption of energy efficient lighting systems that enable existing buildings to improve their ZNE readiness.
2. Improve overall compliance with the Energy Standards in existing buildings.
3. Exceed energy savings currently expected for California's existing buildings as compared to savings expected for lighting alterations completed in compliance with the 2016 Energy Standards.

To achieve these goals, CEA's proposal includes the following elements:

1. Simplified language with reduced application and/or project-specific requirements.
2. An easy-to-understand, energy savings option for small buildings and tenant spaces.
3. A universal threshold for compliance and universal set of exemptions.

2.2 Measure History

Beginning with the 2013 Energy Standards, certain lighting alterations affecting 10 percent or more of the luminaires in an enclosed space were required to comply with lighting power density (LPD) and lighting controls requirements contained in Section 140.6 and Section 130.1 of the Energy Standards. Lighting alterations with a resulting LPD between 85 percent and 100 percent of that allowed were required to install all mandatory lighting controls per Section 130.1. This included area controls, multilevel controls, automatic shut-OFF controls, automatic daylighting controls and demand responsive controls. For alterations with a resulting LPD of 85 percent or less of that allowed, only area controls, multilevel controls and automatic shut-OFF controls were required. The 2013 Energy Standards also began categorizing lighting alteration projects by project type such as luminaire-modification-in-place and lighting wiring alterations. Each category gained its own set of compliance thresholds, requirements, and exemptions.

The 2016 Energy Standards added a third compliance option based on the input power of existing luminaires, as opposed to Energy Standards allowable LPD. In addition, the 2016 Standards further relaxed lighting control requirements for this compliance method. Project type categories were maintained and definitions changed again: entire luminaire alterations, luminaire component modifications and lighting wiring alterations. The requirements, compliance methods, compliance thresholds and exemptions became further nuanced and additional variations across project categories were added in efforts to maximize energy savings.

The intent of CEA's 2019 proposal is to simplify these requirements by eliminating the distinctions between project types, creating a universal threshold for compliance, eliminating unnecessary/redundant exemptions, and maintaining allowances for small projects and routine maintenance to be completed without the need to pull permits or add lighting controls at extra cost. As stated, the overarching and primary goal of this proposal is to improve adoption of energy efficient lighting systems in existing buildings and improve Energy Standards compliance. CEA believes the benefits of a simplified Standard that increases adoption and compliance is as beneficial, if not more so, than any new niche requirements intended to maximize energy savings.

2.3 Summary of Proposed Changes to Code Documents

2.3.1 Standards Change Summary

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

The proposed changes are a mandatory measure that will impact all regulated lighting alterations. The proposed change does not create new standards or address equipment that was previously unregulated. The proposed change impacts the following code sections:

- Section 100.1 Definitions and Rules of Construction
- Section 141.0(b)2.I Entire Luminaire Alterations
- Section 141.0(b)2.J Luminaire Component Modifications

SECTION 100.1 DEFINITIONS AND RULES OF CONSTRUCTION

The proposed measure includes a new definition for the term "one-for-one" as it pertains to luminaire alterations. A one-for-one luminaire replacement or modification is a type of per-unit alteration that only affects one existing luminaire without the addition of other new luminaires, permanent removal of the existing luminaire, or relocation of the existing luminaire.

SECTION 141 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)2.I: The proposed measure would combine requirements for entire luminaire alterations and luminaire component modifications under this subsection. Under the proposed measure, nonresidential buildings in which 10 percent or more of the luminaires in an enclosed space are altered would be required to follow one of three methods for determining the extent of the applicable alteration requirements. A 10 percent threshold would be universally applied to all types of lighting alterations. This is a change from the 2016 Standards, which allows a 10 percent exemption for alterations consisting of luminaire removal and reinstallation; a two-luminaire exemption per enclosed space for all types of lighting alterations; and a 70-unit exemption per building floor or single-story tenant space for luminaire component modifications. The adoption of a universal compliance threshold simplifies the language and is expected to improve comprehension of and compliance with the Energy Standards.

Compliance Method 1. The first method would apply to lighting alterations with an LPA of more than 80 percent and up to 100 percent of that allowed under Section 140.6. These alterations would be required to meet the same lighting controls requirements required for new construction (Section 130.1). This approach is the same as that utilized under the 2016 Energy Standards except that the threshold for compliance has been lowered from 85 percent to 80 percent to align with changes proposed for Method 2 (described below).

Compliance Method 2. The second method would also require compliance with lighting LPAs for new construction and includes installation of certain lighting control devices based on the resulting LPA. This is the same approach included in the 2016 Standards and has been in place since the 2013 Standards took effect. The maximum allowed LPA under this approach is 80 percent of allowed LPAs, down from 85 percent in 2016. This adjustment creates 8 GWh annually of new electricity savings with no anticipated change to current design practice, compliance enforcement or retrofit costs.

Compliance Method 3. The third method, which is also currently included in the 2016 Energy Standards, would be applicable to buildings or tenant spaces 5,000 square feet or smaller. This approach consists of one-for-one luminaire replacements or one-for-one luminaire modifications that result in new/modified luminaires with 40 percent lower rated input power at full output as compared to the luminaires they replace. It is combined with a smaller set of lighting control requirements. The inclusion of a 5,000 square-foot limit and 40 percent universal input power reduction represents the proposed changes. Under the 2016 Energy Standards, the input power method is allowed for all building types and includes different input power reduction thresholds (35 percent or 50 percent) depending on the building type. The

proposed changes result in 3 GWh annually of new savings, simplifies the language and is expected to improve comprehension of and compliance with the Energy Standards.

In addition, the exemption for annual luminaire modifications would be reduced from 70 luminaries to 50 luminaires per building or tenant space and the exemption for alterations involving two or fewer luminaires per enclosed space would be replaced with an exemption for any space with only one luminaire. These changes are designed to accommodate small projects and repairs, where the inclusion of additional lighting control requirements would not be cost-effective. More information regarding these recommended changes to the exemptions is provided in Section 3.3.4.

Subsection 141.0(b)2.J: The proposed regulations remove this subsection dedicated to luminaire component modifications and inserts relevant portions into Subsection 140.0(b)2.I.

2.3.2 Reference Appendices Change Summary

The proposed code change will not modify the appendices of the Standards.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

The proposed code change will not modify the ACM Reference Manuals.

2.3.4 Compliance Manual Change Summary

The proposed code change will modify Chapter 5 of the Nonresidential Compliance Manual dedicated to nonresidential indoor lighting. The following sections will be affected:

- 5.9.3 Alterations – General Information
- 5.9.3.2 Indoor Lighting Exceptions
- 5.9.4 Lighting Alterations
- 5.9.5 Alterations – Luminaire Component Modifications

2.3.5 Compliance Forms Change Summary

The proposed code change will modify the following compliance forms listed below.

- NRCC-LTI-06-E Indoor Lighting Existing Conditions

This form is used to document existing lighting systems when alteration projects elect to follow Method 3 for compliance. The form lists all existing luminaires slated for retrofit along with their existing power consumption (W) and total reduction required to achieve compliance.

2.4 Regulatory Context

2.4.1 Existing Standards

The proposed measure considers ASHRAE 90.1 – 2016 requirements for lighting alterations. Under ASHRAE 90.1 - 2016, Section 9.1.2, the term “one-for-one” is used to describe certain types of lighting alterations that are exempt from some requirements. That term has been adopted as part of this proposed measure. In addition, under ASHRAE 90.1-2016 Section 9.1.2, the threshold for compliance is applied universally to all types of lighting alterations.

This proposed regulation follows this lead and includes a universal compliance threshold independent of lighting alteration type (ANSI/ASHRAE/IES 2016).

2.4.2 Relationship to Other Energy Standards Requirements

Energy use and savings for the proposed measure incorporates one 2019 code change proposal for new construction, which will also impact the lighting alterations section of the Energy Standards. Proposed 2019 LPA values, which are being addressed by the Statewide Utility Codes and Standards team, have been utilized to estimate required LPAs for lighting alterations following Compliance Method 1 or 2.[1] Two other 2019 proposals for new construction that require partial-OFF occupancy controls in restrooms and automatic daylighting controls plus a Full OFF condition may also be incorporated into the 2019 alterations requirements, however, savings from these measures are not included in this report. CEA wishes to show only the results of its proposal to simplify the language resulting from the following changes:

- Change in LPD threshold for Method 1 and Method 2 from 85 percent of allowed 2019 LPA to 80 percent.
- Change in Method 3 input power reduction requirement from mix of 35/50 percent to a universal value of 40 percent for all building types.
- Application of a building size limit for Method 3: Method allowed only for buildings 5,000 sf or smaller.

2.4.3 Relationship to Federal Laws

Not applicable.

2.4.4 Relationship to Industry Standards

Not applicable.

2.4.5 Relationship to State Energy and Environmental Policy

Senate Bill 350 – Clean Energy and Pollution Reduction Act

The Clean Energy and Pollution Reduction Act (SB 350) establishes a goal of doubling cost-effective energy efficiency savings in electricity and natural gas end uses by 2030 in order to help meet greenhouse gas reduction goals. (Public Resources Code § 25310.) California's energy efficiency and greenhouse gas reduction goals cannot be met solely by increasing efficiency in new buildings. New buildings are a small percentage of the total building stock. There is approximately 8 billion square feet of existing, non-residential space in California. Approximately half of this stock was built prior to the establishment of the Building Energy Efficiency Standards. In order to achieve California's energy efficiency and greenhouse gas reduction goals, the CPUC's 2008 *Long Term Energy Efficiency Strategic Plan* calls for

[1] Estimated LPD values utilized in this report were updated by the Utility Case Team after CEA's analysis and draft report was completed. A second set of analyses using the updated LPD values is provided in Appendix F. 2019 LPD values are subject to change by the Energy Commission.

reducing energy consumption in existing residential buildings by 40 percent by 2020 and for 50 percent of California's existing commercial buildings to be zero net energy by 2030.

Effective implementation of Energy Standards for lighting system alterations represent a particularly critical component to meeting these greenhouse gas reduction and energy efficiency goals. Lighting accounts for a significant portion of a commercial building's electrical use. Accordingly, a primary component to meeting these greenhouse gas reduction and energy efficiency goals is the reduction of lighting loads.

Advanced lighting controls are a critical component to reducing this lighting load because they substantially increase a retrofit's energy savings over just putting in more efficient lamps. In their June 1, 2016 Statewide Lighting Market Transformation Report, the IOUs found that LED replacements without advanced controls leave significant energy savings on the table: "These projects demonstrated that controls can provide an additional 25–50 percent savings over even the more efficient lighting technology, depending on the building and control strategies used." (Pacific Gas and Electric Company (U 39-M), San Diego Gas & Electric Company (U 902-M), and Southern California Edison Company's (U 338-E) Statewide Lighting Market Transformation Report (June 1, 2016), R.13-11-005, at p. 12.)

SB 350 also requires the CPUC and the CEC to increase grid reliability by, among other actions, increasing the use of "demand response, including, but not limited to, automated demand response." (Public Utilities Code §400.)

Senate Bill 350 directs the Commission to increase automated demand response capabilities in buildings to help maintain grid reliability as we transition to a Renewable Portfolio Standard ("RPS") target of 50 percent. Because renewable wind and solar energy sources can be unpredictable, a number of measures will need to be taken to ensure grid reliability when meeting the 50 percent RPS goal, including substantially increasing California's automated demand response capabilities. In order to comply with this mandate, existing building energy efficiency programs should be designed to encourage retrofits that not only reduce direct energy consumption, but also install the type of equipment and controls that can lead to automated demand response capability.

Additionally, it is the policy of the State of California[2] to encourage and promulgate actions to modernize the grid and infrastructure to meet future growth. This includes the use of; control technologies to improve reliability, security, and efficiency of the electric grid, dynamic optimization of grid operations, deployment and integration of cost effective distributed resources, and incorporation of demand response resources. These types of assets are critical to exercise during heat storm events such as those experienced during August 2017.

For lighting, automated demand response capabilities rely on the installation of not just automated demand response controls, but also advanced lighting controls such as multi-level lighting controls and automatic daylighting controls. Without the installation of these advanced lighting controls, there is no way for the automated demand response control to reduce the lighting load demand of a building. Once a lighting system is upgraded, it will generally remain in place for six to 12 years. Accordingly, energy efficiency standards that incentivize lamp upgrades without advanced lighting controls that enable demand response

[2] California Public Utilities Code Section 8360.

capabilities will essentially forestall a building's ability to participate in automated demand response programs and achieve deeper savings for years or even decades.

This proposal supports SB 350's demand response and renewable energy goals by tightening exemptions on demand-response-capable controls (while continuing to allow greater exemptions for small buildings that are not targeted for participation in automated demand response programs). At the same time, decreased equipment costs and technological advances in wireless controls combined with the proposed streamlined and simplified regulatory requirements are expected to increase the willingness of building owners to invest in lighting upgrades that are demand-response capable.

California Long Term Energy Efficiency Strategic Plan

In order to achieve California's energy efficiency and greenhouse gas reduction goals, the CPUC's 2008 *Long Term Energy Efficiency Strategic Plan* calls for reducing energy consumption in existing residential buildings by 40 percent by 2020 and for 50 percent of California's existing commercial buildings to be zero net energy by 2030.

The January 2011 CLTEESP Update sets a goal that "50 percent of existing buildings will be retrofit to zero net energy by 2030 through achievement of deep levels of energy efficiency and with the addition of clean distributed generation." As discussed above, the proposal will help meet these goals by increasing deeper savings in lighting system retrofits.

The 2011 Update also directs that "short-term programs such as the replacement of incandescent light bulbs with compact fluorescent light bulbs must be accompanied by solutions which focus on multi-year and holistic *lighting system strategies*, improved conservation actions, and other means of market transformation."

The 2016 adoption of Compliance Method 3, which relies on input power reductions, conflicts with CLTEESP goals. The compliance method, as written, incentivizes lamp upgrades without advanced lighting controls, which reduce the lighting system's contribution to a building's zero net energy readiness and forestalls the necessary upgrades for years to come.

2015 Integrated Energy Policy Report

The 2015 Integrated Energy Policy Report (IEPR) directs agencies to move away from the traditional "siloed" approach to energy planning in which renewable energy goals are considered separately from energy efficiency, demand response or storage goals" and to move toward a "more integrated approach aimed at GHG reductions …" The IEPR also adopted a vision and goal for demand response capabilities to be "integrated" with energy efficiency and other regulatory goals and efforts. The proposal has been crafted to achieve its goal of simplifying and streamlining lighting retrofit energy efficiency requirements while at the same time creating better integration with California's renewable energy and demand response goals.

2.5 Compliance and Enforcement

Compliance and enforcement processes will not change as compared the processes required under the 2016 Energy Standards. Building inspectors, plans examiners and other inspection officials will be required to verify that regulated projects meet the compliance requirements for the compliance method selected for the project. All proposed compliance methods are currently included in the 2016 Energy Standards. However, because the code language will be

shorter, simpler and universally applied, compliance and enforcement officials should require less time to complete their duties and improve in their ability to identify non-compliant designs and systems.

Officials will be required to verify one new requirement pertaining to Compliance Method 3, which is that the method is only applied to buildings or tenant spaces of 5,000 square feet or less. This verification is expected to add no additional time to the plan check or inspection process.

3. MARKET ANALYSIS

CEA relied on published market analysis, which identifies current technology availability and market trends. CEA considered how the proposed standard may impact the general market and individual market players. CEA gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with key stakeholders, Energy Commission, and a wide range of industry players who were invited to participate in stakeholder meetings held in 2016 and 2017.

3.1 Market Structure

3.2 Technical Feasibility, Market Availability and Current Practices

The current ability of the market to supply the measure in response to the possible Energy Standards change is nothing if not robust. No market ramp-up to meet demand associated with the possible change is required. The realities of the existing statutory environments in California and elsewhere, as well as an increasing sophistication of project specifications among ownership groups, has spurred a complementary response from manufacturers and throughout the supply chain.

3.2.1 Lighting Service

Nearly all commercial buildings in California utilize linear fluorescent lamps. A recent study completed on behalf of the California Public Utilities Commission estimates that 82 percent of all lighting energy use is attributed to linear fluorescent technology (Itron 2014). In offices and retail establishments, which make up more than 50 percent of all lighting retrofits in the state (California Utilities Statewide Codes and Standards Team 2011), this value is much higher. Ninety-two percent of lighting energy use in offices and retailers is attributed to linear fluorescent lighting.

Linear fluorescent lighting products can range in size and power consumption. The most typical product installed in commercial businesses is the linear T8 fluorescent lamp with a nominal lamp power of 32 Watts (W). Lamp lengths typically vary between two and eight feet. Between 90 and 96 percent of T8 lamps are four feet in length depending on the size of the business. Lamp wattage can also vary from 32 W down to low-wattage alternatives at 25 W each. Beyond T8, legacy technology, which includes linear T12 lamps and magnetic ballasts, constitute 4 and 29 percent of the installed based depending on business size. Very small establishments have a higher occurrence of legacy technology as compared to larger establishments. Other alternatives include linear T5 lamps and light-emitting diode (LED) lamps designed to replace fluorescent products. These products constitute less than eight percent and one percent of the installed commercial lighting base per business size, respectively (Itron 2014).

Therefore, considering the majority of installed products are T8 linear fluorescents, a market snapshot of this product category illustrates the majority baseline lighting service in California commercial buildings today. Energy consumption of linear fluorescent lighting is best

estimated by the input power required by the ballast to which the lamps are connected. The ballast serves to regulate the current and voltage to the lamps, and also consumes some power to do this job. A snapshot of average performance created from 48 possible lamp/ballast combinations is provided Appendix B. These products, on average, consume 160 kilowatt-hours (kWh) per year in electricity, assuming 250 hours per year of use. This snapshot is typical and representative of the breadth of linear fluorescent products on the market today.

Lighting retrofits can save energy simply by changing the lamps and/or ballasts to a more efficient technology. In addition, lighting retrofit kits, which replace the lamps, ballasts and optical components, can improve savings as compared to lamp/ballast retrofits alone. Entire luminaire replacements represent another retrofit alternative. A survey of more than 5,000 LED lighting products marketed as replacements for linear fluorescent lamps and/or troffer luminaires, shows that, on average, these products use between 20 and 41 watts. At 2500 operating hours per year, this represents 51 kWh to 103 kWh of annual energy use. When compared to an average linear fluorescent baseline of 160 kWh per year, savings range between 15 and 24 percent.

Table 3: Average performance of LED retrofit lighting products

	Average Performance of Products Surveyed				
LED Project Type	**Power (W)**	**Efficacy (Lu/W)**	**Lumens (Lu)**	**Annual Energy Use (kWh)**	**# of Products Surveyed**
LED Replacement Lamp	20.5	111.1	2268.7	51.3	1604
LED Retrofit Kit	36.7	99.4	3610.3	91.7	521
LED Luminaire (Troffer)	41.1	95.1	3883.9	102.7	3508

Source: Design Lights Consortium, database accessed February 16, 2016.

Considering this level of savings, the proposed change is intended to better align Compliance Method 2 with the range of realistic savings that can be achieved through the LPD component. Past lighting requirements were based on a linear fluorescent baseline, and therefore lighting alterations completed over the next several decades will be performed in buildings consisting of the typical linear fluorescent baseline just described. The reduction of the LPD threshold within Compliance Method 2 will serve to center the anticipated savings within the 15 to 24 percent range.

In addition, the proposed change regarding Compliance Method 3 will more realistically reflect a reasonable level of savings achievable in offices, retail and lodging facilities without creating a detriment to light levels (40 percent reduction instead of 50 percent). Since legacy technology is also more often found in small buildings, adding a building size limit to this method helps ensure that larger buildings, which typically have more efficient technology, are not electing to follow a compliance method that promotes aggressive energy and light level reductions over sound lighting design practice and occupant comfort in the lit environment.

3.2.2 Sample Lighting Designs

The authors modeled a sample of common commercial function areas to demonstrate that general recommended light levels and proposed lighting power densities could be met with commercially available products. Light level recommendations for the modeled function areas

come from the Illuminating Engineering Society, Illumination Engineering Handbook, 12th edition. The authors selected a sample of nine function areas from the 14 used as part of the prototype buildings considered in this report. Results show that designs can achieve LPDs well below 80 percent, which is the threshold recommendation included in the proposed measure. Modeled LPDs ranged between 36 percent and 75 percent of the estimated 2019 LPDs allowed per Section 140.6. Sample layouts utilize a mix of LED and fluorescent lighting technology. More information for each design is provided in Appendix C.

Table 4: Sample Lighting Designs - Illuminance and LPDs

Function Area (Applicable to Considered Building Prototypes)	2019 LPD Allowed per Section 140.6 (estimate)	Recommended Horizontal Illuminance (Ave fc)	Modeled Illuminnace (Ave fc)	Modeled LPD (W/ft2)	Modeled LPD Percent of Allowed LPD per Section 140.6	Modeled Product
Commercial Storage	0.50	5-10	13	0.18	36%	2'x2' LED Surface Mount
Corridors, Restroom, Stair, and Support Areas	0.60	1-10	11	0.24	40%	2'x2' LED Surface Mount
Convention, Conference, Multipurpose and Meeting Center Areas	0.93	30	30	0.61	66%	Circular LED Downlight
Electrical, Mechanical, Telephone Rooms	0.39	10	10	0.28	72%	2' LF Suspended Worklight
Office Area > 250 sf	0.75	7.5-30	30	0.49	65%	2'x4' fluorescent troffer
Office Area ≤ 250 sf	0.85	7.5-30	28	0.49	58%	2'x4' LED troffer retrofit kit
Retail - general sales floor / merchanise	0.80	20-50	52	0.6	75%	1'x4' LED surface mount
Kitchen (hospitality)	1.20	10-50	40	0.74	62%	Enclosed LED Strip
Laundry (hospitality)	0.70	30	28	0.44	63%	LED industrial strip

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

Builders will be empowered to deliver a comprehensive and cost effective solution to the customer while navigating a streamlined regulatory path. Amongst licensed and qualified implementers, constructability and inspection norms are already broadly practiced and incorporated as the "due diligence" of doing business. CEA anticipates no impacts in these areas as a result of the proposed measure.

3.3.2 Impact on Building Designers and Energy Consultants

Under the proposed measure, building designers and energy consultants will have more solid statutory tools to work with when balancing the energy budget of any particular project. There are no other anticipated impacts on building designers or energy consultants as existing compliance methods and requirements are generally maintained as compared to current Standards.

3.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Department of

Occupational Safety and Health (Cal/OSHA). All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

Some secondary impacts related to improved lighting service and ability to maintain minimum light levels for safety and way finding are expected for office buildings, retail and lodging facilities. Currently, when using Compliance Method 3, these building types are expected to achieve at least 50 percent lighting power reduction. This is a significant reduction that cannot be achieved in a majority of cases while also maintaining the intended level of lighting service (light levels). Therefore, the change from a 50 percent to 40 percent power reduction level improves overall lighting service within these types of retrofits.

3.3.4 Impact on Building Owners and Occupants (including homeowners and potential first-time homeowners)

According to the 2012 Commercial Buildings Energy Consumption Survey approximately 50 percent of buildings are 5,000 square feet or less (U.S. EIA 2015). The proposed 5,000 ft^2 exemption addresses the prevalence of small buildings and recognizes the potentially negative energy impacts that a full suite of lighting power allowance and lighting control requirements might have on this sector's decision to proceed with energy-efficient lighting retrofits. In addition, while this proposal seeks to accommodate small building owners by creating an exemption for 50 percent of all buildings, these 5,000 ft^2 or smaller buildings represent only approximately 10 percent of the *total square footage* of California's building stock. This means that small business owners can be accommodated while still leaving a majority of California's floor space available for retrofits that require both efficient lamps and energy-saving lighting controls.

In comparison, the next available CBEC's data point shows that buildings 10,000 ft^2 or less make up 72 percent of all commercial buildings and 20 percent of all floor space. When considering a 5,000 ft^2 exemption as compared to a 10,000 ft^2 exemption, the two smallest building size bins for which there is available data, CEA recommends that the 5,000 ft^2 limit apply because increasing the limit to 10,000 ft^2 will effectively exempt more than 70 percent of all California buildings from the expanded breadth of lighting control requirements.

Additionally, it is the policy of the State of California[3] to encourage and promulgate actions to modernize the grid and infrastructure to meet future growth. This includes the use of; control technologies to improve reliability, security, and efficiency of the electric grid, dynamic optimization of grid operations, deployment and integration of cost effective distributed resources, and incorporation of demand response resources. These types of assets are critical to exercise during heat storm events such as those experienced during August 2017.

A building-size limitation on Method 3 will significantly increase and accelerate the necessary modernization needed for California's existing buildings to become grid-responsive and ZNE ready. Setting the building-size threshold at 5,000 ft^2 for compliance method 3 judiciously targets small business while leaving a significant opportunity for energy savings,

[3] California Public Utilities Code Section 8360

dispatchability, and modernization of larger buildings that represent the vast majority of energy saving opportunities.

This proposal also maintains an annual exemption for small-scale luminaire modification projects regardless of building size. CEA proposes to reduce the limit from 70 to 50 luminaires per building or tenant space per year. Assuming each luminaire serves approximately 50 square feet of building stock, a 50-luminaire limit allows a 5,000 ft^2 business to retrofit up to half its lighting each year without adding any type of new lighting controls (2500 square feet). Maintaining a 70-unit exemption would effectively preclude 70 percent of the small building floor stock from requirements to install even the most basic lighting controls as part of lighting system upgrades. For larger buildings, a 50-luminaire limit still allows for small changes to accommodate changing lighting needs each year.

Last, CEA proposes that the exemption of two or fewer luminaires from lighting alterations requirements be removed and replaced with an exemption for any space with only one luminaire. This change would eliminate the compounding exemptions created for alterations that require installation of multilevel controls under Section 130.1(b). Currently, there is confusion from building owners and contractors with respect to these requirements. Alterations that must comply with Section 130.1(b) are given a 2-luminaire exemption under Section 141.0, which is then contradicted by the 1-luminaire per enclosed space exemption listed under Section 130.1(b). This change would align these requirements under the 1-luminaire per enclosed space rule.

In addition, this change would eliminate the loop-hole that allows private offices to avoid installation of simple occupancy controls during lighting modernization projects as required under Section 130.1(c)5. Many private offices include two ambient/overhead luminaires only, which is a design that was widely deployed to comply with A/B switching and manual daylighting requirements previously contained in the Energy Standards. Previous analyses completed as part of the 2013 Standards update demonstrated that the addition of a wall-switch occupancy sensor in private offices was cost-effective. More information on the cost-effectiveness information is provided in Section 5. The elimination of the 2-luminaire exemption will close the automatic shut-OFF controls loop-hole and provide building owners with additional, cost-effective energy savings in these spaces. For larger enclosed spaces that require maintenance or changes to two or fewer luminaires, the project is already exempt as part of the annual 50-unit exemption and/or 10 percent exemption threshold previously discussed.

No other impacts on building owners and occupants are expected.

3.3.5 Impact on Building Component Retailers (including manufacturers and distributors)

The existing manufacturing and distribution structure provides reliable delivery of light sources, luminaires, and lighting controls solutions to every market in the state. Manufacturers and their regional representative agency partners work directly with the design community to provide, through local distributors, constructible solutions to industry in service of the needs of the end user. While the technology surrounding controls solutions continues to follow the semiconductor innovation curve, there is no special, proprietary, or sole-sourced resource that has yet to be developed or employed to implement solid, proven, and repeatable efficiency

solutions. Therefore, no impact on building component retailers, manufacturers or distributors are expected.

3.3.6 Impact on Building Inspectors

Compliance and enforcement processes will not change as compared the processes required under the 2016 Energy Standards. Building inspectors, plans examiners and other inspection officials will be required to verify that regulated projects meet the compliance requirements for the compliance method selected for the project. All proposed compliance methods are currently included in the 2016 Energy Standards. However, because the code language will be shorter, simpler and universally applied, compliance and enforcement officials should require less time complete their duties and improve in their ability to identify non-compliant designs and systems.

Officials will be required to verify one new requirement pertaining to Compliance Method 3, which is that the method is only applied to buildings or tenant spaces of 5,000 square feet or less. This verification is expected to add no additional time to the plan check or inspection process.

3.3.7 Impact on Statewide Employment

This proposed measures should increase employment. Between simplification of the code and decreasing equipment and installation costs, the overall number of retrofits are expected to increase. In addition, the number of retrofits that include the installation of advanced lighting controls are also expected to increase. The installation of lighting controls along with new lamps takes more work hours than installing lamps alone and thus will create more employment. (See discussion in section 3.4.1).

3.4 Economic Impacts

3.4.1 Creation or Elimination of Jobs

As introduced in Section 3.3.7, CEA anticipates its proposal will increase employment. The overall number of retrofits are expected to increase even more under the current proposal due to simplification of the code and decreasing equipment and installation costs. In addition, the number of retrofits that include the installation of advanced lighting controls (ALC) are also expected to increase. The installation of lighting controls along with new lamps takes more work hours than installing lamps alone and thus will create more employment.

During the consideration of the 2016 Energy Standards code proposals, there was a debate about whether the 2013 lighting control requirements for nonresidential lighting alterations had the unintended effect of reducing the number of retrofit jobs and overall energy savings.

One sector of the lighting efficiency industry claimed that the cost and complexity of compliance with the 2013 Energy Standards lighting control requirements for alterations and modifications had reduced the demand for retrofits. Those complaints, which came largely from contractors who employ nonresidential lighting technicians, were not supported by data when looking at the lighting retrofit industry as a whole. Nonresidential lighting technicians are not licensed to install lighting controls. Accordingly, the 2013 Energy Standard requirements to install lighting controls when retrofitting existing lighting systems inherently

reduced the amount of work available to these technicians. However, at the same time it inherently increased the amount of work available to other sectors of the workforce. The perspective by the nonresidential lighting technicians that lighting control requirements reduced demand for retrofits is thus not a surprise as that was likely the case for work that they performed. However, no studies or evidence supported their claim that the 2013 lighting control requirements for alterations and modifications had reduced the overall demand for lighting retrofits including retrofits that they were not licensed to perform. In addition, no studies or evidence were cited that supported the claim that the 2013 code lighting control requirements resulted in reduced energy savings due to its impact on the demand for lighting retrofits.

To the contrary, in comments submitted on April 24, 2015, PG&E testified that its data showed that the 2013 Energy Standards lighting retrofit requirements had a *positive* impact on retrofit energy savings.[4] PG&E evaluated projects that utilized utility incentives and those that did not. In both cases, it found that the 2013 Energy Standards lighting retrofit requirements "have been successfully implemented in the state to generate real energy savings."[5] The PG&E letter noted that the claimed downturn in lighting retrofit business actually predated the effective date of the 2013 Standards and was due to increasing federal appliance regulation baselines.[6] PG&E found that, rather than further decreasing retrofit business demand, the 2013 lighting alteration requirements have increased the demand *for deeper retrofits*, resulting in substantially increased energy savings.[7]

The concern that the cost and complexity of adding lighting controls to existing buildings were reducing the number of retrofit job hours or overall energy savings was not supported by data. But to the extent those anecdotal concerns had any validity, those concerns are now out of date due to technological advances, declining costs, and the changing marketplace. Past studies have demonstrated that the addition of wired lighting controls both substantially increases energy savings over installing high-efficiency lamps alone and is cost-effective (California Statewide Utility Codes and Standards Team 2011). By 2020, wireless controls will have a substantial share of the market, markedly increasing the cost-effectiveness of adding controls and thus increasing the incentive for building owners to move forward with lighting retrofit work.

These controls will not only increase energy savings, they can also provide automated demand response capabilities and allow integration with California's demand response and renewable energy goals. This ancillary impact will help further increase employment by helping to enable the demand response and renewable energy industries.

Finally, the installation of lighting controls requires skilled workers and thus creates better quality jobs. Statewide employment, especially in California, is as much about the quality of the job as it is the quantity. The inevitable deployment of granular, networked lighting environments creates demand for quality in-State jobs. Training programs exist to support that

[4] PG&E Statewide Codes and Standards Program, PG&E Comments on 15 Day Proposed Changes to Nonresidential Lighting Retrofit Requirements in 2016 Title 24 Standards, Docket # 15-BSTD-01 (April 24, 2015) at pp. 4-5, 10.

[5] *Id*. at p. 10.

[6] *Id*. at p. 4.

[7] *Id*. at pp. 4-5.

demand. Building the network infrastructure necessary to achieve policy goals and support a growth economy requires a skilled pool of readily-available labor

3.4.2 Creation or Elimination of Jobs in California

As discussed above, the proposal should result in an overall increase in business and employment opportunities. The proposal simplifies the code requirements and thus should increase compliance and the overall number of retrofits. It should also create more work per retrofit by increasing the number of deeper retrofits by tightening exemptions and eliminating loopholes. In addition, the proposal provides ancillary support for the demand response and renewable energy industries by increasing automated demand response capabilities in existing buildings. The proposal does not add or eliminate any energy efficiency measure technologies and thus will not eliminate any existing businesses.

3.4.3 Competitive Advantages or Disadvantages for Businesses within California

The proposed regulations do not create a competitive advantage or disadvantage for California businesses.

3.4.4 Increase or Decrease of Investments in the State of California

The proposed regulations do not impact investments in the State of California as compared to existing Standards requirements.

3.4.5 Effects on Innovation in Products, Materials, or Processes

The proposal is expected to accelerate the continued development of lighting control technology, particularly wireless technology. The proposal is expected to continue to drive down overall costs of lighting and lighting control equipment. No other impacts on innovation in products, materials or processes are expected.

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

Cost to the State

The proposed regulations present no new cost impacts to the State. The secondary effects of higher employment of skilled workers include a greater contribution to the California tax base, and a smaller burden on state services and resources.

Cost to Local Governments

The proposed regulations are expected to improve comprehension of the lighting alterations requirements and decrease the time necessary to process and approve building permits. Apart from minimal staff time to learn the breadth of the new regulations, CEA expects the cost to local governments for enforcement to be unchanged or decrease.

Impacts on Specific Persons

CEA anticipates no additional impacts on specific persons.

4. ENERGY IMPACT METHODOLOGY

4.1 Key Assumptions for Energy Impact Analysis

CEA ensured that its proposal produced sufficient energy and peak demand savings as compared to lighting alterations completed under the 2016 Energy Standards assuming updated 2019 LPD values.

Energy and demand impact analysis for alteration projects relies on a several key assumptions related to state of the existing building stock and its installed equipment including:

- The distribution of building types within California, associated building stock and function area sizes for each building type
- Lighting hours of use
- Lighting power density values by function area
- Presence of installed lighting controls and associated savings for each type
- Size of the retrofit market in terms of building stock undergoing retrofit each year
- Energy savings associated with different Energy Standards compliance methods
- Distribution of lighting retrofits following each of the available compliance options

To assess the energy impacts of the proposed measure, CEA relied on a lighting alterations analysis tool created by the Statewide IOU Codes and Standards team (California Statewide Codes and Standards Team 2017). The tool considers each of the key assumptions listed above and assigns a value to each in order to compare current code-compliant design practices to design practices that would comply with the proposed changes. CEA made several modifications to the tool to allow for its use in modeling the energy and demand impacts of the proposed measures. The modified tool is referenced throughout this Section as the Analysis Tool.[8]

Note, the lighting measures evaluated in this measure proposal have energy savings that are only secondarily impacted by climate. Installed wattage and hours of operation have significantly more impact on energy savings than climate. Interaction effects with HVAC are small and are neglected in this analysis. As a result, the cost-effectiveness of this measure is deemed to be independent of climate zone.

In addition to modeling energy and peak demand impacts, CEA created several simple building prototype models using Energy Plus in order to generate the annual per-hour demand necessary for TDV analysis. Energy savings were calculated on an hourly basis using Time Dependent Valuation methodology (Energy Commission 2017). Because the proposed measure is not impacted by climate, this analysis utilizes TDV data for Climate Zone 12 to determine savings. Results are deemed to be representative of the state as a whole.

[8] The Utility CASE team released an updated tool (V1b) after CEA's analysis and report were completed. Per the Utility team, the updated tool contains new recommendations for 2019 LPD values as compared to the version of the tool utilized by CEA for this report. The Utility team stated that the updated LPD values represented the most significant change between version 1a and 1b of its analysis tool. Appendix F contains a second set of analyses based on the updated LPD values. Final 2019 LPD values are not known and recommendations are subject to change by the Energy Commission.

4.2 Baseline Conditions

Lighting alterations are currently regulated under the Energy Standards so the existing conditions represented in the Analysis Tool assume a lighting system that closely complies with the appropriate Energy Standard in place at the time the lighting was installed. The Analysis Tool compares the energy use and savings for several building types, across code vintages and compliance methods.

CEA modified the base tool in four ways so that it could be used to analyze the energy impacts of CEA's proposed measure. First, CEA modified the tool to account for energy savings from multilevel lighting controls required under two of the three allowed alterations compliance methods. Second, CEA created a variable to represent the LPD threshold when utilizing Compliance Method 1 and Method 2 so that the energy savings for alternate LPD thresholds could be examined. The base tool utilizes a fixed threshold value of 85 percent. Third, CEA created an array of variables to represent alternative distribution values for the percent of building stock undergoing an alteration under each of the compliance methods. This last change allowed CEA to examine the energy impacts of limiting Compliance Method 3 for use with buildings of a certain size or type. Lastly, CEA added peak demand analysis and reporting features based on the tool's existing building area lighting schedules. A summary of information contained in the Analysis Tool, including CEA modifications, is provided below.

Additional information on base tool assumptions and the analysis framework may be found in *2019 Title 24 Codes and Standard Enhancement (CASE) Report: Nonresidential Indoor Lighting Alterations - Draft Report* authored by the California Utility Statewide Codes and Standards Team.

4.2.1 Existing Buildings

The Analysis Tool estimates nonresidential energy savings for eight building types. These building types are listed in Table 5. The Analysis Tool addresses 66 percent of California's existing building stock according to the tool's developers. CEA requested the type and distribution of nonresidential buildings from the Energy Commission directly. As of the time of this report, the Energy Commission had not provided the requested information. Therefore, CEA relied on building stock information provided in the Analysis Tool, combined with information from the 2012 Commercial Buildings Energy Consumption Survey (CBECS). CBECS data was used to estimate the distribution of nonresidential buildings by building size. California data on building size could not be identified in publically available literature at the time of this report.

Table 5: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type	Statewide Area (square feet)	Total Annual Area Undergoing Retrofit (sf)
Prototype 1	Office – Small	395,000,000	138,000,000
Prototype 2	Office – Large	1,384,000,000	40,000,000
Prototype 3	Retail – Small	624,000,000	22,000,000
Prototype 4	Retail – Large	624,000,000	62,000,000
Prototype 5	Restaurant – Sit Down	196,000,000	62,000,000
Prototype 6	School	604,000,000	42,000,000
Prototype 7	Warehouse	1,117,000,000	89,000,000
Prototype 8	Lodging	71,000,000	71,000,000

Source: Analysis Tool V1.0a2

The Analysis Tool breaks each prototype building down into function areas based on data contained in the Database for Energy Efficiency Resources (DEER). Each function area is assigned an LPD value per Table 7. The map of function areas to building types utilized by the Analysis Tool is provided below.

Table 6: Function Areas for Modeled Building Types

Area Category	Hotel	Office Large	Office Small	Restaurant	Retail Large	Retail Small	School	Warehouse
Classroom, Lecture							X	
Commercial Storage		X	X	X	X	X	X	X
Corridors, Restroom, Stair, and Support Areas	X	X	X	X	X	X	X	X
Convention, Conference, Multipurpose and Meeting Center Areas		X	X					
Dining Area	X	X	X	X	X	X	X	
Electrical, Mechanical, Telephone Rooms		X	X	X	X	X		
Exercise, Gym							X	
General Commercial Low Bay			X		X			
Library Reading Areas							X	
Lobby Area Hotel	X							
Lobby Area Main Entry		X	X					
Lounge Area	X							
Office Area > 250 sf	X	X	X	X	X	X	X	X
Office Area ≤ 250 sf		X	X					
Retail					X	X		
Kitchen, Food Preparation Areas	X			X			X	
Laundry Area	X							
Waiting Area				X			X	

Source: Analysis Tool V1.0a2

4.2.2 Existing Lighting Systems - System Vintage

The Analysis Tool assumes existing conditions consist of a distribution of code-compliant lighting systems meeting the following code vintages: 2001, 2005, 2008, 2013, and 2016. The distribution of lighting systems among vintages is based on information provided in the California Commercial Saturation Survey Report (CSS Report) (Itron 2014) for the age of linear lighting systems installed in California buildings as of 2012 (Itron 2014, Table 5-2). This report also cites that the age of a portion of the lighting stock is unknown. The Analysis Tool distributes this unknown portion to code vintages based on the relative size of the known portion values. Values from all building types are then averaged to create one value to represent the portion of installed lighting systems attributed to each code cycle. These estimates are then projected forward resulting in a distribution of lighting systems by vintage expected for 2020. Final lighting system vintage distributions used as part of this code change proposal are provided below. Calculations pertaining to the development of these values are provided in Attachment A: T2 Analysis Tool V1.0a2 (T2 Analysis Tool V1a2.xls).

- 2001 24% of systems
- 2005 7%
- 2008 14%
- 2013 21%
- 2016 34%

4.2.3 Existing Buildings – Lighting Power Density

The allowed LPD values for each code vintage, by building area, are provided in Table 7. For 2019 Energy Standards values, CEA utilized estimated values provided in the base tool (V1a). These values represented the best estimate of expected values for 2019 at the time the draft version of this report and analysis was completed. The values were used to determine the energy use and savings attributed to the proposed measure under each of its compliance methods.

Table 7: Function Area LPDs by Code Vintage

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)
Classroom, Lecture	1.6	1.2	1.2	1.2	1.2	0.90
Commercial Storage	0.6	0.6	0.6	0.6	0.6	0.46
Corridors, Restroom, Stair, and Support Areas	0.6	0.6	0.6	0.6	0.6	0.54
Convention, Conference, Multipurpose and Meeting Center Areas	1.5	1.4	1.4	1.4	1.2	0.93
Dining Area	1.1	1.1	1.1	1.1	1.0	0.54
Electrical, Mechanical, Telephone Rooms	0.7	0.7	0.7	0.7	0.55	0.39
Exercise, Gym	1.0	1.0	1.0	1.0	1.0	0.63
General Commercial Low Bay	1.0	1.0	0.9	0.9	0.9	0.61
Library Reading Areas	1.2	1.2	1.2	1.2	1.1	0.77
Lobby Area Hotel	1.7	1.1	1.1	1.1	0.95	0.48
Lobby Area Main Entry	1.5	1.5	1.5	1.5	0.95	0.86
Lounge Area	1.1	1.1	1.1	1.1	0.9	0.44
Office Area > 250 sf	1.3	1.2	0.9	0.75	0.75	0.68
Office Area ≤ 250 sf	1.3	1.2	1.1	1.0	1.0	0.85
Retail	2.0	1.7	1.6	1.2	1.2	0.79
Kitchen, Food Preparation Areas	1.7	1.6	1.6	1.6	1.2	0.92
Laundry Area	0.9	0.9	0.9	0.9	0.7	0.43
Waiting Area	1.1	1.1	1.1	1.1	0.8	0.72
AVERAGE LPD	**1.4**	**1.2**	**1.2**	**1.1**	**1.1**	**0.67**

Source: Analysis Tool V1.0a2

Note, the Utility CASE team released new recommendations for 2019 LPDs after CEA's analysis and proposal was complete. In response, CEA developed a second set of analyses based on the newly proposed LPD values. The second set of analyses is presented in Appendix F. All 2019 LPDs are unknown and recommendations are subject to change by the Energy Commission.

4.2.4 Existing Lighting Systems – Baseline Hourly Load Profiles

Hourly lighting load profiles were developed for each prototype building using information contained in DEER. DEER contains hourly percentage-of-total-use values by building type, building area and lamp type for a weekdays, weekends and holidays. These schedules account for the presence of existing lighting controls, which serve to reduce the value of lighting that is "ON" at any given hour from 100 percent to a lower value.

The base version of the Analysis Tool considers the addition of occupancy and automatic daylighting controls for applicable compliance options. Savings from the use of automated demand response controls are ignored, as are savings from multilevel controls. CEA modified the base tool's lighting profiles to account for multilevel controls requirements contained in the 2013 and 2016 Energy Standards. The assumption for their exclusion within the base version of the Analysis Tool is that multilevel controls are already installed in California buildings and accounted for in the DEER lighting profiles (DEER 2016). However, comprehensive multilevel lighting control requirements did not go into effect until July 1, 2014 and the DEER profiles were updated with the best data available at the time – data on buildings taken prior to May 2013. Therefore, CEA believes an adjustment to account for their use based on code requirements that went into effect after the DEER profile update is justified.

For open office areas in the small and large office building prototypes, CEA reduced the annual hours under Compliance Methods 1 and 2 by 15 percent, which is the value of savings attributed to use of multilevel controls per the California Utility Statewide Codes and Standards Team report prepared to justify their inclusion in the 2013 Energy Standards (California Statewide Codes and Standards Team 2011). The modification was made to open office areas within office buildings only. CEA believes this a conservative method for adjusting the baseline to account for the energy impacts of multilevel controls, and does not assume unsubstantiated savings for building types or building areas that traditionally do not utilize the control strategies enabled by multilevel lighting controls such as manual daylight harvesting, manual dimming, institutional tuning, and scheduled dimming.

4.2.5 Existing Lighting Systems – Peak Demand

CEA added peak demand analysis and reporting features to the base tool. Baseline lighting profiles, as described in Section 4.2.4, are used to reduce the full lighting load (100 percent of LPD) to a level representative of building operating conditions. Each building area within each vintage of building includes an hourly load profile for a weekday, a weekend and a holiday. CEA modified the tool to examine only the load profile for weekdays between 2:00 pm and 5:00 pm, consistent with the DEER definition of peak demand (DEER 2014). The control factors applied in the base version of the tool were constant across these peak hours. Peak demand and peak demand reductions represent the base condition LPD adjusted by the DEER hourly use profile and the peak period control factor applied for a given building vintage, building type and building area. Resulting peak demand values are provided by the Analysis Tool as a per-unit value (W/sf) and a total value statewide for each building type considered (MW). Results for the estimated 2020 baseline of existing buildings is provided in Table 8.

Table 8: Existing Buildings - Peak Demand of Lighting Systems

Building Type	Per Unit Peak Demand (W/sf)	Statewide Peak Demand (MW)
Lodging (excl. rooms)	0.99	70.6
Office Large	0.46	643
Office Small	0.51	201
Restaurant	0.64	126
Retail Large	1.01	631
Retail Small	0.72	449
School	0.34	206
Warehouse (Non-Refrigerated)	0.27	301

Source: Analysis Tool V1.0a2

4.3 Altered Lighting Systems

4.3.1 Use of Proposed Compliance Methods

The proposed conditions are defined as design conditions that will comply with the proposed code change. Specifically, CEA's proposed code change assumes that 51 percent of alteration projects will follow Compliance Method 1, 46.8 percent will follow Method 2, and 2.2 percent will follow Method 3. These assumptions are based on a survey conducted by the Utility CASE team in 2016-2017, which asked respondents to report, based on their experience, the type of compliance approach utilized as part of their lighting alteration projects. Survey results are shown in Table 9 – Column 2 and were taken from the Analysis Tool (California Statewide Utility Codes and Standards Team 2017). Note, a portion of respondents reported that they completed lighting alterations that followed the performance approach to compliance. This percentage was added to Compliance Method 1.

CEA modified these survey values to account for it proposal to limit the use of Compliance Method 3 to buildings of 5,000 square feet or smaller. Per CBECS 2012, approximately 9.2 percent of building stock (50 percent of all buildings) is attributed to buildings of 5,000 square feet or less. CEA assumed that these small buildings were retrofitted under the same distribution of compliance methods as reported in the utility survey. To account for the building size threshold under Method 3, CEA assumed a new compliance rate for this method equal to the product of the survey reported rate and the rate of available building stock attributed to buildings of 5,000 square feet or less (24%*9.2% = 2.2%). The balance of building stock remaining under Method 3 was transferred to Method 2 assuming that those projects that previously chose Method 3 did so because of apparent simplicity and reduced

lighting controls requirements and would thus choose Method 2 as the next simplest option. CEA added an array of variables to the base Analysis Tool to allow for modified compliance method rates. The final values used to represent the portion of lighting alterations following each of the compliance methods is provided Table 9 – Column 3.

Table 9: Distribution of Alteration Projects by Proposed Compliance Method

Compliance Method	Utility Survey	Final - Adjusted
Method 1: 80-100% LPA	51%	51%
Method 2: ≤80% LPA	25%	46.8%
Method 3: Input Power (40% reduction over existing conditions and building size limit)	24%	2.2%

Source: Analysis Tool V1.0a2 and CEA Calculations using 2012 CBECS

4.3.2 Altered Lighting Systems – Lighting Controls

Under each compliance method, certain lighting controls must be installed as part of the alteration. Control requirements vary with each method. A map of required controls to compliance methods is provided Table 10. The variance in lighting controls among the three compliance methods results in different hours of use for each method. To account for these differences, the Analysis Tool utilizes a control weighting factor for each prototype building to reflect the specific set of lighting controls required under each compliance method.

Method 1 requires the same control requirements as new construction. Under compliance Method 2, there are small variances in required controls based on the function area within the building as compared to Method 3. Under Method 2, occupancy controls are required for stairwells, corridors, library book stacks and guestrooms in lodging facilities. Under Method 3, they are not. Also, under Method 1 and 2 a minimum level of multilevel controls are required, while multilevel controls are not required under Method 3.

Table 10: Lighting Control Requirements for Regulated Lighting Alterations

Qualification Criteria	Building Type and Size		Available for use with any size building or tenant space	Available for use with any size building or tenant space	Available for use with buildings or tenant spaces ≤ 5000 ft^2
	Resulting lighting power of enclosed space as compared to lighting power allowance (LPA) provided in Section 140.6(c)2, Area Category Method		80% LPA < Lighting Power ≤ 100% LPA	Lighting Power ≤ 80% LPA	-
	Replacement luminaire rated power at full output as compared to existing luminaires		-	-	At least 40% less
Lighting Control Requirements	Area Controls	Section 130.1(a)1. A through B	Required	Required	Required
		Section 130.1(a)2. A through B	Required	Required	Required
		Section 130.1(a)3.A	Required	Required	Required
		Section 130.1(a)4. A through C	Not required	Not required	Not required
	Multilevel Controls	Section 130.1(b)	Required	At least one control step between 30 and 70% of full power	Not required
	Shut-OFF Controls	Section 130.1(c) 1. A through D	Required	Required	A through C only
		Section 130.1(c) 2.	Required	Required	Required
		Section 130.1(c) 3. A through B	Required	Required	Required
		Section 130.1(c) 4.	Required	Required	Required
		Section 130.1(c) 5.	Required	Required	Required
		Section 130.1(c) 6. A through C	Required	Required	A only
		Section 130.1(c) 7. A through B	Required	Required	B only
		Section 130.1(c) 8.	Required	Required	Not required
	Automatic Daylighting Controls	Section 130.1(d)	Required	Not required	Not required
	Demand Responsive Controls - only for alterations that change the area or occupancy type of the enclosed space along with redesign of the lighting system.	Section 130.1(e)	Required	Not required	Not required

Source: CEA

4.3.3 Altered Lighting Systems – Hourly Load Profiles

The base tool applies a control factor to account for occupancy and automatic daylighting controls. A control factor for each of these two control types is applied to the lighting load profile used for Method 1, while only one control factor to account for occupancy controls is applied to Method 2 and Method 3. As previously stated, to account for the use of multilevel controls in large office buildings, CEA applied an additional control factor of 0.85. Modified load profiles for weekday, weekend, and holiday were then applied to each building type assuming 104 weekend days, 10 holidays and 251 working days per year. The final annual hours of use for each building type and its function areas is provided in Appendix D.

4.3.4 Altered Lighting Systems – Peak Demand

CEA added peak demand analysis and reporting features to the base tool. Baseline lighting profiles, as described in Section 4.2.4, are used to reduce the full lighting load (100 percent of LPD) to a level representative of building operating conditions. Each building area within each vintage of building includes an hourly load profile for a weekday, a weekend and a holiday.

CEA modified the tool to examine only the load profile for weekdays between 2:00 pm and 5:00 pm, consistent with the DEER definition of peak demand (DEER 2014). The control factors applied in the base version of the tool were constant across these peak hours. Peak demand and peak demand reductions represent the base condition LPD adjusted by the DEER hourly use profile and the peak period control factor applied for a given building vintage, building type, building area and 2019 alterations compliance method. Results were then weighted by the percent of alterations following each compliance approach. Resulting peak demand values are provided in the Analysis Tool as a per-unit value (W/sf) and a total value statewide for the percentage of each building type undergoing renovation (MW). First year peak demand energy impacts are provided in Section 4.5.

4.4 Altered Lighting Systems – Parametric Simulations

The proposed measure is focused on creating a simplified standard without a detriment to anticipated energy savings expected from the current Energy Standards. CEA completed 30 energy models varying lighting power reduction and building size threshold assumptions using the Analysis tool in order to determine the savings associated with each permutation. CEA considered the impacts of the following elements:

1. LPD Threshold – Method 2: Current code is 85 percent of allowed under 140.6 (modeling runs considered 85 percent, 80 percent, and 75 percent).
2. Input Power Reduction - Method 3: Current code is a mix of 35 percent and 50 percent reduction as compared to existing conditions (modeling runs considered existing 35/50 percent split, 35 percent reduction for all building types, 40 percent for all, 45 percent for all and 50 percent for all).
3. Application of a building size limit for Method 3: Current code allows this option for all buildings (modeling runs consider with and without a limit on this method so that it is only available for buildings 5,000 sf or smaller).

Results yielded an average savings of 1.6 percent and median savings of 2.2 percent. Based on these results, CEA elected to propose the combination of measures that best supported and balanced its primary goals of Energy Standards simplification, migration to ZNE readiness and energy savings. The selected combination of measures is:

- Method 1 and 2: LPD threshold of 80 percent
- Method 3: Universal input power reduction of 40 percent
- Method 3: Building size qualification criteria of 5,000 sf.

The proposed measures produce 3.3 percent savings as compared to an alteration complying with the expected 2019 non-CEA measures only (no change in compliance thresholds or building size limits). Results are of all 30 modeling runs are provided in Appendix E[9].

[9] A second set of analyses were completed based on alternative LPDs recommended by the Utility CASE team after CEA's initial analysis and report. Results are provided in Appendix F. Final 2019 LPDs are unknown and recommended values are subject to change by the Energy Commission.

4.5 Per Unit Energy Impacts

Per unit energy and demand impacts of the proposed measures as compared to lighting alterations completed under the 2016 Energy Standards requirements are presented in Table 11. Savings are based on estimated 2019 LPD values. Savings are the result of the following items:

- Change in LPD threshold for Method 1 and Method 2 from 85 percent of allowed 2019 LPA to 80 percent.
- Change in Method 3 input power reduction requirement from mix of 35/50 percent to a universal value of 40 percent for all building types.
- Application of a building or tenant space size limit for Method 3 of 5,000 sf

Savings resulting from the addition of partial-OFF occupancy control requirements for Method 1 and Method 2 are not included. Savings resulting from the addition of automatic daylighting plus full OFF controls for Method 1 are not included. CEA assumed that these savings are reported in the separate code change proposal, *2019 Title 24 Codes and Standard Enhancement (CASE) Report: Nonresidential Indoor Lighting Alterations - Draft Report* prepared by the Statewide Utility Codes and Standards Team.

Average statewide per unit savings for the first year are expected to be 0.02 kilowatt-hours per year per square foot (kWh/yr-sf). Average statewide demand savings are negligible. The first year per unit TDV energy savings are 0.03 TDVkBTU per square foot. Savings by building type are shown in Table 11.

Table 11: First Year Energy Impacts per Square Foot

	Electricity Savings (kWh/yr-sf)	Peak Electricity Demand Savings (kW/sf)	TDV Energy Savings (TDVkBTU/sf-yr)
State Average	0.02	0.00	0.03
Lodging	0.06	0.00	0.09
Office - Large	(0.01)	(0.01)	(0.02)
Office – Small	(0.01)	0.00	(0.02)
Restaurant	0.18	0.02	0.30
Retail – Large	0.05	0.01	0.09
Retail – Small	0.04	0.01	0.06
School	0.04	0.01	Not modeled for TDV
Warehouse	0.02	0.00	0.03

A comparison of the proposed measure to the anticipated 2020 existing building baseline is provided in Table 12. This information provides a broader view of future energy savings for lighting alterations as a whole in California under the proposed measure; however this information should not be considered savings attributed to this code change proposal alone. It contains savings estimates for alterations completed under the current alteration requirements contained in the 2016 Energy Standards plus updates to reflect CEA's proposed changes. It is provided for reference only.

Table 12: First Year Energy Use Impacts per Square Foot as Compared to Existing Building Baseline

	Per Unit Electricity Use – Existing Buildings (kWh/yr-sf)	Per Unit Electricity Use – After Retrofit (kWh/yr-sf)	Electricity Savings (kWh/yr-sf)
State Average	1.93	1.12	0.81
Lodging	3.82	2.09	1.73
Office - Large	1.66	1.09	0.57
Office – Small	1.43	0.88	0.55
Restaurant	3.51	1.92	1.59
Retail – Large	3.61	2.0	1.61
Retail – Small	2.76	1.55	1.21
School	1.22	0.75	0.47
Warehouse	1.01	0.65	0.36

5. LIFE CYCLE COST AND COST-EFFECTIVENESS

5.1 Energy Cost Savings Methodology

Lighting Alterations – Simple Compliance Methods does not significantly alter the stringency of the existing Energy Standards. The code change proposal is based on simple modifications to the compliance methods currently contained in the Energy Standards. Therefore, measure cost-effectiveness was demonstrated when the original language was adopted.

In particular, as part of the rulemaking process for the 2013 update to the Energy Standards, significant analysis was completed to justify a reduction in the threshold used to trigger compliance for lighting alterations (California Statewide Utility Codes and Standards Team 2011). Under the 2008 Standards, an alteration affecting 50 percent or more of the lighting in an enclosed space triggered compliance with the Energy Standards. Proposals were developed to demonstrate that this threshold could be lowered to 10 percent and that lighting controls consistent with the new construction provisions could be required. The threshold applied to all types of lighting alterations including luminaire removal and reinstallation, the addition of luminaires and luminaire modifications. The proposal was vetted through a public stakeholder process, approved and implemented as part of the 2013 Standards, which became effective on July 1, 2014.

5.2 Energy Cost Savings Results

The intent of this code change proposal is to simplify the existing lighting alterations requirements contained in the 2016 Energy Standards. CEA balanced the effects of its proposed measures against the estimated energy use, energy savings and costs of lighting retrofits completed under the 2016 Energy Standards to ensure its proposal did not result in negative impacts. Savings beyond current Energy Standards estimates are a secondary benefit. Overall measure cost-effectiveness was demonstrated when the current language was adopted as part of the 2013 Energy Standards. The resulting energy cost savings of CEA's rebalancing effort only are presented below.

CEA estimates that the first year TDV energy cost savings statewide is $1.44 million for building types considered. This translates to approximately 15,878,000 TDVkBTU. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. For the purposes of this analysis, peak is assumed to occur between 2:00 pm and 5:00 pm, June to September. The lighting power reductions resulting under each compliance method are largely constant across the days of the year and they are not climate dependent. The following TDV information is provided for reference, however a full Life Cycle Cost analysis was not performed as the measures composing CEA's proposed change were determined to be cost-effective under the 2013 rulemaking process.

Table 13: TDV Energy Cost Savings Over 15 Year Period of Analysis – Per Square Foot

Building Type	15 Year TDV Electricity Cost Savings per sf (2020 PV $)
Lodging	$0.12
Office - Large	($0.03)
Office – Small	($0.02)
Restaurant	$0.40
Retail – Large	$0.12
Retail – Small	$0.09
Warehouse	$0.04

5.3 Lifecycle Cost-Effectiveness

This measure proposes a change in mandatory requirements, however no change in stringency is proposed as compared to the 2013 Energy Standards requirements. In addition, CEA ensured that energy savings under its proposed measure exceeded that expected for the 2016 Energy Standards. For the present proposal, cost-effectiveness was demonstrated as part of the rulemaking process for the 2013 Energy Standards and that analysis is summarized here for reference. In addition, a discussion on the expected future cost of technology and installation is provided.

5.3.1 Review of Published Analysis

A 2011 codes and standards enhancement (CASE) study completed to support changes to the nonresidential lighting provisions being considered for the 2013 Energy Standards demonstrated the cost-effectiveness of two key elements included in the current measure proposal. The study focused on the requirement for a 10 percent compliance threshold for regulated lighting alterations and the requirement to install area and automatic shut-OFF controls. These two elements were both new as compared to the Energy Standards in effect at the time (2008 Energy Standards). The analysis examined the retrofit of large and small office buildings, which did (and still do) represent the majority of lighting alterations completed in California, using multiple strategies (in terms of installed equipment) to achieve compliance.

The study showed that LPD requirements applied to retrofits consisting of 10 percent or more luminaires per enclosed space were cost-effective with a benefit cost ratio ranging from 1.0 to 2.9 depending on the type of luminaire used as part of the alteration. The study also showed that the requirement to add lighting controls was cost-effective in 15 of 16 scenarios examined. The benefit cost ratio across compliance scenarios ranged from 1.21 to 3.55.

The outcome of that effort resulted in adoption of the lighting alterations language composing the same measures under consideration as part of this code change proposal. A summary of 2011 results are presented in Table 14.

Table 14: Cost-effectiveness Summary (2011$)

	Total Cost per Square Foot	Savings TDV$/Square Foot	Benefit Cost Ratio
Replacement Luminaires/Sources to meet LPD requirements	$1.44 – $4.04	$4.19	1.0-2.9
Occupancy Control in Enclosed Rooms	$0.53-$0.56	$1.90	3.38-3.55
Occupancy Control in Open Areas	$0.25-$0.53	$0.65	1.21-2.76
Occupancy Control – Whole Building	$0.32-$0.66	$1.02	1.55-3.55

Source: CASE Draft Measure – Lighting Retrofits, 2011

The above referenced study followed the Energy Commission's TDV methodology, which presents TDV Energy Costs Savings (present valued energy cost savings) over the 15 year period of analysis. These methods utilize The Total Incremental Cost, which represents the incremental initial construction and maintenance costs of the proposed measure relative to existing conditions (current minimally compliant construction practice when there are existing Title 24 Standards). Costs incurred in the future (such as periodic maintenance costs or replacement costs) were discounted by a three percent real discount rate, per Energy Commission's LCC Methodology. The Benefit to Cost (B/C) Ratio is the incremental TDV Energy Costs Savings divided by the Total Incremental Costs. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective. For a detailed description of the Cost-effectiveness Methodology referenced in this report, please see *CASE Draft Measure – Lighting Retrofits* prepared in support of the 2013 California Building Energy Efficiency Standards.

Referenced literature on cost-effectiveness is based on these guidelines. It is assumed that Energy Commission guidance dictated which costs were included in the analysis including incremental first cost and incremental maintenance costs over the 15 year period of analysis. The TDV energy cost savings from electricity savings were also considered. Design costs were not included nor was the incremental cost of code compliance verification.

5.3.2 Life Cycle Costs Looking Ahead

The price of lighting technology has decreased since 2011 when the study was issued, and product availability has increased. Therefore, it is likely that the cost-benefit ratios by the time the 2019 Code is effective in 2020 will be much higher than the conservative estimates based on 2011-era technology and prices. Product costs have dropped significantly and are expected to continue dropping. At the same time new wireless technology will further reduce the cost of retrofitting controls in existing buildings compared to what was assumed in the above analysis based on 2011-era technology and prices.

Wireless controls install much more quickly than wired controls in building retrofits since they do not require the same amount of new wiring. A CALCTP survey of California lighting contractors, conducted in April, 2017, found that on average, wireless ALC installation times are 62 percent lower than installation times for wired ALC. The same April, 2017 survey of California lighting contractors found that the time required to install wireless ALCs in an existing 10,000 square foot office (in addition to installing new lamps and ballasts), takes only an additional 17 percent of the time needed to perform a lamp and ballast replacement. That major saving in installation hours is driving greater and greater demand for wireless controls (CALCTP 2017).

The CALCTP survey also reported that contractors saw a 15.6 percent decline in the cost of wireless ALC controls from 2014 to 2017. By the time the 2019 Code is effective in 2020, lighting control contractors estimate that the cost of wireless controls should will drop by an additional 28 percent compared to today's prices as more products and new technology become available.

While code cycle intervals seem short at only about three years, that is a long time in terms of advancing technology. The progress of wireless controls is a compelling example of how this dynamic is having a substantive impact on the lighting efficiency market. As technology advances and prices decline, cost-effectiveness rises. This in turn allows exemptions to lighting control requirements in existing buildings to become tightened and streamlined.

In summary, the following factors are increasing and will continue to increase the cost-effectiveness of ALC requirements:

- More wireless controls
- Shorter installation times
- Lower prices for equipment and installation

As a result of these factors, ALCs are more cost effective than they were in 2014, and will be even more cost effective by 2020 (when the 2019 code is implemented). These factors support the proposal to simplify and reduce the confusing array of exemptions to lighting control requirements.

Finally, CEA notes that the cost-effectiveness calculations do not take into account the additional savings and benefits that result from the installation of lighting controls that are demand-response-capable. As automated demand response requirements expand across the state in order to support the grid reliability and an increase in renewable energy capabilities, the ancillary savings and benefits from the installation of demand-response-capable controls will also increase.

6. FIRST YEAR STATEWIDE IMPACTS

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

First year statewide savings represent the savings attributed to CEA's proposal that exceed savings currently associated with the lighting alterations portion of the 2016 Energy Standards. Savings are based on estimated 2019 LPD values. Savings are the result of the following items:

- Change in LPD threshold for Method 1 and Method 2 from 85 percent of allowed 2019 LPA to 80 percent
- Change in Method 3 input power reduction requirements from mix of 35/50 percent to a universal 40 percent reduction requirement for all building types.
- Application of a building size limit for Method 3 of 5,000 square feet

Two pending code change proposals authored by the Statewide Utility Codes and Standards team are not included in the reported savings impacts. Savings resulting from the addition of partial-OFF occupancy control requirements in restrooms for Method 1 and Method 2 are not included. Savings resulting from the addition of automatic daylighting plus full OFF controls for Method 1 are not included (Statewide Utility Codes and Standards Team 2017).

To determine the first year statewide savings, CEA multiplying the per unit savings, which are presented in Section 4.5, by the 2020 forecast of statewide building stock expected to undergo retrofit. The first year energy impacts represent the first year annual savings from all applicable lighting alterations completed in 2020. The lifecycle energy cost savings represents the energy cost savings over the entire 15-year period of analysis. Results are presented in Table 15.

Given data regarding the rate of lighting alterations completed as well as the rate of new commercial construction forecast for 2020, CEA estimates that the proposed code change will reduce annual statewide electricity use by 11 GWh with an associated demand reduction of 2.1 MW. Secondary energy impacts associated with changes in heating and cooling loads resulting from reduced lighting loads are not considered in this analysis. Therefore results are not provided by climate zone.

Table 15: Statewide Energy, Peak Demand and TDV Impacts

Building Type	Statewide Construction in 2020 (million sf)	First Year[1] Electricity Savings (GWh)	First Year[1] Peak Electrical Demand Reduction (MW)	Lifecycle[2] Present Value Energy Cost Savings (PV$ million)
Lodging	395,000,000	0.4	0.02	$882,000
Office - Large	1,384,000,000	-1.7	-0.52	($3,950,000)
Office – Small	624,000,000	-0.4	-0.17	($906,000)
Restaurant	624,000,000	3.9	0.65	8,690,000
Retail – Large	196,000,000	3.2	0.80	7,360,000
Retail – Small	604,000,000	2.3	0.42	5,340,000
School	1,117,000,000	1.7	0.43	Not modeled for TDV
Warehouse	71,000,000	1.7	0.43	3,770,000
TOTAL		**11.1**	**2.1**	**21,186,000**

1. First year savings from all buildings completed statewide in 2020.
2. Energy cost savings from all buildings completed statewide in 2020 accrued during 15-year period of analysis.

6.2 Statewide Greenhouse Gas Emissions Reductions

CEA calculated avoided greenhouse gas (GHG) emissions assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard (RPS) goal of 33 percent renewable electricity generation by 2020. [10] Table 16 presents the estimated first year avoided GHG emissions of the proposed code change. During the first year, greenhouse gas emissions of 3918 metric tons of carbon dioxide equivalents ($MTCO_2e$) are expected.

[10] When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

Table 16: First Year[1] Statewide Greenhouse Gas Emissions Impacts

Electricity Savings (GWH/yr)	Reduced GHG Emissions from Electricity Savings (MT CO_2e)	Natural Gas Savings (Million Therm/yr)	Reduced GHG Emissions form Natural Gas Savings (MMT CO_2e)	Total Reduced CO2e Emissions[2] (MT CO_2e)
11.1	3918	0	0	**3918**

1. First year savings from all buildings completed statewide in 2020.
2. Assumes the following emission factors: 353 MTCO2e/GWh and 5,303 MTCO2e/Million Therms.

6.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.4 Statewide Material Impacts

The proposed code change will not result in material impacts.

6.5 Other Non-Energy Impacts

The proposed code change will not result in any additional non-energy impacts.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards – Strike Through

Proposed change to Section 100.1, adding definition for:

One-for-One: A one-for-one luminaire replacement or modification is a type of per-unit alteration that only affects one existing luminaire without the addition of other new luminaires, permanent removal of the existing luminaire, or relocation of the existing luminaire.

Proposed change to Section 141.0(b)2I:

I. **Altered Lighting Systems. ~~Entire Luminaire Alterations~~.**
~~Entire~~ Indoor ~~L~~luminaire alterations that affect 10 percent or more of the luminaires in an enclosed space 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) modifying existing luminaires; or (c~~b~~) replacing or adding entire luminaires; or (~~c~~ d) adding, removing, or replacing walls or ceilings along with any redesign of the lighting system, shall ~~meet~~
   a. Result in an enclosed space with ~~the~~ a lighting power allowance ~~in~~ that complies with Section 140.6;
   b. ~~and~~ Meet the ~~altered luminaires shall meet~~ the applicable requirements in Table 141.0-E for altered luminaires; ~~or~~
   c. Not disable or prevent the use of other lighting controls installed in the enclosed space;

   OR

ii. For one-for-one luminaire replacements or one-for-one luminaire modifications completed in buildings or tenant spaces 5,000 square feet or smaller in size, ~~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~~ new/modified luminaires ~~in each office, retail, and hotel occupancy~~ shall
   a. have at least ~~50~~ 40 percent~~, and in all other occupancies at least 35 percent,~~ lower rated power at full light output as compared to the ~~existing~~ luminaires being replaced;

b. ~~and shall~~ meet the applicable requirements in Table 141.0-E; ~~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.~~

c. Not prevent or disable the use of other lighting controls installed in the enclosed space;

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.~~ Any enclosed space with only one luminaire.

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.

EXCEPTION 5 to Section 141.0(b)2I. Lamp replacements alone or ballast/driver replacements alone.

EXCEPTION 6 to Section 141.0(b)2I. 50 or less luminaire modifications per year per building floor or single-story tenant space.

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.~~

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 50-70 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 LIGHTING CONTROL REQUIREMENTS FOR LIGHTING ALTERATIONS

Qualification Criteria	Building Type and Size		Available for use with any size building or tenant space	Available for use with any size building or tenant space	Available for use with buildings or tenant spaces ≤ 5000 ft^2
	Resulting lighting power of enclosed space as compared to lighting power allowance (LPA) provided in Section 140.6(c)2, Area Category Method		80% LPA < Lighting Power ≤ 100% LPA	Lighting Power ≤ 80% LPA	-
	Replacement luminaire rated power at full output as compared to existing luminaires		-	-	At least 40% less
Lighting Control Requirements	Area Controls	Section 130.1(a)1. A through B	Required	Required	Required
		Section 130.1(a)2. A through B	Required	Required	Required
		Section 130.1(a)3.A	Required	Required	Required
		Section 130.1(a)4. A through C	Not required	Not required	Not required
	Multilevel Controls	Section 130.1(b)	Required	At least one control step between 30 and 70% of full power	Not required
	Shut-OFF Controls	Section 130.1(c) 1. A through D	Required	Required	A through C only
		Section 130.1(c) 2.	Required	Required	Required
		Section 130.1(c) 3. A through B	Required	Required	Required
		Section 130.1(c) 4.	Required	Required	Required
		Section 130.1(c) 5.	Required	Required	Required
		Section 130.1(c) 6. A through C	Required	Required	A only
		Section 130.1(c) 7. A through B	Required	Required	B only
		Section 130.1(c) 8.	Required	Required	Not required
	Automatic Daylighting Controls	Section 130.1(d)	Required	Not required	Not required
	Demand Responsive Controls - only for alterations that change the area or occupancy type of the enclosed space along with redesign of the lighting system.	Section 130.1(e)	Required	Not required	Not required

7.2 Standards – Clean

Proposed change to Section 100.1, adding definition for:

One-for-One: A one-for-one luminaire replacement or modification is a type of per-unit alteration that only affects one existing luminaire without the addition of other new luminaires, permanent removal of the existing luminaire, or relocation of the existing luminaire.

Proposed change to Section 141.0(b)2I:

I. Altered Lighting Systems. Indoor luminaire alterations that affect 10 percent or more of the luminaires in an enclosed space shall meet the following requirements:

i. For each enclosed space, alterations that consist of (a) removing and reinstalling existing luminaires; or (b) modifying existing luminaires; or (b) replacing or adding entire luminaires; or (d) adding, removing, or replacing walls or ceilings along with any redesign of the lighting system, shall
   a. Result in an enclosed space with a lighting power allowance that complies with Section 140.6;
   b. Meet the applicable requirements in Table 141.0-E for altered luminaires;
   c. Not disable or prevent the use of other lighting controls installed in the enclosed space;

OR

ii. For one-for-one luminaire replacements completed in buildings or tenant spaces 5,000 square feet or smaller in size, new luminaires shall
   a. Have at least 40 percent lower rated power at full light output as compared to the luminaires being replaced;
   b. Meet the applicable requirements in Table 141.0-E;
   c. Not disable or prevent the use of other lighting controls installed in the enclosed space;

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. 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.

EXCEPTION 5 to Section 141.0(b)2I. Lamp replacements alone or ballast/driver replacements alone.

EXCEPTION 6 to Section 141.0(b)2I. 50 or less luminaire modifications per year per building floor or single-story tenant space.

TABLE 141.0-E LIGHTING CONTROL REQUIREMENTS FOR LIGHTING ALTERATIONS

Qualification Criteria	Building Type and Size		Available for use with any size building or tenant space	Available for use with any size building or tenant space	Available for use with buildings or tenant spaces ≤ 5000 ft^2
	Resulting lighting power of enclosed space as compared to lighting power allowance (LPA) provided in Section 140.6(c)2, Area Category Method		80% LPA < Lighting Power ≤ 100% LPA	Lighting Power ≤ 80% LPA	-
	Replacement luminaire rated power at full output as compared to existing luminaires		-	-	At least 40% less
Lighting Control Requirements	Area Controls	Section 130.1(a)1. A through B	Required	Required	Required
		Section 130.1(a)2. A through B	Required	Required	Required
		Section 130.1(a)3.A	Required	Required	Required
		Section 130.1(a)4. A through C	Not required	Not required	Not required
	Multilevel Controls	Section 130.1(b)	Required	At least one control step between 30 and 70% of full power	Not required
	Shut-OFF Controls	Section 130.1(c) 1. A through D	Required	Required	A through C only
		Section 130.1(c) 2.	Required	Required	Required
		Section 130.1(c) 3. A through B	Required	Required	Required
		Section 130.1(c) 4.	Required	Required	Required
		Section 130.1(c) 5.	Required	Required	Required
		Section 130.1(c) 6. A through C	Required	Required	A only
		Section 130.1(c) 7. A through B	Required	Required	B only
		Section 130.1(c) 8.	Required	Required	Not required
	Automatic Daylighting Controls	Section 130.1(d)	Required	Not required	Not required
	Demand Responsive Controls - only for alterations that change the area or occupancy type of the enclosed space along with redesign of the lighting system.	Section 130.1(e)	Required	Not required	Not required

7.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

7.4 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

7.5 Compliance Manuals

Chapter 5 of the Nonresidential Compliance Manual will require revision. This chapter addresses nonresidential indoor lighting including alterations. Changes will be required to update the applicable definitions, compliance thresholds and exemptions.

7.6 Compliance Forms

Forms NRCC-LTI-06-E Indoor Lighting Existing Conditions will require revision. This form is used to document existing luminaires slated for a lighting alteration including their input power when using Compliance Method 3. Input power reduction values stated on this form will require revision.

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APPENDICES

Appendix A: Environmental Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

The avoided GHG emissions were calculated assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. The authors calculated air quality impacts associated with the electricity savings from the proposed measure using emission factors that indicate emissions per GWh of electricity generated.[11] When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios. The authors used data from CARB's analysis to inform the air quality analysis presented in this report.

The GHG emissions factor is a projection for 2020 assuming the state will meet the 33 percent RPS goal. CARB calculated the emissions for two scenarios: (1) a high load scenario in which load continues at the same rate; and (2) a low load rate that assumes the state will successfully implement energy efficiency strategies outlined in the AB32 scoping plan thereby reducing overall electricity load in the state.

To be conservative, the authors calculated the emissions factors of the incremental electricity between the low and high load scenarios. These emission factors are intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario. The incremental emissions were calculated by dividing the difference between California emissions in the high and low generation forecasts by the difference between total electricity generated in those two scenarios. While emission rates may change over time, 2020 was considered a representative year for this measure.

Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

Water Use and Water Quality Impacts Methodology

The proposed measure results in no water use or water quality impacts.

[11] California power plants are subject to a GHG cap and trade program and linked offset programs until 2020 and potentially beyond.

Appendix B: Fluorescent Lighting Snapshot

System Type	Lamp Type	Ballast Factor	# of lamps	Lamp Power	Input Power (W)	Annual Energy Use (kWh)
HIGH-EFFICIENCY	F32T8	0.77	1	32	25	6.25
	F32TS(ES)	0.77	1	28	22	5.5
	F32TS(ES)	0.77	1	25	21	5.25
	F32T8	0.87	1	32	28	7
	F32TS(ES)	0.87	1	28	25	6.25
	F32TS(ES)	0.87	1	25	23	5.75
	F32T8	1.17	1	32	37	9.25
	F32TS(ES)	1.18	1	28	32	8
	F32TS(ES)	1.17	1	25	31	7.75
	F32T8	0.77	2	32	48	12
	F32TS(ES)	0.77	2	28	42	10.5
	F32TS(ES)	0.77	2	25	38	9.5
	F32T8	0.87	2	32	55	13.75
	F32TS(ES)	0.87	2	28	47	11.75
	F32TS(ES)	0.87	2	25	44	11
	F32T8	1.17	2	32	74	18.5
	F32TS(ES)	1.18	2	28	65	16.25
	F32TS(ES)	1.17	2	25	60	15
	F32T8	0.77	3	32	73	18.25
	F32TS(ES)	0.77	3	28	64	16
	F32TS(ES)	0.77	3	25	58	14.5
	F32T8	0.87	3	32	82	20.5
	F32TS(ES)	0.87	3	28	72	18
	F32TS(ES)	0.87	3	25	65	16.25
	F32T8	1.17	3	32	110	27.5
	F32TS(ES)	1.18	3	28	95	23.75
	F32TS(ES)	1.17	3	25	89	22.25
	F32T8	0.77	4	32	96	24
	F32TS(ES)	0.77	4	28	84	21
	F32TS(ES)	0.77	4	25	77	19.25
	F32T8	0.87	4	32	109	27.25
	F32TS(ES)	0.87	4	28	96	24
	F32TS(ES)	0.87	4	25	87	21.75
	F32T8	1.17	4	32	147	36.75
	F32TS(ES)	1.18	4	28	127	31.75
	F32TS(ES)	1.17	4	25	115	28.75
STANDARD EFFICIENCY	F32T8	0.91	1	32	29	7.25
	F32TS(ES)	0.91	1	28	25	6.25
	F32TS(ES)	0.91	1	25	23	5.75
	F32T8	0.89	2	32	56	14
	F32TS(ES)	0.89	2	28	48	12
	F32TS(ES)	0.92	2	25	45	11.25
	F32T8	0.91	3	32	87	21.75
	F32TS(ES)	0.9	3	28	77	19.25
	F32TS(ES)	0.94	3	25	71	17.75
	F32T8	0.9	4	32	112	28
	F32TS(ES)	0.89	4	28	100	25
	F32TS(ES)	0.9	4	25	91	22.75

Source: Philips Lighting 2016

Appendix C: Sample Lighting Designs

The following sample lighting designs were completed to demonstrate the viability of designing retrofits with a resulting LPD of 80 percent or less of that expected to be allowed under Section 140.6 (2019). Each design utilizes fluorescent or LED solutions available today from major lighting manufacturers. Design criteria are based on recommendations provided by the Illuminating Engineering Society in the Illumination Engineering Handbook, 12th edition. Models vary in terms of selected lighting products, ceiling types, and ceiling heights, in order to demonstrate that today's products can be used to meet recommended light levels at LPDs sufficiently below those expected under the 2019 Energy Standards. In all designs, a light loss factor of 0.7 is assumed to demonstrate system performance at the end of the products useful life (assumes standard LED product life – rated life ends when product's light output has diminished to 70 percent of initial output). A summary of modeled results is provided below along with a summary of the designs including lighting layout.

Function Area (Applicable to Considered Building Prototypes)	2019 LPD Allowed per Section 140.6 (estimate)	Recommended Horizontal Illuminance (Ave fc)	Modeled Illuminnace (Ave fc)	Modeled LPD (W/ft2)	Modeled LPD Percent of Allowed LPD per Section 140.6	Modeled Product
Commercial Storage	0.50	5-10	13	0.18	36%	2'x2' LED Surface Mount
Corridors, Restroom, Stair, and Support Areas	0.60	1-10	11	0.24	40%	2'x2' LED Surface Mount
Convention, Conference, Multipurpose and Meeting Center Areas	0.93	30	30	0.61	66%	Circular LED Downlight
Electrical, Mechanical, Telephone Rooms	0.39	10	10	0.28	72%	2' LF Suspended Worklight
Office Area > 250 sf	0.75	7.5-30	30	0.49	65%	2'x4' fluorescent troffer
Office Area ≤ 250 sf	0.85	7.5-30	29	0.6	71%	2'x4' LED troffer retrofit kit
Retail - general sales floor / merchanise	0.80	20-50	52	0	0%	1'x4' LED surface mount
Kitchen (hospitality)	1.20	10-50	40	0.74	62%	Enclosed LED Strip
Laundry (hospitality)	0.70	30	27	0.54	77%	Enclosed LED strip

Table 17: Commercial Storage Rooms

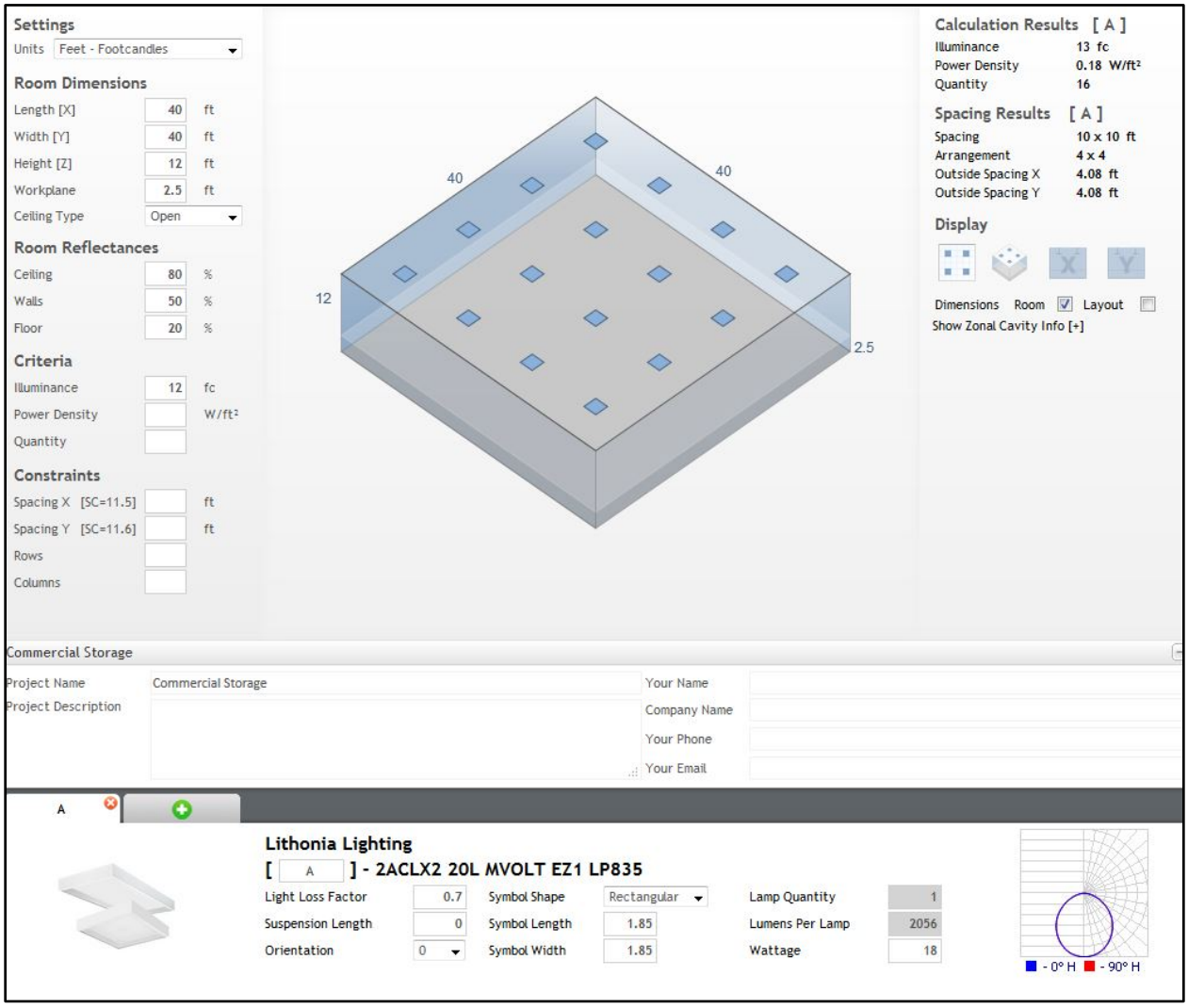


Table 18: Restroom, Corridors, Stairs and Support Areas

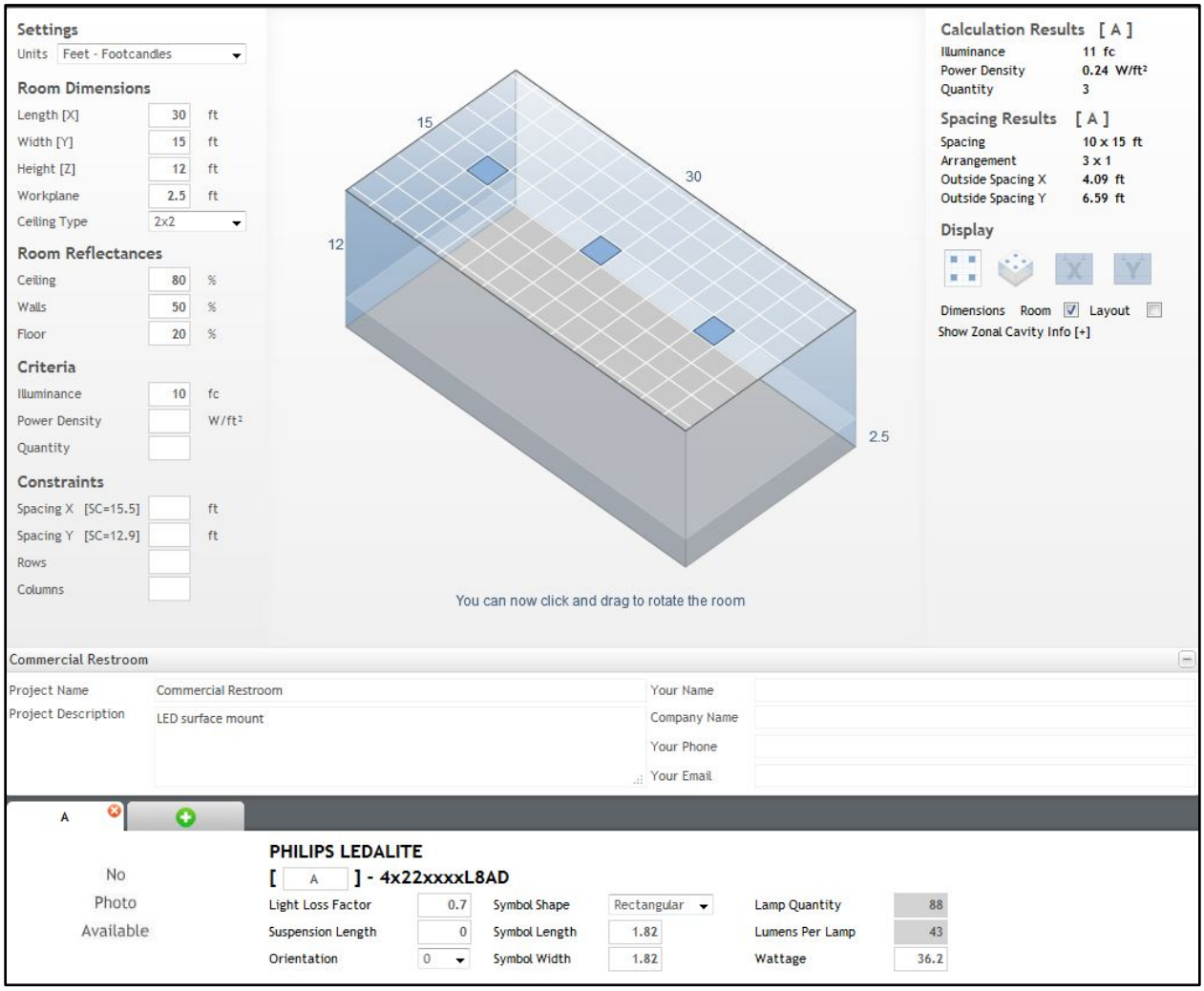


Table 19: Convention, Conference, Multipurpose and Meeting Center Areas

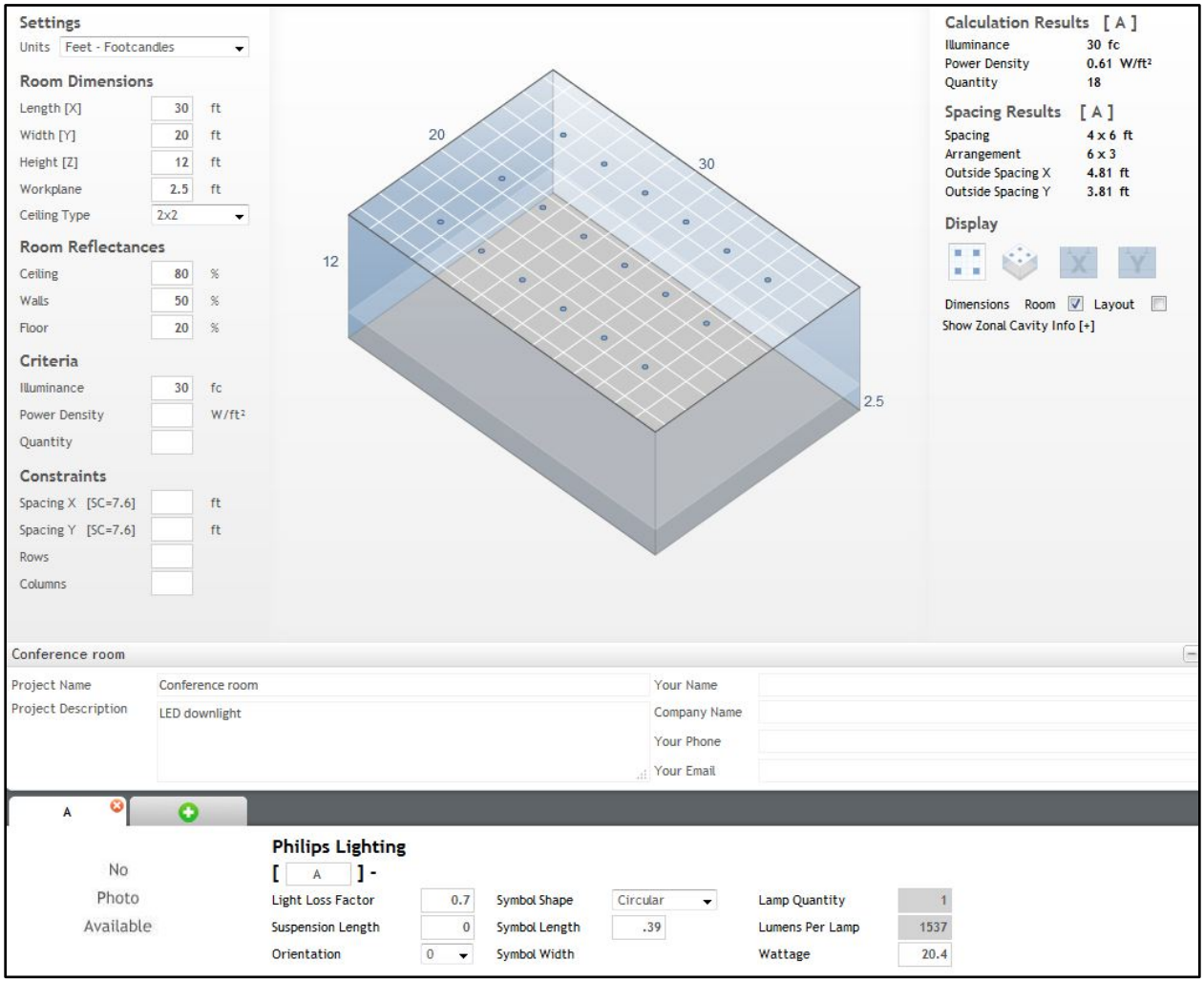


Table 20: Mechanical, Electrical, Utility and Telephone Rooms

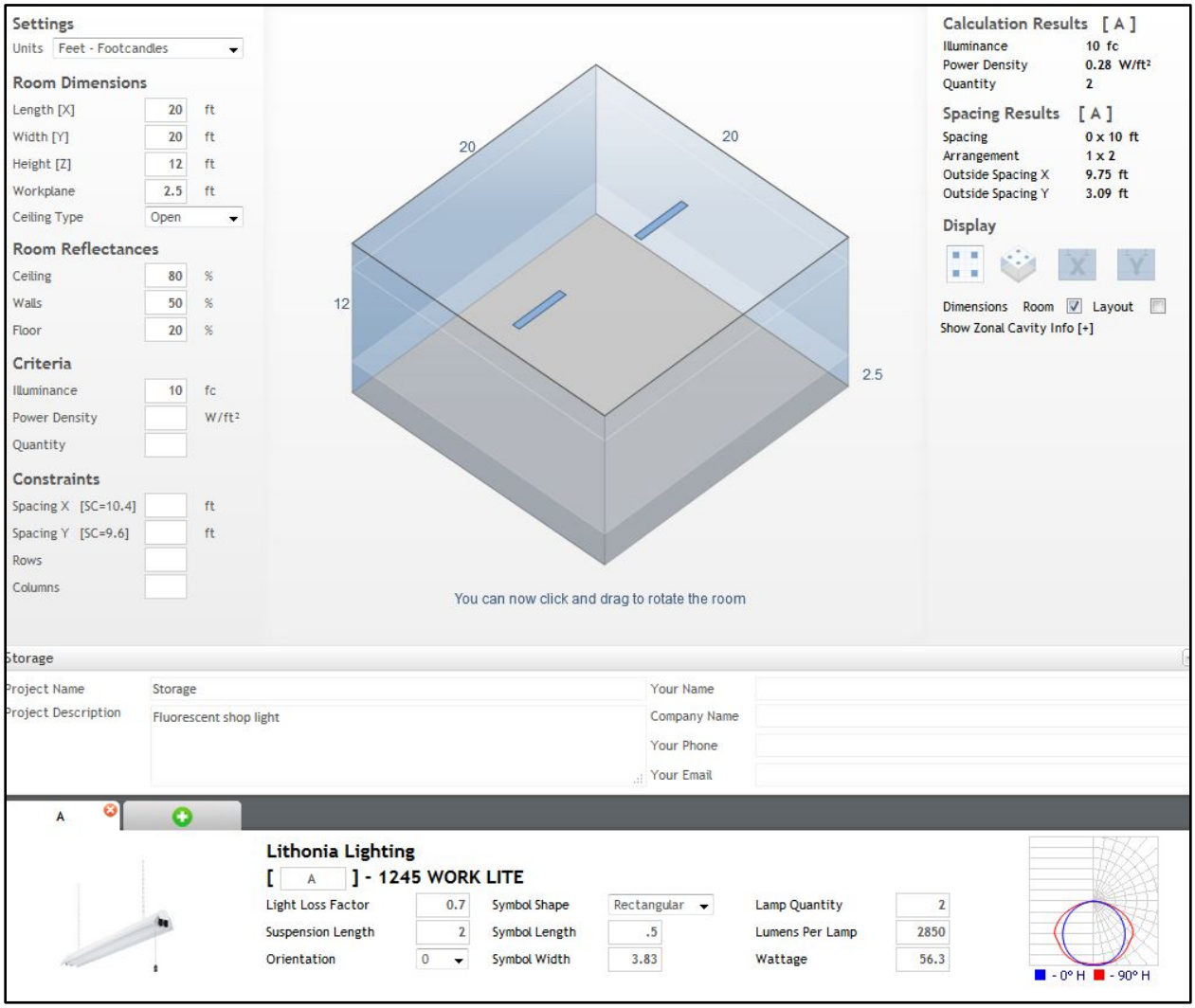


Table 21: Open Offices > 250 square feet

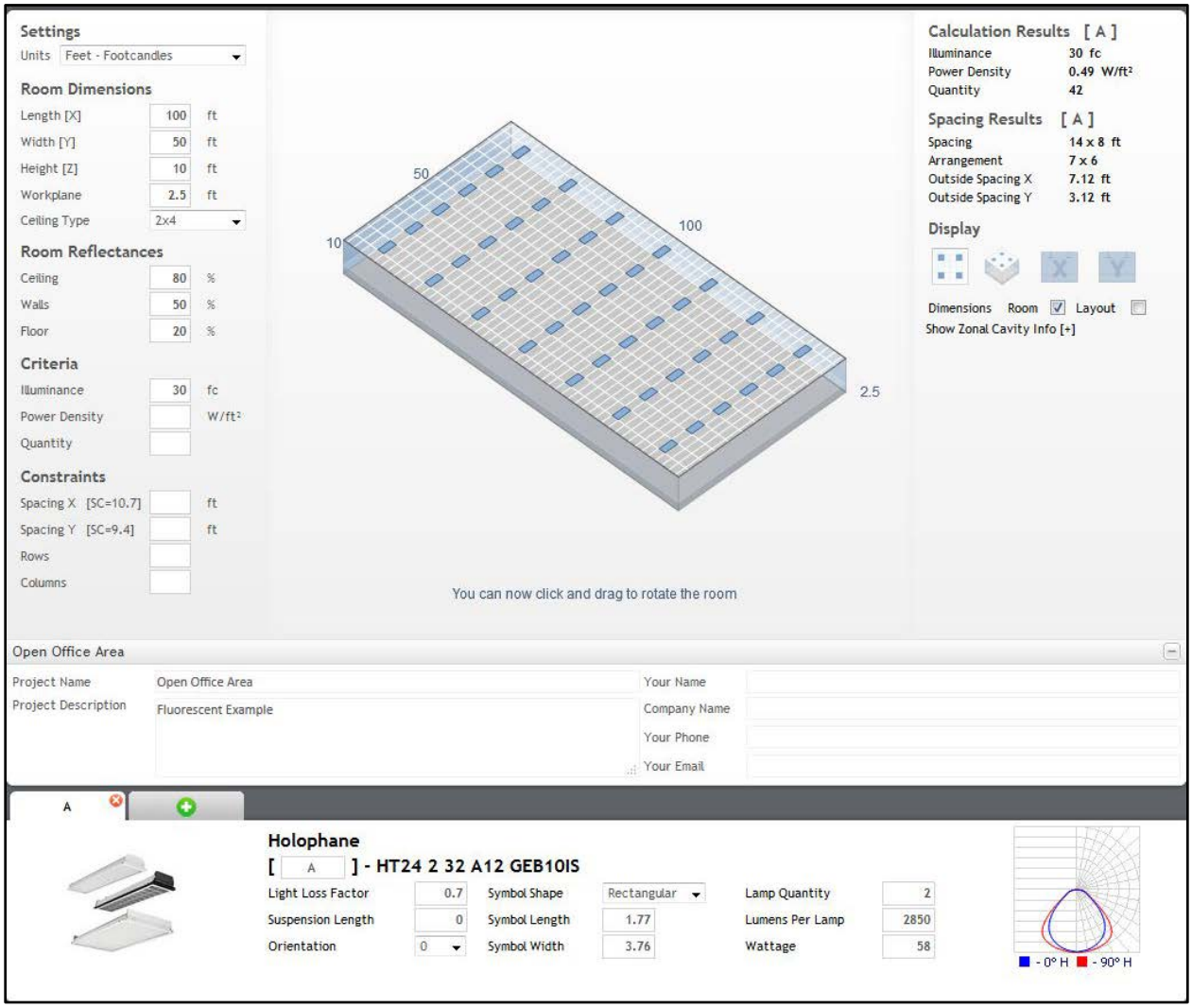


Table 22: Private Offices - 250 square feet or smaller

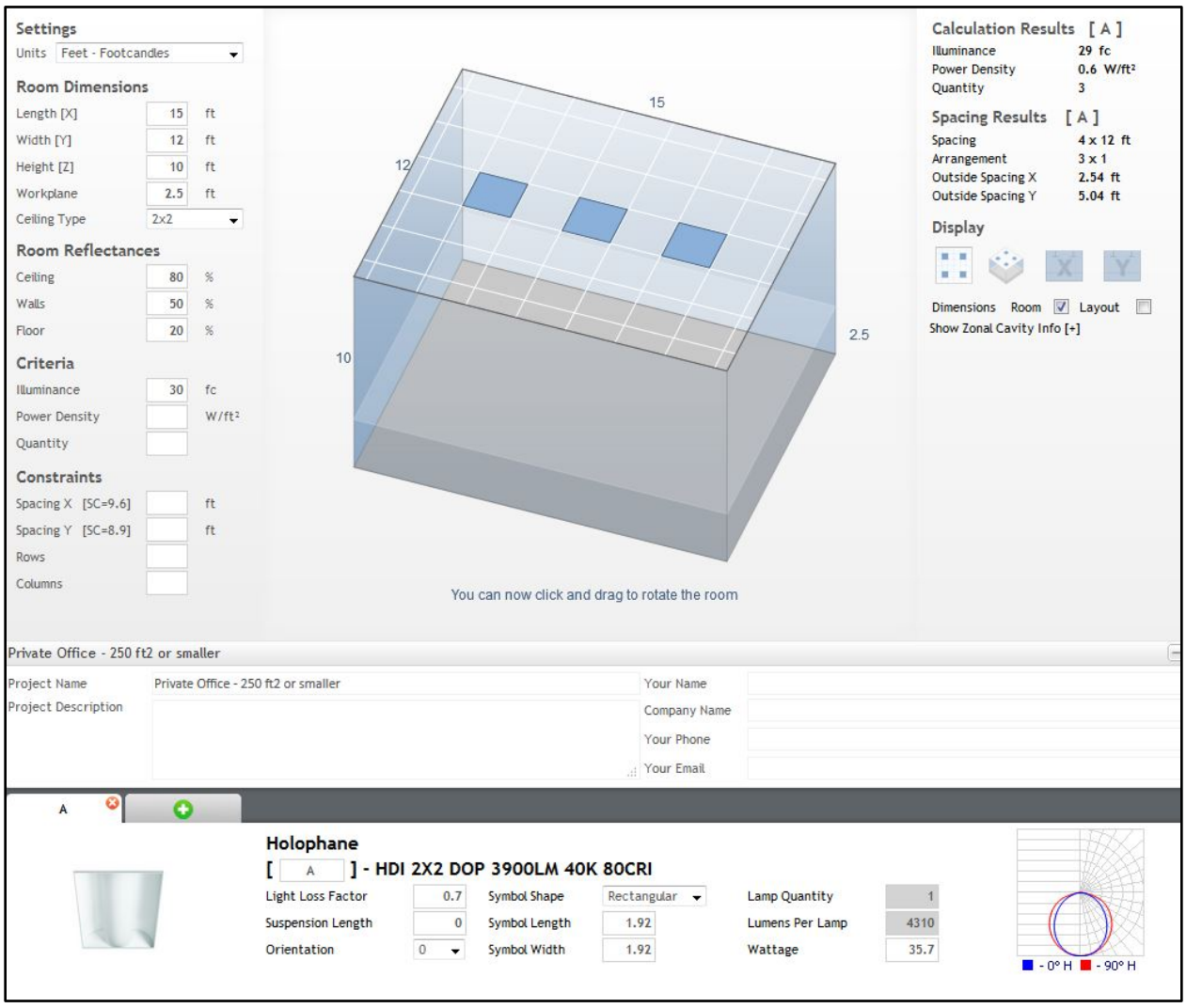


Table 23: Retail

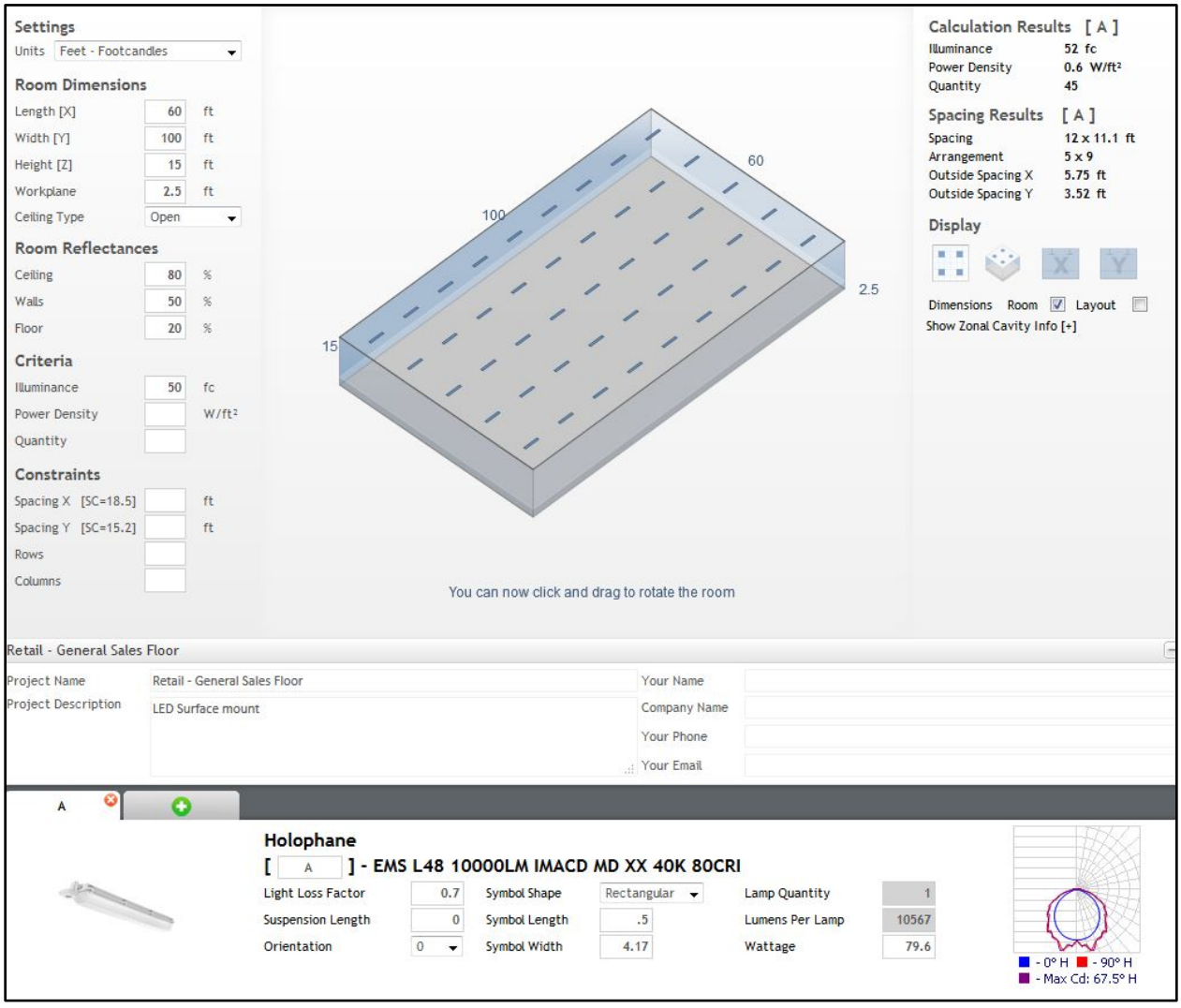


Table 24: Commercial Kitchen

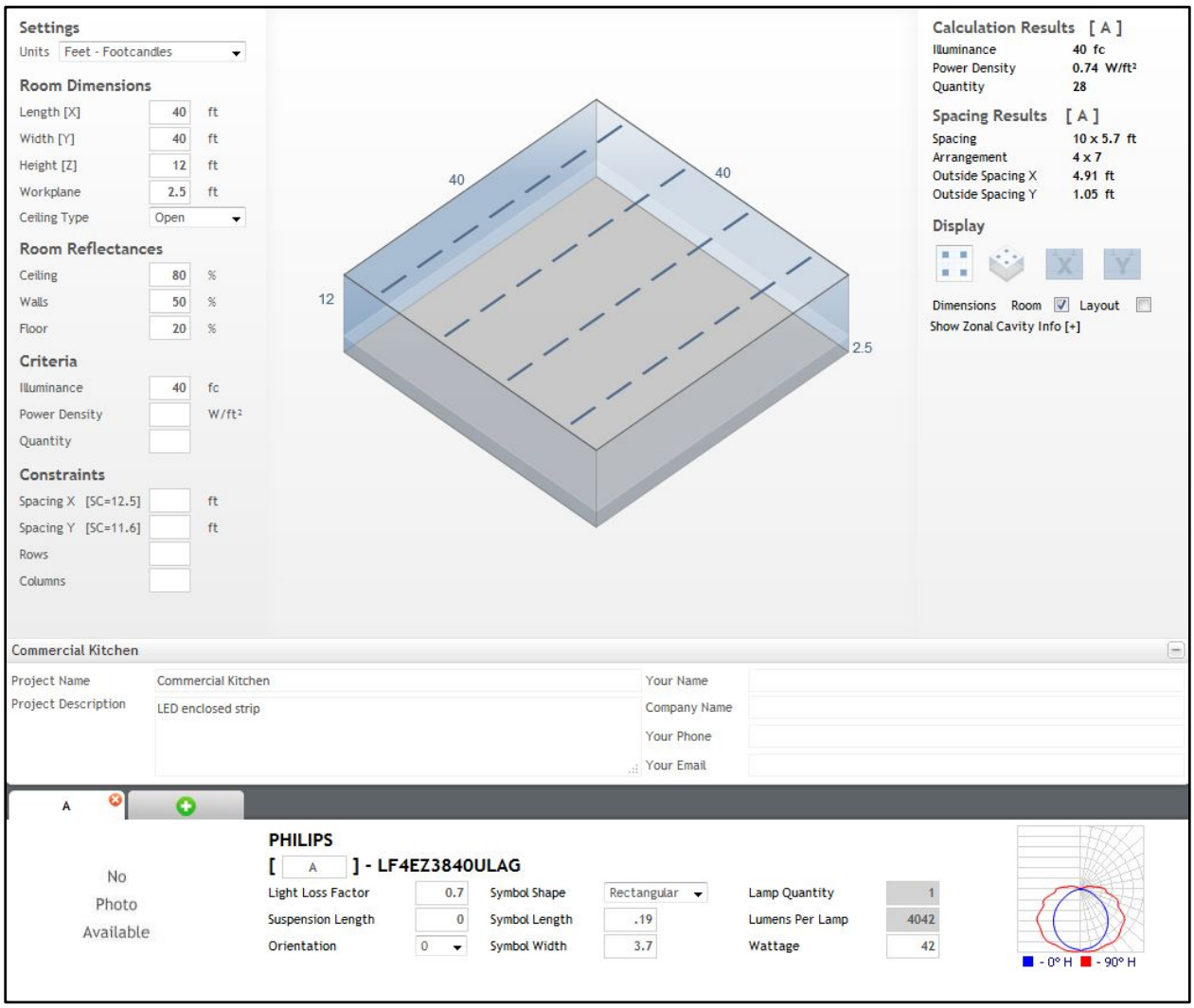
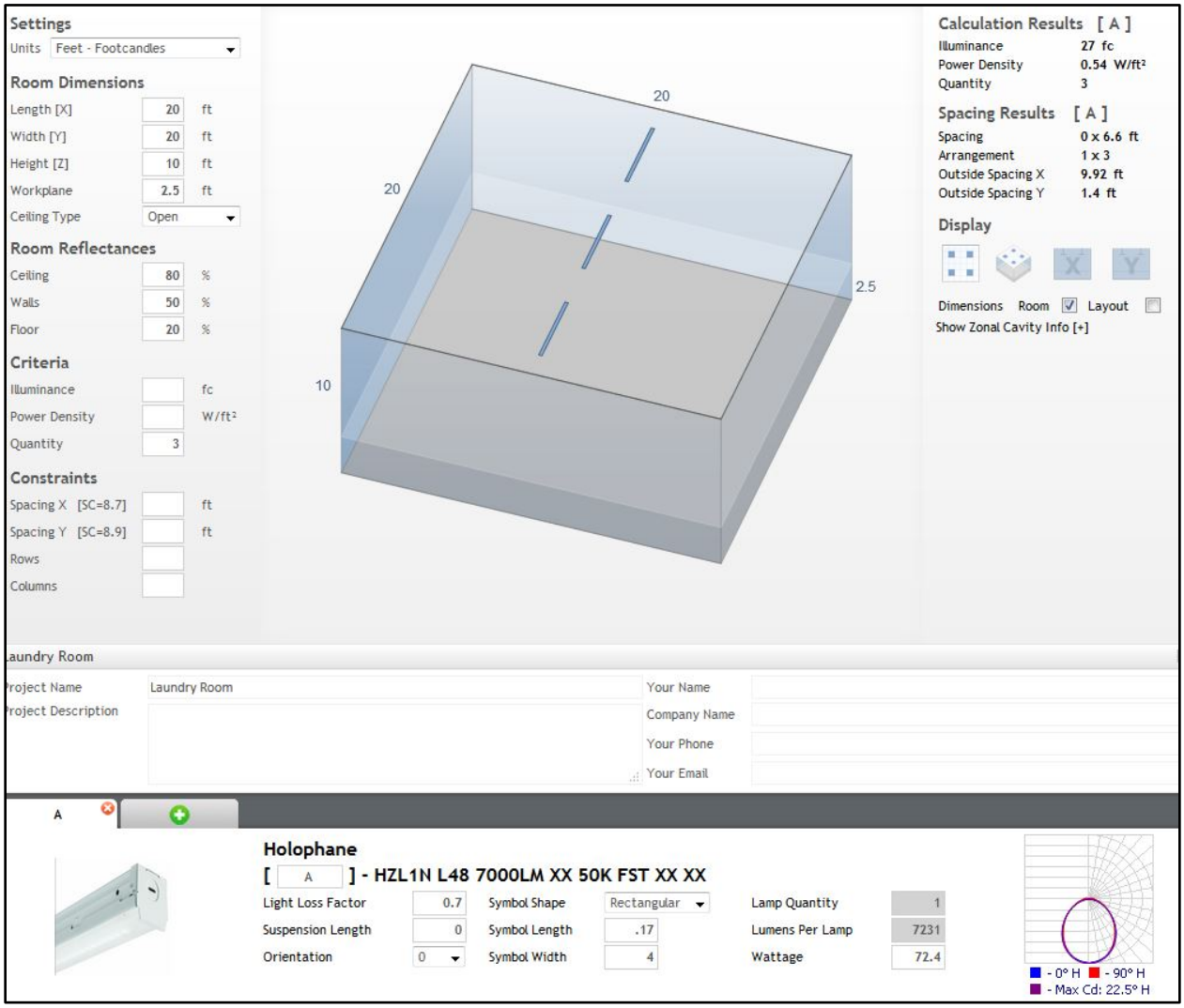


Table 25: Laundry Room



Appendix D: Annual Lighting Hours of Use

Hotel

Compliance Method 1: 80-100% of 2019 LPD Allowance

Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Dining		Yes (plus OFF)		2,767
GuestRmCorrid	Yes (partial)			4,201
GuestRmOcc				737
HotelLobby		Yes (plus OFF)		6,010
Kitchen				2,579
Laundry				4,154
BarCasino				3,485
OfficeGeneral		Yes (plus OFF)		1,834
Restroom	Yes			1,651
StockRoom				889
GuestRmUnOcc				737

Compliance Method 2: <=80% of 2019 LPD Allowance

Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Dining				3,485
GuestRmCorrid	Yes (partial)			4,201
GuestRmOcc				737
HotelLobby				7,884
Kitchen				2,579
Laundry				4,154
BarCasino				3,485
OfficeGeneral				2,023
Restroom	Yes			1,651
StockRoom				889
GuestRmUnOcc				737

Compliance Method 3: Input Power Method (40% reduction)

Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Dining				3,485
GuestRmCorrid				4,346
GuestRmOcc				737
HotelLobby				7,884
Kitchen				2,579
Laundry				4,154
BarCasino				3,485
OfficeGeneral				2,023
Restroom				2,438
StockRoom				889
GuestRmUnOcc				737

Office - Large

Compliance Method 1: 80-100% of 2019 LPD Allowance

Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
OfficeOpen		Yes (plus OFF)	Yes	1,940
OfficeSmall	Yes	Yes (plus OFF)		757
CorridorStairway	Yes (partial)			3,223
StorageSmlCond				1,317
LobbyWaiting		Yes (plus OFF)		2,204
Conference	Yes	Yes (plus OFF)		788
Restroom	Yes			645
Break		Yes (plus OFF)		1,802
MechElecRoom				1,573
CopyRoom				2,139

Compliance Method 2: <=80% of 2019 LPD Allowance

Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
OfficeOpen			Yes (partial)	2197
OfficeSmall	Yes			974
CorridorStairway	Yes (partial)			3223
StorageSmlCond				1317
LobbyWaiting				2482
Conference	Yes			823
Restroom	Yes			645
Break				2032
MechElecRoom				1573
CopyRoom				2139

Compliance Method 3: Input Power Method (40% reduction)

Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
OfficeOpen				2375
OfficeSmall	Yes			974
CorridorStairway				3600
StorageSmlCond				1317
LobbyWaiting				2482
Conference	Yes			823
Restroom	Yes			645
Break				2032
MechElecRoom				1573
CopyRoom				2139

Office - Small				
Compliance Method 1: 80-100% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Office Open		Yes (plus OFF)	Yes	1,494
Office Small	Yes	Yes (plus OFF)		1,047
Storage Small Cond				1,113
Hall	Yes (partial)			2,126
Lobby Waiting		Yes (plus OFF)		1,826
Conference	Yes	Yes (plus OFF)		618
Restroom	Yes			633
Break		Yes (plus OFF)		1,252
MecElecRoom				1,506
CompRoomData				2,717
CopyRoom				2,139
Compliance Method 2: <=80% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Office Open			Yes (partial)	1811
Office Small	Yes			1337
Storage Small Cond				1113
Hall	Yes (partial)			2126
Lobby Waiting				2107
Conference	Yes			654
Restroom	Yes			633
Break				1618
MecElecRoom				1506
CompRoomData				2717
CopyRoom				2139
Compliance Method 3: Input Power Method (40% reduction)				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Office Open				1957
Office Small	Yes			1337
Storage Small Cond				1113
Hall				2374
Lobby Waiting				2107
Conference	Yes			654
Restroom	Yes			633
Break				1618
MecElecRoom				1506
CompRoomData				2717
CopyRoom				2139

Restaurant				
Compliance Method 1: 80-100% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Dining		Yes (plus OFF)		2,572
Kitchen				4,110
Restroom	Yes			1,790
StockRoom				2,292
OfficeGeneral		Yes (plus OFF)		2,557
LobbyWaiting		Yes (plus OFF)		2,448
CorridorStairway	Yes (partial)			4,176
Compliance Method 2: <=80% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Dining				3,106
Kitchen				4,110
Restroom	Yes			1,790
StockRoom				2,292
OfficeGeneral				2,739
LobbyWaiting				3,106
CorridorStairway	Yes (partial)			4,176
Compliance Method 3: Input Power Method (40% reduction)				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Dining				3106
Kitchen				4110
Restroom	Yes			1790
StockRoom				2292
OfficeGeneral				2739
LobbyWaiting				3106
CorridorStairway				4320

Retail - Large				
Compliance Method 1: 80-100% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
RetailSales		Yes (plus OFF)		3,313
StockRoom				3,103
Work		Yes (plus OFF)		3,007
OfficeGeneral		Yes (plus OFF)		2,464
Restroom	Yes			2,415
Break		Yes (plus OFF)		2,349
MechElecRoom				1,998
Compliance Method 2: <=80% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
RetailSales				3,313
StockRoom				3,103
Work				3,313
OfficeGeneral				2,710
Restroom	Yes			2,415
Break				2,752
MechElecRoom				1,998
Compliance Method 3: Input Power Method (40% reduction)				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
RetailSales				3,313
StockRoom				3,103
Work				3,313
OfficeGeneral				2,710
Restroom	Yes			2,415
Break				2,752
MechElecRoom				1,998

Retail - Small				
Compliance Method 1: 80-100% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
RetailSales		Yes (plus OFF)		3,131
StockRoom				1,946
Hall	Yes (partial)			3,033
OfficeGeneral		Yes (plus OFF)		1,928
Restroom	Yes			566
Break		Yes (plus OFF)		1,286
MechElecRoom				2,012
Compliance Method 2: <=80% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
RetailSales				3,131
StockRoom				1,946
Hall	Yes (partial)			3,033
OfficeGeneral				2,145
Restroom	Yes			566
Break				1,610
MechElecRoom				2,012
Compliance Method 3: Input Power Method (40% reduction)				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
RetailSales				3131
StockRoom				1946
Hall				3138
OfficeGeneral				2145
Restroom	Yes			566
Break				1610
MechElecRoom				2012

School				
Compliance Method 1: 80-100% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Classroom	Yes	Yes (plus OFF)		797
Gymnasium				2,122
OfficeGeneral		Yes (plus OFF)		1,424
Kitchen				1,566
Restroom	Yes			640
LibraryReading				1,162
StorageSmlCond				365
CorridorStairway	Yes (partial)			1,778
Dining		Yes (plus OFF)		815
CompRoomClassrm	Yes	Yes (plus OFF)		778
LobbyWaiting				2,100
Compliance Method 2: <=80% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Classroom	Yes			864
Gymnasium				2,122
OfficeGeneral				1,500
Kitchen				1,566
Restroom	Yes			640
LibraryReading				1,162
StorageSmlCond				365
CorridorStairway	Yes (partial)			1778
Dining				1057
CompRoomClassrm	Yes			864
LobbyWaiting				2100
Compliance Method 3: Input Power Method (40% reduction)				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
Classroom	Yes			864
Gymnasium				2122
OfficeGeneral				1500
Kitchen				1566
Restroom	Yes			640
LibraryReading				1162
StorageSmlCond				365
CorridorStairway				1945
Dining				1057
CompRoomClassrm	Yes			864
LobbyWaiting				2100

Warehouse				
Compliance Method 1: 80-100% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
WarehouseUnCond	Yes (partial)	Yes (plus OFF)		1,419
OfficeGeneral		Yes (plus OFF)		1,817
Restroom	Yes			441
Compliance Method 2: <=80% of 2019 LPD Allowance				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
WarehouseUnCond	Yes (partial)			1,625
OfficeGeneral				2,004
Restroom	Yes			441
Compliance Method 3: Input Power Method (40% reduction)				
Function Area	Occupancy Controls	Automatic Daylighting	Multilevel Controls	Annual FLE Hours (hr)
WarehouseUnCond	Yes (partial)			1625
OfficeGeneral				2004
Restroom	Yes			441

Appendix E: Altered Lighting Systems – Alternate Modeling Assumptions and Results

Assumptions			Per Unit Electricity Use			Statwide Electricity Savings				
Method 2: LPD Threshold	Method 3: Input Power Reduction Required	Method 3: 5000 sf threshold applied? (Y,N)	Method 1	Method 2	Method 3	Option 1: All projects	Option 2: All projects	Option 3: All projects	Blended	Difference Compared to Baseline
85%	35%/50%	N	1.23	1.13	1.11	336	388	398	364	
85%	35%	N	1.23	1.13	1.34	336	388	283	336	-7.7%
85%	40%	N	1.23	1.13	1.23	336	388	332	348	-4.4%
85%	45%	N	1.23	1.13	1.13	336	388	382	360	-1.1%
85%	50%	N	1.23	1.13	1.03	336	388	432	372	2.2%
85%	35%/50%	Y	1.23	1.13	1.11	336	388	398	361	-0.8%
85%	35%	Y	1.23	1.13	1.34	336	388	283	359	-1.4%
85%	40%	Y	1.23	1.13	1.23	336	388	332	360	-1.1%
85%	45%	Y	1.23	1.13	1.13	336	388	382	361	-0.8%
85%	50%	Y	1.23	1.13	1.03	336	388	432	362	-0.5%
80%	35%/50%	N	1.23	1.06	1.11	336	419	398	372	2.2%
80%	35%	N	1.23	1.06	1.34	336	419	283	344	-5.5%
80%	40%	N	1.23	1.06	1.23	336	419	332	356	-2.2%
80%	45%	N	1.23	1.06	1.13	336	419	382	368	1.1%
80%	50%	N	1.23	1.06	1.03	336	419	432	380	4.4%
80%	35%/50%	Y	1.23	1.06	1.11	336	419	398	376	3.3%
80%	35%	Y	1.23	1.06	1.34	336	419	283	374	2.7%
80%	40%	Y	1.23	1.06	1.23	336	419	332	375	3.0%
80%	45%	Y	1.23	1.06	1.13	336	419	382	376	3.3%
80%	50%	Y	1.23	1.06	1.03	336	419	432	377	3.6%
75%	35%/50%	N	1.23	0.99	1.11	336	451	398	380	4.4%
75%	35%	N	1.23	0.99	1.34	336	451	283	352	-3.3%
75%	40%	N	1.23	0.99	1.23	336	451	332	364	0.0%
75%	45%	N	1.23	0.99	1.13	336	451	382	376	3.3%
75%	50%	N	1.23	0.99	1.03	336	451	432	388	6.6%
75%	35%/50%	Y	1.23	0.99	1.11	336	451	398	391	7.4%
75%	35%	Y	1.23	0.99	1.34	336	451	283	389	6.9%
75%	40%	Y	1.23	0.99	1.23	336	451	332	390	7.1%
75%	45%	Y	1.23	0.99	1.13	336	451	382	391	7.4%
75%	50%	Y	1.23	0.99	1.03	336	451	432	392	7.7%

Source: CEA

Appendix F: Altered Lighting Systems – Modeling Assumptions and Results using Alternative 2019 LPDs

After this report was completed, the Statewide Utility Codes and Standards team released an updated version of its analysis tool that included new recommendations for 2019 nonresidential LPDs (Version 1b). According to utility team leads, the updated values represent the most significant change to the tool as compared to the version of the analysis tool used for this effort (email from S. Becking, April 2017). Because the entire body of work is impacted by LPD values, CEA chose to add this appendix to demonstrate the energy and peak demand impacts of using this alternative set of LPD values. There was not enough time to recreate the entire set of analyses including cost and TDV information given the 2019 Energy Standards development timeline followed by the Energy Commission. Results of the second set of analyses is provided below.

Results of this second round of analyses show that the proposed measures save energy as compared to alterations completed with methods allowed under the 2016 Energy Standards. Statewide first year energy and peak demand savings are 4.0 GWh and 0.95 MW, respectively. This is less than that estimated using the first set of recommended LPDs. The difference is primarily a result of a significant change in the recommended LPD for retail establishments, which constitute 24 percent of California's building stock. Initial recommended LPDs for large retail function areas resulted in a weighted average LPD for this building type of 0.69 W/ft^2. Second round LPD estimates increased this to 0.85 W/ft^2, a change of 23 percent. For small retail buildings, initial LPD recommendations resulted in a weighted average LPD of 0.65 W/ft^2. Second round LPDs increased this to 0.78 W/ft^2, an increase of 20 percent.

It should be noted that neither the original LPD recommendations nor the updated LPD recommendations are approved for inclusion in the 2019 Energy Standards at the time this appendix was added. Values are based on recommendations only. Therefore, the results from both sets of analyses may be viewed as an estimated range of savings that could be expected from the adoption of CEA's measure proposal when paired with reasonable estimates for expected 2019 LPD values. The range of expected savings is:

- 4.0 to 11 GWh annually
- 0.95 to 2.1 MW peak demand reduction

Alternative 2019 Nonresidential LPDs

Generally, new Utility CASE team recommendations for 2019 LPD values include lower values as compared to its first set of recommendations; however the overall average is higher by 0.03 W/ft^2 due largely to the increase in LPDs for retail buildings. Of the 18 building function areas considered for this report, eight second round LPD values are lower as compared to initial recommendations, six are unchanged, and four are higher. A comparison of the initial LPD values used in the body of this report and the updated values used for analyses in this appendix are provided in Table 26.

Table 26: Comparison of Initial and Second Round 2019 LPD Recommendations

Area Category	Initial Set of Recommended 2019 LPD Values	Second Set of Recommended 2019 LPD Values	Difference between second round and initial values
Classroom, Lecture	0.90	0.72	(0.18)
Commercial Storage	0.46	0.46	0
Corridors, Restroom, Stair, and Support Areas	0.54	0.60	0.60
Convention, Conference, Multipurpose and Meeting Center Areas	0.93	0.85	(0.08)
Dining Area	0.54	0.47	(0.07)
Electrical, Mechanical, Telephone Rooms	0.39	0.39	0
Exercise, Gym	0.63	0.50	(0.13)
General Commercial Low Bay	0.61	0.61	0
Library Reading Areas	0.77	0.77	0
Lobby Area Hotel	0.48	0.82	0.34
Lobby Area Main Entry	0.86	0.82	(0.04)
Lounge Area	0.44	0.60	0.26
Office Area > 250 sf	0.68	0.64	(0.04)
Office Area ≤ 250 sf	0.85	0.68	(0.17)
Retail	0.79	1.06	0.27
Kitchen, Food Preparation Areas	0.92	0.92	0
Laundry Area	0.43	0.43	0
Waiting Area	0.72	0.60	(0.12)
AVERAGE LPD	**0.67**	**0.70**	

Parametric Modeling using 2nd Round LPDs

The proposed measure is focused on creating a simplified standard without a detriment to anticipated energy savings expected under the current Energy Standards. CEA completed 30 energy models varying lighting power reduction and building size threshold assumptions using the Analysis tool with 2nd round recommended LPD values in order to determine the savings associated with each permutation under these new assumptions. CEA considered the impacts of the following elements, impacts which do not vary from that considered in the first round of analysis:

1. LPD Threshold – Method 2: Current code is 85 percent of allowed under 140.6 (modeling runs considered 85 percent, 80 percent, and 75 percent).
2. Input Power Reduction - Method 3: Current code is a mix of 35 percent and 50 percent reduction as compared to existing conditions (modeling runs considered existing 35/50 percent split, 35 percent reduction for all building types, 40 percent for all, 45 percent for all and 50 percent for all).

3. Application of a building size limit for Method 3: Current code allows this option for all buildings (modeling runs consider with and without a limit on this method so that it is only available for buildings 5,000 sf or smaller).

Results yielded an average savings of 0.8 percent and median savings of 1.5 percent. The proposed measures, highlighted below in yellow, produce 1.2 percent savings as compared to an alteration complying with the expected 2019 non-CEA measures only (no change in compliance thresholds or building size limits). Results of all 30 modeling runs are shown in Table 27.

Table 27: Alternate Modeling Results using 2nd Round Recommended 2019 LPDs

	Assumptions			Per Unit Electricity Use			Statwide Electricity Savings				
Model ID	Method 2: LPD Threshold	Method 3: Input Power Reduction Required	Method 3: 5000 sf threshold applied? (Y,N)	Method 1	Method 2	Method 3	Option 1: All projects	Option 2: All projects	Option 3: All projects	Blended	Difference Compared to Baseline
1	85%	35%/50%	N	1.32	1.2	1.11	289	350	398	330	
2	85%	35%	N	1.32	1.2	1.34	289	350	283	302	-8.5%
3	85%	40%	N	1.32	1.2	1.23	289	350	332	314	-4.8%
4	85%	45%	N	1.32	1.2	1.13	289	350	382	326	-1.2%
5	85%	50%	N	1.32	1.2	1.03	289	350	432	338	2.4%
6	85%	35%/50%	Y	1.32	1.2	1.11	289	350	398	320	-3.0%
7	85%	35%	Y	1.32	1.2	1.34	289	350	283	317	-3.9%
8	85%	40%	Y	1.32	1.2	1.23	289	350	332	318	-3.6%
9	85%	45%	Y	1.32	1.2	1.13	289	350	382	319	-3.3%
10	85%	50%	Y	1.32	1.2	1.03	289	350	432	320	-3.0%
11	80%	35%/50%	N	1.32	1.13	1.11	289	384	398	339	2.7%
12	80%	35%	N	1.32	1.13	1.34	289	384	283	311	-5.8%
13	80%	40%	N	1.32	1.13	1.23	289	384	332	323	-2.1%
14	80%	45%	N	1.32	1.13	1.13	289	384	382	335	1.5%
15	80%	50%	N	1.32	1.13	1.03	289	384	432	347	5.2%
16	80%	35%/50%	Y	1.32	1.13	1.11	289	384	398	336	1.8%
17	80%	35%	Y	1.32	1.13	1.34	289	384	283	333	0.9%
18	80%	40%	Y	1.32	1.13	1.23	289	384	332	334	1.2%
19	80%	45%	Y	1.32	1.13	1.13	289	384	382	335	1.5%
20	80%	50%	Y	1.32	1.13	1.03	289	384	432	336	1.8%
21	75%	35%/50%	N	1.32	1.06	1.21	289	418	398	347	5.2%
22	75%	35%	N	1.32	1.06	1.34	289	418	283	319	-3.3%
23	75%	40%	N	1.32	1.06	1.23	289	418	332	331	0.3%
24	75%	45%	N	1.32	1.06	1.13	289	418	382	343	3.9%
25	75%	50%	N	1.32	1.06	1.03	289	418	432	355	7.6%
26	75%	35%/50%	Y	1.32	1.06	1.11	289	418	398	351	6.4%
27	75%	35%	Y	1.32	1.06	1.34	289	418	283	349	5.8%
28	75%	40%	Y	1.32	1.06	1.23	289	418	332	350	6.1%
29	75%	45%	Y	1.32	1.06	1.13	289	418	382	351	6.4%
30	75%	50%	Y	1.32	1.06	1.03	289	418	432	352	6.7%

Source: CEA

Per Unit Energy Impacts

Per unit energy and demand impacts of the proposed measure as compared to lighting alterations completed under the 2016 Energy Standards requirements are presented in Table 28. Savings are based on 2nd round estimated 2019 LPD values. Savings are the result of the following items:

- Change in LPD threshold for Method 1 and Method 2 from 85 percent of allowed 2019 LPA to 80 percent.
- Change in Method 3 input power reduction requirement from mix of 35/50 percent to a universal value of 40 percent for all building types.
- Application of a building or tenant space size limit for Method 3 of 5,000 sf

Savings resulting from the addition of partial-OFF occupancy control requirements in restrooms under Method 1 and Method 2 are not included. Savings resulting from the addition of automatic daylighting plus full OFF controls for Method 1 are not included. CEA assumed that these savings are reported in the separate code change proposals including *2019 Title 24 Codes and Standard Enhancement (CASE) Report: Nonresidential Indoor Lighting Alterations - Draft Report* prepared by the Statewide Utility Codes and Standards Team.

Average statewide per unit savings for the first year are expected to be 0.01 kilowatt-hours per year per square foot (kWh/yr-sf). Average statewide demand savings are negligible. The first year per unit TDV energy savings were not modeled for this iteration of the analysis due to time constraints related to the rulemaking process timeline. Savings by building type are shown in Table 28.

Table 28: First Year Energy Impacts per Square Foot

	Electricity Savings (kWh/yr-sf)	Peak Electricity Demand Savings (kW/sf)
State Average	0.01	0.00
Lodging	(0.06)	(0.01)
Office - Large	0.00	0.00
Office – Small	0.00	0.00
Restaurant	0.19	0.03
Retail – Large	(0.03)	(0.01)
Retail – Small	(0.03)	(0.01)
School	0.06	0.01
Warehouse	0.02	0.00

A comparison of the proposed measure to the anticipated 2020 existing building baseline is provided in Table 29. This information provides a broader view of future energy savings for lighting alterations as a whole in California under the proposed measure; however this information should not be considered savings attributed to this code change proposal alone. It contains savings estimates for alterations completed under the current alteration requirements contained in the 2016 Energy Standards plus updates to reflect CEA's proposed changes. It is provided for reference only.

Table 29: First Year Energy Use Impacts per Square Foot as Compared to Existing Building Baseline

	Per Unit Electricity Use – Existing Buildings (kWh/yr-sf)	Per Unit Electricity Use – After Retrofit (kWh/yr-sf)	Electricity Savings (kWh/yr-sf)
State Average	1.93	1.23	0.70
Lodging	3.82	2.63	1.19
Office - Large	1.66	1.05	0.61
Office – Small	1.43	0.82	0.61
Restaurant	3.51	1.83	1.68
Retail – Large	3.61	2.45	1.16
Retail – Small	2.76	1.92	0.84
School	1.22	0.64	0.58
Warehouse	1.01	0.65	0.36

First Year Statewide Savings

First year statewide savings represent the savings attributed to CEA's proposal that exceed savings currently associated with the lighting alterations portion of the 2016 Energy Standards. Savings are based on 2nd round recommended 2019 LPD values. Savings are the result of the following items:

- Change in LPD threshold for Method 1 and Method 2 from 85 percent of allowed 2019 LPA to 80 percent
- Change in Method 3 input power reduction requirements from mix of 35/50 percent to a universal 40 percent reduction requirement for all building types.
- Application of a building size limit for Method 3 of 5,000 square feet

Two pending code change proposals authored by the Statewide Utility Codes and Standards team are not included in the reported savings impacts. Savings resulting from the addition of partial-OFF occupancy control requirements in restrooms for Method 1 and Method 2 are not included. Savings resulting from the addition of automatic daylighting plus full OFF controls for Method 1 are not included (Statewide Utility Codes and Standards Team 2017).

To determine the first year statewide savings, CEA multiplying the per unit savings, which are presented in Table 29, by the 2020 forecast of statewide building stock expected to undergo

retrofit. The first year energy impacts represent the first year annual savings from all applicable lighting alterations completed in 2020. Results are presented in Table 30.

Given data regarding the rate of lighting alterations completed as well as the rate of new commercial construction forecast for 2020, CEA estimates that the proposed code change will reduce annual statewide electricity use by 4.0 GWh with an associated demand reduction of 0.95 MW. Secondary energy impacts associated with changes in heating and cooling loads resulting from reduced lighting loads are not considered in this analysis. Therefore, results are not provided by climate zone.

Table 30: Statewide Energy, Peak Demand and TDV Impacts

Building Type	Statewide Construction in 2020 (million sf)	First Year[1] Electricity Savings (GWh)	First Year[1] Peak Electrical Demand Reduction (MW)
Lodging	395,000,000	(0.40)	(0.05)
Office - Large	1,384,000,000	(0.06)	0.05
Office – Small	624,000,000	0.10	0.02
Restaurant	624,000,000	4.20	0.68
Retail – Large	196,000,000	(1.90)	(0.46)
Retail – Small	604,000,000	(1.80)	(0.41)
School	1,117,000,000	2.50	0.72
Warehouse	71,000,000	1.9	0.42
TOTAL		**4.00**	**0.95**

1. First year savings from all building alterations completed statewide in 2020.