

# Nonresidential Daylighting



2022-NR-LIGHT1-D | Nonresidential Lighting | June 2020

DRAFT CASE REPORT

Prepared by Energy Solutions

**Please submit comments to [info@title24stakeholders.com](mailto:info@title24stakeholders.com) by July 10, 2020.**



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# Executive Summary

*This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in September 2020.*

- 1. Feasibility of adjustments in acceptance testing with proposed adjustments. Please see the questions posed to stakeholders in Appendix F. The Statewide CASE Team is looking for further responses from stakeholders reviewing this report.*
- 2. Acceptance Technician feedback on impact of testing Daylight Dimming to 10 percent.*
- 3. Data or information on occupant acceptance of dimming to 10 percent, including qualitative data on Daylight Dimming to 10 percent or OFF.*

*Email comments and suggestions to [info@title24stakeholders.com](mailto:info@title24stakeholders.com) by **July 10, 2020**. Comments will not be released for public review or will be anonymized if shared.*

## Introduction

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

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy



Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: <https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency>.

The overall goal of this CASE Report is to present a code change proposal that would affect the daylighting controls requirements as they apply to nonresidential applications. The report contains pertinent information supporting the code change.

## Measure Description

### Background Information

Mandatory requirements for automatic daylighting controls were first introduced in the 2005 Title 24, Part 6 Standards. The daylighting control requirements were structured to accommodate the most common illumination technology solution available at the time: fluorescent sources with stepped dimming. Automatic daylighting controls were required to reduce light output of the general lighting by least half when there was adequate daylighting. The automatic daylighting control requirements were refined in the 2008, 2013, and 2016 code cycles to adjust for changes in technology, address ambiguities, and simplify code compliance. Notably, for the 2013 code cycle, a requirement was added to clarify that multi-level lighting controls were mandatory in enclosed areas 100 square feet and larger with a connected lighting load greater than 0.5W/ft<sup>2</sup> (Section 130.1(b)), and that LED luminaires and LED sources must have the capability to continuously dim between 10 to 100 percent (Table 130.1-A). For the 2019 code cycle, lighting power densities (LPDs) were updated to use an LED baseline, which means LEDs will be more common and it is expected that nearly all spaces will have continuous dimming between 10 and 100 percent. The proposed code change would align the automatic daylighting control requirements with the capabilities of lighting systems that are commonly installed in nonresidential buildings today. Specifically, the code requirement would require the dimming down to 10 percent as opposed to the current requirement that systems have the capability to dim to 35 percent.

The Statewide CASE Team often hears feedback from stakeholders that the code requirements are overly complex. This is particularly true for the lighting control requirements. The second proposed code change presented in this report would simplify the prescriptive lighting control requirements in response to stakeholders' requests.

### Proposed Code Change

The Statewide CASE Team recommends two revisions to the daylighting controls requirements in Title 24, Part 6, as described below.



## **Daylight Dimming to 10 Percent**

This proposed code change would update the mandatory automatic daylight dimming controls provisions to require deeper reductions in lighting power when illuminance levels are met with daylight. Current code requires general lighting power in the daylight zone to be reduced to 35 percent or less when daylight illuminance is greater than 150 percent of design illuminance. The proposed requirements would require general lighting power to be reduced to 10 percent or less. There are no changes to the threshold daylight illuminance level triggers.<sup>1</sup> This measure leverages the proliferation of solid-state lighting and its dimming capability in the nonresidential sector and takes full advantage of the 10-100 percent dimming range that is already required for LED luminaires and sources found in Table 130.1-A of Title 24, Part 6. The existing mandatory requirements for automatic daylight dimming controls apply to new construction, additions, and alterations of nonresidential, high-rise residential, and hotel/motel buildings. The proposed changes would not apply to parking garages.

The proposed code change does not recommend revisions to the existing definition or applicability of the prescriptive power adjustment factor (PAF) for daylight dimming plus OFF controls in Section 140.6(a)2H. However, the factor itself needs to be updated to account for the PAF applying to dim from 10 percent to OFF instead of dim from 35 percent to OFF.

## **Mandatory Controls in Secondary Sidelit Daylit Zones**

This proposed code change would move the prescriptive requirements for automatic daylighting controls in secondary sidelit daylit zones (SDZs) to Section 130.1, the mandatory indoor lighting controls section of Title 24, Part 6. Currently, the requirement for automatic daylighting controls in SDZs is the only prescriptive lighting control requirement. Since this is the only prescriptive lighting control requirement, stakeholders have reported there is confusion and uncertainty during code compliance verification process whether controls in SDZs are required, particularly when the building complies

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<sup>1</sup> Illuminance is the amount of light on the surface of an area. Daylight illuminance is the amount of sunlight on the surface of an area. For the automatic daylighting controls requirements to be triggered, the amount of sunlight, or daylight illuminance, that reaches the photosensor must exceed 150 percent of the design illuminance for general lighting of the space. Design illuminance is the light level that a space has been designed to have. General lighting refers to luminaires and lamps that are designed to provide overall lighting to a space, as opposed to task lighting which is designed to provide illumination for a specific need or task. As an example, if an office lighting system has been designed to deliver 10 foot-candles of general lighting to desk areas, the amount of daylight illuminance that needs to enter the space and reach the photosensor must be more than 15 foot-candles for the automatic daylighting controls to reduce power to the general lighting system.

using the performance approach where this is the only lighting control requirement that a designer could opt not to install as long as they achieve the required energy budget. Moving the requirements for controls in SDZs to the mandatory section would simplify the lighting control requirements and subsequently the compliance and enforcement process for lighting controls. This change would also align the daylighting requirements in Title 24, Part 6 with daylighting requirements in ASHRAE 90.1. Finally, the proposed change would provide certainty about when daylighting controls in SDZs are required, which would make it more likely that lighting in SDZs are controlled with photocontrols.

## Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents that would be modified as a result of the proposed change(s).

**Table 1: Scope of Code Change Proposal**

<b>Measure Name</b>	<b>Type of Requirement</b>	<b>Modified Section(s) of Title 24, Part 6</b>	<b>Modified Title 24, Part 6 Appendices</b>	<b>Would Compliance Software Be Modified</b>	<b>Modified Compliance Document(s)</b>
Daylight Dimming to 10%	Mandatory	Section 130.1(d)	Nonresidential Appendix 7: NA 7.6.6.2.2	Yes	Yes
Mandatory Controls in Secondary Sidelit Daylit Zones	Mandatory	Sections 130.1(e) and 140.6(D)	No	No	Yes

## Market Analysis and Regulatory Assessment

The market for this measure is well established. Many manufacturers produce a plethora of products that can be used to meet the proposed requirements. The Statewide CASE Team found that as solid-state lighting technology advances, more manufacturers have added lighting controls to their product offerings. Likewise, more manufacturers are offering whole-building energy management solutions which include photocontrols and occupancy controls. Despite their wide availability and the presence of various requirements within state and national model energy codes, studies have shown a relatively low penetration rate of occupancy sensors and daylighting controls which indicates opportunity for energy savings.

The proposed measure would increase stringency of an existing requirement in Title 24, Part 6 while simultaneously align with a separate requirement. Specifically, automatic daylighting controls are already required to dim to 35 percent; the proposed requirement increases the dimming requirement to 10 percent. Likewise, LEDs are already required to be capable of dimming to 10 percent, so the proposed update is an alignment with this requirement. The proposed update somewhat aligns with ASHRAE 90.1-2013 as a slightly less stringent version. ASHRAE 90.1-2013 requires automatic daylight dimming to OFF, whereas this proposed update is dim to 10 percent. There are no additional requirements in other parts of the California Building Code that are directly related. However, there are voluntary requirements in Title 24, Part 11 that encourage the use of daylight redirecting devices (DRDs). These DRDs increase daylight penetration into a space which is beneficial for spaces to achieve the 150 percent design light level required for the automatic daylight dimming to 10 percent to trigger.

### **Cost Effectiveness**

There are no costs associated with the proposed daylight dimming to 10 percent code change because LEDs are already required to dim to 10 percent. Since reducing lighting power to 10 percent will yield energy cost savings in all building types and climate zones, the proposed code change has an infinite B/C ratio in all climate zones. See the energy cost savings (benefit) of the proposed code change by building type and climate zone in Appendix H. See Section 5 for methodology and assumptions.

A cost-effectiveness analysis is not needed to move the prescriptive requirements for automatic daylighting controls in SDZs to the mandatory section. This submeasure was already proven to be cost effective in order to be added to the prescriptive requirements (California Utilities Statewide Codes and Standards Team 2011).

### **Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions Impacts**

Table 2 presents the estimated energy and demand impacts of the proposed code change that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Section 6 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Section 4 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

**Table 2: First-Year Statewide Energy and Impacts**

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDVkBtu/yr)
<b>Daylight Dimming to 10%</b>	59.7	0.2	-0.4	1,274.9
New Construction	14.0	0.1	-0.1	299.3
Additions and Alterations	45.7	0.2	-0.3	975.6
<b>Mandatory Controls in Secondary Sidelit Daylit Zones</b>	N/A	N/A	N/A	N/A

Table 3 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in metric tonnes of carbon dioxide equivalent (metric tonnes CO<sub>2</sub>e).

Assumptions used in developing the GHG savings are provided in Section 6.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

**Table 3: First-Year Statewide GHG Emissions Impacts**

Measure	Avoided GHG Emissions (metric tonnes CO <sub>2</sub> e/yr)	Monetary Value of Avoided GHG Emissions (\$2023)
Daylight Dimming to 10%	9,852	\$295,552
Mandatory Controls in Secondary Sidelit Daylit Zones	N/A	N/A

## Water 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.

## Compliance and Enforcement

### Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Section 2.5. Impacts that the proposed measure would have on market actors is described in Section 3.3 and Appendix E. Automatic daylighting controls requirements have been in

place since the 2005 code cycle and the proposed refinements to the requirements are minimal. Changes to the compliance process that has been in place for over a decade would be minimal.

### **Field Verification and Acceptance Testing**

Automatic daylighting controls do require acceptance testing. The procedure is described in Section 7.6.1 of the Nonresidential Appendix, Automatic Daylighting Controls Acceptance Tests. The proposed code change would make minor revisions to the protocol to account for the requirement to dim to 10 percent. The preferred methodology for confirming controls may be to change from the distance method to the illuminance method. These methods are described in Section 2.5, Section 7.6, and Appendix E.

# 1. Introduction

*This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in September 2020. For this report, the Statewide CASE Team is requesting input on the following:*

- 1. Feasibility of adjustments in acceptance testing with proposed adjustments. Please see the questions posed to stakeholders in Appendix F. The Statewide CASE Team is looking for further responses from stakeholders reviewing this report.*
- 2. Acceptance Technician feedback on impact of testing Daylight Dimming to 10 percent.*
- 3. Data or information on occupant acceptance of dimming to 10 percent, including qualitative data on Daylight Dimming to 10 percent or OFF.*

*Email comments and suggestions to [info@title24stakeholders.com](mailto:info@title24stakeholders.com). by **July 10, 2020**. Comments will not be released for public review or will be anonymized if shared with stakeholders.*

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

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy

Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: <https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency>.

The overall goal of this Draft CASE Report is to present a code change proposal for mandatory daylight dimming controls to 10 percent. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including acceptance testing technicians, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on September 5, 2019, and March 3, 2020.

The following is a brief summary of the contents of this report:

- Section 2 – Measure Description of this CASE Report describes the measure and its background. This section also presents how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 3 – In addition to the Market Analysis, this section includes a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section 4 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 5 – This section includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 6 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or



reductions) on material with emphasis placed on any materials that are considered toxic by the State of California. Statewide water consumption impacts are also reported in this section.

- Section 7 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.
- Section 8 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.
- Appendix C: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix D: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix E: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix G: Nominal Savings Tables presents the energy cost savings in nominal dollars by building type and climate zone.
- Appendix H: Per Unit Energy and Cost Results by Prototypical Building present energy savings per square foot for each prototypical building modeled and the 15-year energy cost savings associated with energy savings in 2023 present value dollars.

## 2. Measure Description

### 2.1 Measure Overview

The Statewide CASE Team recommends two revisions to the daylighting controls requirements in Title 24, Part 6, as described below.

#### **Daylight Dimming to 10 Percent**

This proposed code change would update the mandatory automatic daylight dimming controls provisions to require deeper reductions in lighting power when illuminance levels are met with daylight. Current code requires general lighting power in the daylit zone to be reduced to 35 percent or less when daylight illuminance is greater than 150 percent of design illuminance. The proposed requirements would require general lighting power to be reduced to 10 percent or less. There are no changes to the threshold daylight illuminance level triggers.<sup>2</sup> This measure leverages the proliferation of solid-state lighting and its dimming capability in the nonresidential sector and takes full advantage of the 10-100 percent dimming range that is already required for LED luminaires and sources found in Table 130.1-A of Title 24, Part 6. The existing mandatory requirements for automatic daylight dimming controls apply to new construction, additions, and alterations of nonresidential, high-rise residential, and hotel/motel buildings. The proposed changes would not apply to parking garages.

The proposed code change does not recommend revisions to the existing definition or applicability of the prescriptive power adjustment factor (PAF) for daylight dimming plus OFF controls in Section 140.6(a)2H. However, the factor itself needs to be updated to account for the PAF applying to dim from 10 percent to OFF instead of dim from 35 percent to OFF.

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<sup>2</sup> Illuminance is the amount of light on the surface of an area. Daylight illuminance is the amount of sunlight on the surface of an area. For the automatic daylighting controls requirements to be triggered, the amount of sunlight, or daylight illuminance, that reaches the photosensor must exceed 150 percent of the design illuminance for general lighting of the space. Design illuminance is the light level that a space has been designed to have. General lighting refers to luminaires and lamps that are designed to provide overall lighting to a space, as opposed to task lighting which is designed to provide illumination for a specific need or task. As an example, if an office lighting system has been designed to deliver 10 foot-candles of general lighting to desk areas, the amount of daylight illuminance that needs to enter the space and reach the photosensor must be more than 15 foot-candles for the automatic daylighting controls to reduce power to the general lighting system.

## **Mandatory Controls in Secondary Sidelit Daylit Zones**

This proposed code change would move the prescriptive requirements for automatic daylighting controls in secondary sidelit daylit zones (SDZs) to Section 130.1, the mandatory indoor lighting controls section of Title 24, Part 6. Currently, the requirement for automatic daylighting controls in SDZs is the only prescriptive lighting control requirement. Since this is the only prescriptive lighting control requirement, stakeholders have reported there is confusion and uncertainty during code compliance verification process whether controls in SDZs are required, particularly when the building complies using the performance approach where this is the only lighting control requirement that a designer could opt not to install as long as they achieve the required energy budget. Moving the requirements for controls in SDZs to the mandatory section would simplify the lighting control requirements and subsequently the compliance and enforcement process for lighting controls. This change would also align the daylighting requirements in Title 24, Part 6 with daylighting requirements in ASHRAE 90.1. Finally, the proposed change would provide certainty about when daylighting controls in SDZs are required, which would make it more likely that lighting in SDZs are controlled with photocontrols.

## **2.2 Measure History**

Mandatory requirements for automatic daylighting controls were first introduced in the 2005 Title 24, Part 6 Standards. The daylighting control requirements were structured to accommodate the most common illumination technology solution that was available at the time: fluorescent sources with stepped dimming. Automatic daylighting controls were required to reduce light output of the general lighting by least half when there was adequate daylighting. The automatic daylighting control requirements were refined in the 2008, 2013, and 2016 code cycles to adjust for changes in technology, address ambiguities, and simplify code compliance. Several of these multi-cycle refinements have a connection to the proposals in this report.

In the 2008 Standards, the automatic daylighting controls requirements were updated to require that lighting output be reduced by at least 35 percent when adequate daylighting is available. This requirement has not been updated since this code iteration, even though lighting and controls technologies have evolved over the past decade.

In the 2013 Title 24, Part 6 Standards, the requirements for automatic daylighting controls were simplified significantly. As described in the 2013 CASE Report on nonresidential daylighting for the 2013 code, a wattage calculation method was introduced to simplify the method to calculate the savings from daylighting controls (California Utilities Statewide Codes and Standards Team 2011). Compliance methods were simplified further by addressing the threshold that triggered photocontrol requirements. Table 130.1-A was also added in the 2013 code cycle and included the requirements for LEDs have capability to continuously dim between 10 to 100 percent.

In the 2016 Title 24, Part 6 code cycle, the requirements for automatic daylighting were updated again. Section 130.1(d)2D, which describes requirements for the access to the calibration adjustment controls for photocontrol systems, was clarified. The primary purpose of this requirement was to prevent tampering with the photosensor and to have the calibration controls readily accessible so that adjustments to daylighting controls could be easily performed by authorized personnel in response to changes in interior geometry or reflectance, changes in occupancy or tasks, or occupant requests for more or less light.

In addition, the 2016 Title 24, Part 6 Standards added a power adjustment factor for daylighting controls that include the OFF step (i.e., controls that turn OFF lights when enough daylight is available). The goal of the new optional power adjustment factor was to prepare the market for this control strategy as a mandatory measure in the 2019 code cycle. These revisions are described in the 2016 CASE Report on nonresidential lighting controls (California Utilities Statewide Codes and Standards Team 2017).

In the 2019 Title 24, Part 6 code cycle, definitions of daylit spaces were updated. The Statewide CASE Team also pursued a code change proposal that would have updated the mandatory automatic daylighting control requirements such that luminaires in daylit zones would need to include an OFF setting when sufficient daylighting was available. The 2019 CASE Report on nonresidential indoor lighting controls includes a submeasure, “mandatory automatic daylight dimming plus OFF controls.” This report explores the technical feasibility, market readiness, energy savings, and cost effectiveness of a mandatory dimming plus OFF requirement. As discussed in the report, the Statewide CASE Team found that dimming plus OFF was technically feasible and cost effective (California Utilities Statewide Codes and Standards Team 2017).

In response to the Statewide CASE Team’s proposal for the 2019 code cycle, some stakeholders stated that adding an OFF setting implied the need for architectural dimming systems, which have continuous dimming to one percent or lower and is more expensive than standard dimming technology. However, the Statewide CASE Team did not intend to require architectural dimming. The intent was to have an OFF setting, but not continuous dimming all the way to OFF. The Statewide CASE Team interviewed industry experts to gather more information on the cost and reliability issues associated with daylight dimming plus OFF. Through these interviews, the Statewide CASE Team verified that the cost and time required to dim plus OFF were not significantly greater than those required to dim to power levels below 35 percent. Some experts attested, though, that dimming plus OFF could jeopardize the long-term reliability of lighting systems due to line noise and frequent high/low cycling.

Other stakeholders raised concerns regarding building occupant confusion and/or dissatisfaction resulting from daylight dimming plus OFF in office buildings, classrooms, and other areas where users expect to have more control over their electric lighting.

These stakeholders argued that in buildings with indoor lights that dimmed and turned OFF, building occupants may be inclined to believe that the lighting system was malfunctioning when dimmed and then shut OFF and potential disable the entire daylight dimming system. Due to concerns regarding both cost and occupant confusion, the Energy Commission did not adopt the Statewide CASE Team's proposal for mandatory automatic daylight dimming plus OFF controls in the 2019 code cycle.

When considering code change proposals for the 2022 code cycle, the Statewide CASE Team continued investigations into market acceptance concerns raised during the 2019 code cycle with the intent of finding assurance that market actors in California would feel comfortable with a plus OFF requirement similar to what has been ASHRAE 90.1 for several code cycles. The Statewide CASE Team conducted outreach to manufacturers, contractors, designers, and acceptance test technicians (ATTs). Specifically, the Statewide CASE Team asked over three dozen manufacturers, contractors, designers and other stakeholders for their feedback daylight harvesting<sup>3</sup> when attending LightFair 2019, Strategies in Light, Design Light Expo, and LightShow West. The Statewide CASE Team also worked with California Lighting Technology Center (CLTC) who conducted research and stakeholder outreach, including discussions with the California Energy Alliance.<sup>4</sup> Finally, the Statewide CASE Team conducted a survey of ATTs and asked for feedback during the first utility-sponsored stakeholder meeting held on September 5, 2020 (Statewide CASE Team 2019).

The continued investigation into the dimming plus OFF requirements aimed to:

- Confirm that dimming plus OFF (without architectural dimming) is technically feasible and cost-effective.
- Find quantitative data to determine building occupants' satisfaction with daylighting dimming plus OFF.
- Identify a solution to concerns that building occupant confusion and/or dissatisfaction would result in daylighting controls being disabled, should it occur.

The Statewide CASE Team has confirmed findings in the 2019 CASE Report that dimming plus OFF is technically feasibility and cost effective. Despite a significant attempt, the Statewide CASE Team did not find qualitative data indicating dissatisfaction with daylight dimming plus OFF controls. There were no specific

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<sup>3</sup> Daylight harvesting refers to strategies for using daylighting to offset the amount of electric lighting needed. Daylight dimming plus OFF is an example of a daylight harvesting strategy.

<sup>4</sup> California Energy Alliance's website can be found here: <https://caenergyalliance.org/>.

examples, anecdotal or qualitative, to determine that dimming plus OFF yields occupant dissatisfaction. Outreach did reveal, however, that some stakeholders contend that building occupants would be confused by a dimming plus OFF system. Some stakeholders also reported an aversion for dimming plus OFF and noted that designer/specifier prefer architectural dimming and may elect architectural dimming to comply with a dimming plus OFF requirement despite the additional costs.

Despite hearing anecdotal evidence that both supported and refuted claims that the plus OFF step would face market acceptance challenges, with the absence of quantitative data the Statewide CASE Team cannot offer concrete evidence that market acceptance concerns are resolved. As a result, the Statewide CASE Team is pursuing a code change that would expand the automatic daylighting control requirements to require deeper power reductions (90 percent reduction in power or 10 percent power remaining).

When speaking with stakeholders about potential revisions to the daylighting requirements, the Statewide CASE Team received confirmation that moving the automatic daylighting control requirements for SDZs to the mandatory section would make the code easier to understand and comply with. Currently, to understand automatic daylighting controls requirements readers must go through multiple sections to comprehend all the requirements. This results in perceived complexity with the daylighting section of the code. Moving the prescriptive requirement for secondary daylighting controls to the mandatory section would reduce code complexity.

## 2.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

### 2.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 7.2 of this report for marked-up code language.

#### **SECTION 130.1 – Mandatory Indoor Lighting Controls**

- **Section 130.1(d)3D:** The 2019 Standards require daylight controls to dim the general lighting to 35 percent of rated power (or lower) when daylight illuminance is 150 percent design illuminance or greater. The proposed code change requires dimming to 10 percent or lower when daylight illuminance exceeds 150 percent design illuminance.



- **Section 130.1(e):** Move the prescriptive requirements for automatic daylighting controls in SDZs from Section 140.6(d) here. No changes are proposed to the language other than moving to the mandatory lighting section.

## **SECTION 140.6 – Prescriptive Requirements for Indoor Lighting**

- **Section 140.6(d):** Delete the automatic daylighting controls in SDZs requirement from the prescriptive section and move to the mandatory section (Section 130.1(e)).
- **Table 140.6-A:** Reduce PAF for Daylight Dimming plus OFF Control to account for baseline now being 10 percent instead of 35 percent.

### **2.3.2 Summary of Changes to the Reference Appendices**

- **NA 7.6.1 Lighting Control Acceptance Requirements:** Add a definition for “daylight illuminance” and “design illuminance.” Currently, “daylight illuminance” is undefined, but is an integral term for understanding and applying the proposed dim to 10 percent measure. “Daylight illuminance” refers to the amount of sunlight that can be measured on the surface of an interior space. Currently, “design illuminance” is undefined but is an integral term for understanding and applying the proposed dim to 10 percent measure. “Design illuminance” refers to the amount of artificial light that can be measured on the surface of a space when the light source is the lighting system for the space. The proposed definitions are adapted from the IES definition for illuminance (Illuminating Engineering Society 2018).
- **NA7.6.1.2.1 Continuous Dimming Control Systems:** Adjust procedures to verify and document that the lighting power reduction of controlled luminaires is at least 90 percent instead of 65 percent.
- **NA7.6.1.2.2 Stepped Switching or Stepped Dimming Control Systems:** Adjust procedures to verify and document that the lighting power reduction of controlled luminaires is at least 90 percent instead of 65 percent.

See Section 7.3 of this report for the detailed proposed revisions to the text of the reference appendices.

### **2.3.3 Summary of Changes to the Nonresidential ACM Reference Manual**

This proposal would modify the Nonresidential ACM Reference Manual to allow daylight dimming controls to dim to a 90 percent lighting power reduction once at 150 percent design illuminance. Software sensitivity tests for dimming would likely need to be updated to test for appropriate capacity.



Section 5.4.5 of the ACM Reference Manual would be updated to reflect that the standard design power fraction and light output is 0.1. It would also be updated to note that daylighting controls for SDZs are mandatory.

See Section 7.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual. Appendix D presents proposed changes to the compliance software.

### **2.3.4 Summary of Changes to the Nonresidential Compliance Manual**

The proposed code change would modify the following sections of the Nonresidential Compliance Manual:

- Chapter 5.2 General Requirements for Mandatory Measures
- Chapter 5.4.4.4 Automatic Daylighting Control Installation and Operation
- Chapter 5.4.8 Summary of Mandatory Controls
- Chapter 5.5 Prescriptive Daylighting Requirements
- Chapter 13.1 New or Modified Acceptance Test Requirements for 2019
- Chapter 13.24 NA7.6.1 Automatic Daylighting Control Acceptance

The compliance manual would need to be updated to account for daylighting dimming to 10 percent because it currently provides guidance on dimming to 35 percent. It would also need to update language to note that automatic daylighting controls for SDZs are mandatory and not prescriptive and move them from Chapter 5.5.3 to Chapter 5.4.4.

See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

### **2.3.5 Summary of Changes to Compliance Documents**

The proposed code change would modify the NRCA-LTI-03-A Automatic Daylighting Control Acceptance Document. In addition, any equivalent performance forms must be generated on a per-project basis. Examples of the revised documents are presented in Section 7.6.

## **2.4 Regulatory Context**

### **2.4.1 Existing Requirements in the California Energy Code**

The Mandatory Indoor Lighting Controls section of Title 24, Part 6 (Section 130.1) includes requirements for lighting control, including automatic daylighting controls in Section 130.1(d). Current requirements specify that general lighting luminaires in or partially in Skylit Daylit Zones or Primary Sidelit Daylit Zones need to be controlled independently and lighting power be reduced to 35 percent when the area receives daylight that is 150 percent or greater than the designed lighting level. Likewise, Section

140.6 has the same requirements for all general lighting luminaires in or partially in the Secondary Sidelit Daylit Zones that are not in the Primary Sidelit Daylit Zones.<sup>5</sup>

General lighting in enclosed spaces that are 100 square feet or larger with a connected lighting load of 0.5W/ft<sup>2</sup> or greater must have multi-level controls that comply with the number of control steps in Table 130.1-A. Table 130.1-A requires LEDs to be capable of continuous dimming between 10 and 100 percent.

#### **2.4.2 Relationship to Requirements in Other Parts of the California Building Code**

There are no requirements directly related to the minimum dimming requirements in other parts of the California Building Code. However, there are voluntary requirements in 2019 California Green Building Standards (CALGreen or Title 24, Part 11) that encourage daylight devices. To meet the Tier 1 and Tier 2 energy efficiency levels in CALGreen, either one or two prerequisite requirements must be met, respectively. Installing daylighting devices that comply with Title 24, Part 6 Section 140.3(d) is one of the five prerequisite options. Installing daylight devices (i.e., clerestory fenestration, interior and exterior horizontal slats, or interior and exterior light shelves) brings more daylight into the space and would therefore increase the opportunity for the luminaires to dim.

#### **2.4.3 Relationship to Local, State, or Federal Laws**

There are no relevant local, state, or federal laws.

#### **2.4.4 Relationship to Industry Standards**

ASHRAE 90.1 includes mandatory daylight dimming control requirements for sidelighting and toplighting in Section 9.4.1.1(e) and (f), respectively. For both sidelighting and toplighting, the controls must reduce lighting power continuously down to 20 percent and have an OFF setting. ASHRAE 90.1 has included daylighting dimming plus OFF requirement since 2013. ASHRAE 90.1-2019 requires automatic daylight dimming for all space types except guestrooms, interior parking areas, storage rooms less than 50 square feet, living quarters in dormitories, sleeping quarters in fire stations, facilities for the visually impaired, and imaging and operating rooms at

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<sup>5</sup> Daylit Zones are areas that are either under skylights or near windows that receive daylight. Skylit Daylit Zones are the areas that receive daylighting from skylights. Primary Sidelit Daylit Zones are areas next to windows that receive daylight. Secondary Sidelit Daylit Zones are areas that are close to windows but not directly adjacent to them. They still receive some daylight despite not being directly adjacent to windows. (CLTC, 2016. Nonresidential Lighting and Electrical Power Distribution)

healthcare facilities. For the sales area space type, automatic daylight dimming controls are required for skylit areas only, not sidelit areas.

## 2.5 Compliance and Enforcement

This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors. When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced.

The activities that need to occur during each phase of the project are described below. Automatic daylighting controls requirements have been in place since the 2005 code cycle and the proposed refinements to the requirements are minimal. Changes to the compliance process that has been in place for over a decade would be minimal.

- **Design Phase:** During the design phase, the lighting designer is responsible for ensuring automatic daylighting controls are incorporated into the design and specifying controls that meet the code requirements. The design team documents intent to comply in the NRCC-LTI-E Indoor Lighting Certificate of compliance document and other lighting design documents.
- **Permit Application Phase:** Plans examiner review design documents and confirm that the design complies with the daylighting control requirements.
- **Construction Phase:** The automatic daylighting controls are installed and commissioned during the construction phase. The details and capabilities of these controls are documented in NRCI-LTI-03-E, the Certificate of Installation for Energy Management Control System or Lighting Control System. If using the daylight dimming plus OFF power adjustment factor credit, details are documented on the NRCI-LTI-05 Power Adjustment Factors form. The controls must be programmed/configured so the system can automatically implement the control strategy that is tested during the acceptance test. A certified ATT conducts functional performance testing on the control system to complete required acceptance tests and the commissioning process. Automatic daylighting controls do require acceptance testing. The acceptance test procedure is described in Section 7.6.1 of the Nonresidential Appendix, Automatic Daylighting Controls Acceptance Tests. The proposed code change would make minor revisions to the protocol to account for the requirement to dim to 10 percent. The ATT completes the NRCA-LTI-03-A: Daylighting Control Acceptance Document a passing score on the acceptance test.

- **Inspection Phase:** The building inspector confirms acceptance tests were completed and the appropriate controls were installed to complete those tests by reviewing the NRCA documents during inspection.

## 3. Market Analysis

### 3.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The Statewide CASE Team then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders, including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on September 5, 2020 and March 3, 2020.

The market for daylighting control solutions, including luminaire level lighting controls (LLLCs), wired and wireless photocontrols, is well established in the United States (U.S.). Table 4 summarizes the market actors in the commercial lighting distribution chain.

**Table 4: Lighting Distribution Chain**

<b>Market Actor</b>	<b>Core Function</b>
Manufacturers	Production
Wholesale Distributors	Distribution of Product, Logistics, Financing
Manufacturer Representatives	Sales Generation
Electrical Contractors	Installation and Sales
Commercial End-Users	Decision Maker

A 2015 study conducted by Bonneville Power Administration characterized four distribution channels used by manufacturers to sell lighting products to end-users. The four channels include wholesale distribution, retail, online only, and direct distribution. Furthermore, both independent and in-house manufacturer representatives act as brokers for deals, thus playing an important role in the distribution chain (Bonneville Power Authority 2015). Table 5 summarizes the key points about each distribution channel.

**Table 5: Market Channels**

<b>Distribution Channel</b>	<b>Description</b>
Wholesale Distribution	<ul style="list-style-type: none"><li>• Dominant channel</li><li>• Not all inventory is physically stored at distributor site, some manufactures “drop-ship” directly from factory to project site</li></ul>
Retail	<ul style="list-style-type: none"><li>• Selling products through traditional retail facilities</li></ul>
Online Only	<ul style="list-style-type: none"><li>• Selling only through websites and shipping directly from a central warehouse</li><li>• Offering minimal customer service</li></ul>
Direct	<ul style="list-style-type: none"><li>• Smallest channel used by large customers</li><li>• Product direct to consumer without use of third-party representatives</li></ul>

Fixture manufacturers have been adding lighting controls to their product lines as the demand for lighting controls increases. With the advancement of solid-state lighting technology, which enables easier integration of lighting controls and opportunities to include non-lighting related features within a lighting system, manufacturers have been shifting the focus from stand-alone products, such as lamps and ballasts, to full-system offerings.

Some of the major manufacturers that offer lighting controls include Acuity Controls, CREE, Douglas Lighting Controls, Eaton Corporation, Echelon Corporation, Finelite, GE Lighting, Hubbell Control Solutions, Leviton, WattStopper, Lutron, Organic Response, OSRAM Encelium, Signify, PLC-Multipoint, Inc., Schneider Electric, and Sensor Switch, Inc.

Many of these large companies, along with emerging companies such as Daintree Networks, Digital Lumens, and Enlighted, offer photocontrols and occupancy controls as part of whole building energy management solutions.

A 2015 study conducted by the National Lighting Product Information Program (NLPPIP) noted that wireless lighting controls are available from more than 40 companies in the U.S. (National Lighting Product Information Program 2015). NLPPIP’s outreach to 152 lighting specifiers not associated with a particular manufacturer concluded that the most frequently selected brands of wireless lighting controls are Leviton, Lutron, and Legrand’s WattStopper.

The U.S. Energy Information Administration (EIA) conducted the 2012 Commercial Buildings Energy Consumption Survey (CBECS). According to the survey, the estimated adoption of occupancy and daylighting controls in U.S. is as follows:

- Daylighting controls are present in two percent of the U.S. buildings, but account for seven percent of total floor area, since larger buildings are more likely to have daylighting controls.

- Occupancy controls are present in 15 percent of the U.S. buildings, which account for 41 percent of total floor area (U.S. Energy Information Administration 2016).

In a U.S. Department of Energy (U.S. DOE) study released in 2016, 140 sources of published literature were reviewed to assess market penetration of and energy savings from lighting controls. This study made the following estimations for the 2015 installed lighting stock<sup>6</sup> penetration of lighting controls in the commercial sector:

- Daylighting controls are in less than one percent of installed fixtures in the U.S. commercial lighting stock.
- Occupancy controls are included in six percent of installed fixtures in the U.S. commercial lighting stock (DOE 2016).

The 2014 California Commercial Saturation (CSS) survey conducted by Itron and prepared for the California Public Utilities Commission, collected “information on the distribution of interior lamps by control type and the business’s participation in IOU EE (sic: energy efficient) lighting, EE lighting control, and DR (sic: demand response) registration” (Itron, Inc. 2014). The study found that “participants have a statistically significant smaller share of their lamps manually controlled than non-participants and a higher share of their lamps controlled by EMS (sic: energy management systems), occupancy sensors, motion sensors, photocells, and time clocks than non-participants” (Itron, Inc. 2014).

Table 6 describes the percentage of distribution of interior lamps with daylighting controls by business participants in IOU Energy Efficiency and Demand Response Programs. The data shows that few businesses utilize daylighting and other controls unless they participate in IOU Energy Efficiency and Demand Response Programs. Those businesses that utilize lighting control programs have the highest rate of adoption of daylighting and other controls. The data is based on an analysis of 1,730 surveyed sites.

**Table 6: Distribution of Indoor Lamps by Control Type and EE/DR Participation**

<b>Control Type</b>	<b>Non-Participants (percent)</b>	<b>EE Lighting Participants</b>	<b>EE Lighting Control Participants</b>	<b>DR Participants</b>
Daylighting and Other	0.1%	1.4%	2.9%	2.1%

Source: California Commercial Saturation, Itron.

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<sup>6</sup> Installed stock is presented the U.S. DOE’s study “in terms of lighting systems (lamp(s), ballast and fixture are counted as one unit)” (DOE 2016).



Although the 2012 CBECS, 2016 U.S. DOE study, and the 2014 CSS survey found different levels of adoption of occupancy and daylighting controls, all studies demonstrate that occupancy sensors and daylighting controls have a low penetration rate across the U.S. and reveal an opportunity for energy savings.

## **3.2 Technical Feasibility, Market Availability, and Current Practices**

### **3.2.1 Technical Feasibility and Market Availability**

To evaluate the technical feasibility and market availability of the proposed measure, an examination of the components of automatic daylighting control systems used to meet the current standard as compared to the proposed measure is useful. The typical components of automatic daylighting control systems are the:

- Photocell
- Daylighting logic controller
- Power controller
- Light source

Below is a discussion of each component of the daylighting control system and their ability to accommodate dimming to 10 percent and dimming plus OFF. According to staff interviewed at Acuity Brands, Lutron, CJS Lighting, Performance Lighting Systems, and one certified lighting controls acceptance test provider, the majority of daylight controls and integrated fixtures with daylight controls have the option to be configured to dim to 10 percent or dim plus OFF.

The Statewide CASE Team is conducting a survey to determine the market availability and current practices for daylight dimming controls, as well as to gather feedback on end-user acceptance of automatic daylighting controls with the OFF and 10 percent step. Results of the findings would be presented in the Final CASE Report.

#### **Photocell**

The photocell's function is to output a signal proportionate to the daylighting level in the space. The photocell equipment used to meet the current standard is also appropriate for the proposed measure. There is no expected change for the photocell for the proposed measure compared to the current standard.

#### **Daylighting Logic Controller**

The daylighting logic controller's function is to receive an input signal from the photocell and output an appropriate control signal to the lamp power controller. The daylighting logic controller equipment used to meet the current standard is also appropriate for the proposed measure. There is no expected change for the daylighting logic controller for the proposed measure compared to the current standard.

The combination of photocell and daylighting logic controller are referred to as the photosensor. The photosensor output determines the photocontrol.

As summarized in Table 7, there are three types of photocontrol products: wireless, wired, and wired stand-alone. All three types of photocontrols are widely available on the market. Wired products are most prevalent. Wireless controls are a popular choice in alterations as the increased cost of wireless systems often balance out with reduced need for wiring or drywall and similar renovation tasks.

**Table 7: Types of Photocontrol Products**

Type of Photocontrol	Description
Wireless Systems	Photosensor sends a wireless signal to a controller that turns off or dims lighting at the pre-determined setpoint(s)
Wired Stand-Alone Products	Photosensor sends a wired signal (line- or low-voltage) directly to the lighting to be turned OFF or dimmed
Wired Systems	Photosensor sends a wired signal (usually low-voltage) to a controller at the pre-determined setpoint(s); the controller then relays a control signal to the lighting to be turned OFF or dimmed

Daylight dimming control systems that use photosensors are typically configured using one of three options: open-loop, closed-loop, and hybrid systems employing both open and closed-loop system concepts. Each of these configurations are described below:

- **Open-loop systems** orient the photosensor to sense daylight only and adjust the electric light accordingly. An open-loop system would respond only to changes in daylight and may not accurately respond to actual light levels in the interior space.
- **Closed-loop systems** orient the photosensor to sense both daylight and electric lighting contributions. However, the photosensor is limited to a single zone and the system is unable to distinguish transient light level changes in daylight from occupant interference or reflectance shift. Thus, closed-loop systems are most appropriate in skylit zones with high bay lighting, where occupant interference and reflectance shift are minimal.
- **Hybrid systems** combine open-loop and closed-loop systems into a system with a proprietary name, such as “partial open loop” by Lutron or “dual loop systems” licensed to Legrand’s WattStopper. Since these systems combine the algorithms of closed-loop and open-loop systems, they are less reactive to reflectance shift.

The photocontrols are integrated into system-level controls or LLLCs. Both system-level control options and LLLC solutions are available from multiple distribution channels. When first released, LLLCs were primarily marketed for office spaces. Applications have grown to include warehouses and high bay application and connectivity with non-LLLC luminaires for customized granularity.

Dimming control strategies are summarized in Table 8. The controls method used most frequently to control daylighting dimming controls is 0-10VDC, for which the average time delay before dimming is two to six minutes of continuous lumen input from lighting in the space. The most common strategies for daylight dimming controls are 0-10 Volt direct current ( $V_{DC}$ ) and digital, including Digital Addressable Lighting Interface (DALI) due to the controls compatibility to dim fluorescent and LEDs without major flickering issues. Forward and reverse phase dimming is used for incandescent and fluorescent technology and can cause drop-out, flickering, and other lighting quality issues.

**Table 8: Types of Dimming Control Strategies**

Type of Photocontrol	Description
0-10 $V_{DC}$	Analog controller adjusts the voltage from 0-10 volts (V) with the low voltage wire pair connecting the controller to one or more LED drivers. There is no industry-wide standard for low end cutoff, which varies from OFF to ten percent of full lighting output.
Digital, including Digital Addressable Lighting Interface (DALI)	A standard for digital control of individual fixtures via a low voltage communication protocol comprising of a single set of control wires form a low-voltage control bus. The digital control can send information to light fixtures while also receiving information from the fixtures. DALI protocol provides 254 levels of brightness between OFF and 100 percent of full lighting output.
Two-Wire Forward Phase	Reverse phase dimming controls the amount of voltage delivered to the fixture by turning off part of the trailing edge of the sine wave for a preset amount of time resulting in reduced lamp output. Forward phase uses the leading edge of the sine wave. The low-end cutoff is usually around 15 percent of full lighting output; some go as low as one percent of full lighting output.
Two-Wire Reverse Phase	Dimmer controls the voltage delivered by turning off part of the trailing edge of the sine wave for a preset time. Tends to offer a flicker-free dimming experience for Electronic Low Voltage (ELV) transformers and common LED drivers.

### Lamp Power Controller and Lamp

The market share of different lamp types has changed since the analysis for the current standard was performed. The daylighting requirements adopted into the current standard was conducted in 2011, based on T8 fluorescent lamp fixtures (California

Utilities Statewide Codes and Standards Team 2011). At that time, T8 fluorescent lamps were approximately 45 percent of the commercial building market (Navigant Consulting, Inc. 2012). By 2021 LEDs are predicted to have 52 percent of the market (Pike Research 2019). Given that LEDs would have even more market share than T8 fluorescents had when they were used to justify an update to the standard, it is judged appropriate to base the 2022 lamp power controller on LEDs.

### **3.2.2 Market Acceptance of Dimming Plus OFF**

As discussed in Section 2.2, stakeholders have expressed concern about building occupant acceptance of daylight dimming plus OFF controls. To date, the Statewide CASE Team has not received substantive quantitative or qualitative findings. The Statewide team continues to reach out to stakeholders and encourages feedback. Further findings will be presented in the Final CASE Report.

While daylighting controls with the OFF step are not widely deployed in California, two large retail chains – Walmart and COSTCO – specified daylighting controls with the OFF step in their stores as a standard practice. Walmart and COSTCO lighting fixtures turn OFF when the daylight illuminance exceeds the design illuminance. COSTCO stores began integrating daylighting controls and skylights in the late 1980s. Walmart has over 1,000 stores with skylights and daylighting controls while COSTCO has over 250 stores with skylights and daylighting controls. As of 2019, Walmart is dimming to 50 percent, this does add energy costs and is expected to revert back to dim plus OFF in the next year.

## **3.3 Market Impacts and Economic Assessments**

### **3.3.1 Impact on Builders**

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 9).<sup>7</sup> In 2018, total payroll was \$80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The

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<sup>7</sup> Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

**Table 9: California Construction Industry, Establishments, Employment, and Payroll**

<b>Construction Sectors</b>	<b>Establishments</b>	<b>Employment</b>	<b>Annual Payroll (\$)</b>
<b>Residential</b>	<b>59,287</b>	<b>420,216</b>	<b>\$23.3</b>
Residential Building Construction Contractors	22,676	115,777	\$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	\$3.6
Building Equipment Contractors	14,444	105,441	\$6.0
Building Finishing Contractors	15,544	123,778	\$6.2
<b>Commercial</b>	<b>17,273</b>	<b>343,513</b>	<b>\$27.8</b>
Commercial Building Construction	4,508	75,558	\$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	\$3.7
Building Equipment Contractors	6,015	128,812	\$10.9
Building Finishing Contractors	4,597	85,612	\$6.2
<b>Industrial, Utilities, Infrastructure, &amp; Other</b>	<b>4,103</b>	<b>96,550</b>	<b>\$9.2</b>
Industrial Building Construction	299	5,864	\$0.5
Utility System Construction	1,643	47,619	\$4.3
Land Subdivision	952	7,584	\$0.9
Highway, Street, and Bridge Construction	770	25,477	\$2.4
Other Heavy Construction	439	10,006	\$1.0

It is expected that builders would not be impacted significantly by any one proposed code change or the collective effect of all the proposed changes to Title 24, Part 6. Builders could be impacted by changes in demand for new buildings and construction costs. Demand for new buildings is driven more by factors such as the overall health of the economy and population growth than the cost of construction. The cost of complying with Title 24, Part 6 requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on demand for new buildings or the builders' profits.

Builders would need to invest in training and education to ensure the workforce, including designers, acceptance technicians, engineers, and contractors know how to comply with the proposed requirements. Workforce training is not unique to the building industry and is common in many fields associated with the production of goods and services. Costs associated with workforce training are typically accounted for in long-

term financial planning and spread out across the unit price of many units as to avoid price spikes when changes in designs and/or processes are implemented.

### **3.3.2 Impact on Building Designers and Energy Consultants**

Mandatory daylighting controls were first introduced in the 2005 Title 24, Part 6 code cycle, making this type of control a standard practice in nonresidential buildings. The proposals included in this Draft CASE Report enhance existing daylighting control requirements. The Statewide CASE Team's market research found that daylight harvesting systems available on the market already include the capability to dim to 10 percent or turn the lighting OFF.

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building Standards Code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials and ASHRAE 90.1) are typically updated on three-year revision cycles. As discussed in Section 3.3.1, all market actors should, and do, plan for training and education needed to update design practices to comply with new building codes. As a whole, the measures the Statewide CASE Team is proposing for the 2022 code cycle aims to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility in how requirements can be met.

### **3.3.3 Impact on Occupational Safety and Health**

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building. Impact on Building Owners and Occupants

Building owners and occupants would benefit from lower energy bills. As discussed in Section 3.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2019 code cycle to impact building owners or occupants adversely.

### **3.3.4 Impact on Building Component Retailers (Including Manufacturers and Distributors)**

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses



(including refrigerated). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California’s total annual energy use. The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

The Statewide CASE Team interviewed manufacturers and concluded that the proposed changes would not significantly impact companies who manufacture, distribute, or sell lighting controls. Refer to Section 3.4.2 for more information.

### 3.3.5 Impact on Building Inspectors

The proposed code changes would have a minimal impact on the existing inspection application process. The Statewide CASE Team identified current lighting inspection forms and tables which would need to be updated in Section 7.6. Building inspectors and acceptance testers would need to be trained on the new control requirements as well as the field verified process through acceptance testing.

### 3.3.6 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to Title 24, Part 6. Installing lighting controls is a normal task in nonresidential buildings.

Table 10 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

**Table 10: Employment in California State and Government Agencies with Building Inspectors**

<b>Sector</b>	<b>Govt.</b>	<b>Establishments</b>	<b>Employment</b>	<b>Annual Payroll (millions \$)</b>
Administration of Housing Programs <sup>a</sup>	State	17	283	\$29.0
	Local	36	2,882	\$205.7
Urban and Rural	State	35	552	\$48.2



Development Admin <sup>b</sup>	Local	52	2,446	\$186.6
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### 3.3.7 Impact on Statewide Employment

As described in Sections 3.3.1 through 3.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.4, the Statewide CASE Team estimated the proposed change in daylight dimming to 10 percent would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in daylight dimming to 10 percent would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

## 3.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes. While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by architects, energy consultants, and building inspector in commercial building industry. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

### 3.4.1 Creation or Elimination of Jobs

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

Building codes that reduce energy consumption provide jobs through direct employment, indirect employment, and induced employment.<sup>8</sup> Title 24, Part 6 creates jobs in all three categories with a significant quantity of these attributed to induced employment, which accounts for the expenditure induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by energy cost savings from energy efficiency measures. Wei, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years<sup>9</sup> per GWh saved. By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. Using the mid-point for the energy efficiency range (0.38 net job-years per GWh saved) and estimates that this proposed code change would result in a statewide first-year savings of 55.5 GWh, this measure would result in approximately 21.1 jobs created in the first year. See Table 20 for statewide savings estimates.

The daylighting proposal would have marginal impact on labor hours as daylighting controls are already required in most projects.

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<sup>8</sup> The definitions of direct, indirect, and induced jobs vary widely by study. Wei et al (2010) describes the definitions and usage of these categories as follows: "Direct employment includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. Indirect employment refers to the "supplier effect" of upstream and downstream suppliers. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. Induced employment accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees, e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers."

<sup>9</sup> One job-year (or "full-time equivalent" FTE job) is full time employment for one person for a duration of one year.

### **3.4.2 Creation or Elimination of Businesses in California**

As stated in Section 3.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to daylight dimming to 10 percent which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

### **3.4.3 Competitive Advantages or Disadvantages for Businesses in California**

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is incorporated inside or outside of the state.<sup>10</sup> Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

### **3.4.4 Increase or Decrease of Investments in the State of California**

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).<sup>11</sup> As Table 11 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

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<sup>10</sup> Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

<sup>11</sup> Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

**Table 11: Net Domestic Private Investment and Corporate Profits, U.S.**

<b>Year</b>	<b>Net domestic investment: Private: Domestic business, Billions of Dollars</b>	<b>Corporate Profits After Tax (without IVA and CCAAdj), Billions of Dollars</b>	<b>Ratio of Net Private Investment to Corporate Profits</b>
2000	536.886	513.164	105%
2001	341.373	518.939	66%
2002	256.813	627.911	41%
2003	253.600	756.378	34%
2004	347.990	979.169	36%
2005	415.630	1285.370	32%
2006	490.113	1413.731	35%
2007	506.331	1359.859	37%
2008	376.756	1123.169	34%
2009	-69.106	1263.326	-5%
2010	171.732	1561.483	11%
2011	269.331	1537.152	18%
2012	426.619	1821.235	23%
2013	495.274	1788.739	28%
2014	579.438	1857.164	31%
2015	609.245	1740.349	35%
2016	455.980	1739.838	26%
2017	509.276	1813.552	28%
2018	618.247	1843.713	34%
2019	580.849	1826.971	32%
<b>Average 2015-2019</b>			<b>31%</b>

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

The proposed code changes are not expected to have a significant impact on the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are personal income taxes, corporation taxes, sales and use taxes, and property taxes. The proposed changes for the 2022 Title 24, Part 6 Standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected

to change. Reductions in energy expenditures are expected to increase discretionary income. State and local sales tax revenues may increase if building occupants spend their additional discretionary income on taxable items. Although logic indicates there may be changes to sales tax revenue, the impacts that are directly related to revisions to Title 24, Part 6 have not been quantified. Finally, revenue generated from property taxes is directly linked to the value of the property, which is usually linked to the purchase price of the property. The proposed changes would likely increase construction costs, but there is no statistical evidence that the increased construction cost associated with Title 24, Part 6 compliance impacts building purchase prices.

### **3.4.6 Impacts on Specific Persons**

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters, or persons by age, race, or religion. Given that construction costs are not well correlated with building prices, the proposed code changes are not expected to have an impact on financing costs for business.

Renters would typically benefit from lower energy bills if they pay energy bills directly. These savings should more than offset any capital costs passed through from landlords. Renters who do not pay directly for energy costs may see some net savings depending on if and how landlords account for energy costs when determining rent prices.

## 4. Energy Savings

### 4.1 Key Assumptions for Energy Savings Analysis

To calculate energy savings, the Statewide CASE Team used building energy modeling software to simulate energy savings associated with dimming to 35 percent versus 10 percent in prototypical buildings. The next section describes the methodology in detail. The only key assumption is a change in the lighting power in dimmed conditions. Energy savings were modeled using the 2019 Title 24, Part 6 lighting power densities. The mandatory automatic daylighting control requirements apply to skylit and primary sidelit areas.

Table 12 details the total area of skylit, primary sidelit, and secondary sidelit daylit zones within each building prototype that was used in the analysis.

An energy and cost-effectiveness analysis using the methodology accepted by the Energy Commission in order to consider a code change proposal is not needed to move the prescriptive requirements for automatic daylighting controls in SDZs to the mandatory section. This submeasure was already proven to be cost effective in order to be added to the prescriptive requirements (California Utilities Statewide Codes and Standards Team 2011).

### 4.2 Energy Savings Methodology

#### 4.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used to develop per unit savings for new construction, additions, and alterations are presented in Table 12. The hospital prototypes is listed in Table 12, but their impacts are not presented in this report. The Final CASE Report will include the impacts of hospitals. The proposed code change will apply to grocery stores, but the prototype for grocery stores does not include any daylit space which results in no measured savings. However, a percentage of grocery stores do have daylit spaces. The Statewide CASE Team will determine how to estimate savings for grocery stores and will include in the Final CASE Report.

**Table 12: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis**

Prototype Name	Number of Stories	Floor Area (ft <sup>2</sup> )	Description	Areas with Daylighting	Total Area of Skylit Daylit Zone (ft <sup>2</sup> )	Total Area of Primary Sidelit Daylit Zone (ft <sup>2</sup> )	Total Area of Secondary Sidelit Daylit Zone (ft <sup>2</sup> )	Percent of Total Building Area in Affected Daylit Zones	Total Affected Area of Daylit Zones (ft <sup>2</sup> )
Assembly	1	34,007	5-zone assembly building DEER prototype model provided by SCE	Office Zones	0	9,834	7,229	28.90%	9,834
Small Hotel	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%	Front Lounge, Offices and Meeting Rooms	0	2,023	2,023	4.80%	2,023
OfficeLarge	12	498,589	12 story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-0.40	Perimeter Zones	0	24,706	19,660	5.00%	24,706
OfficeMedium	3	53,628	3 story office building with 5 zones and a ceiling plenum on each floor. WWR-0.33	Perimeter Zones	0	11,784	10,074	22.00%	11,784
OfficeSmall	1	5,502	1 story, 5 zone office building with pitched roof and unconditioned attic. WWR-0.24	Perimeter Zones	0	2,022	1,520	34.80%	2,022
RestaurantFastFood	1	2,501	Fast food restaurant with a small kitchen and dining areas. 14%	Dining Area	0	566	396	38.40%	962



Prototype Name	Number of Stories	Floor Area (ft <sup>2</sup> )	Description	Areas with Daylighting	Total Area of Skylit Daylit Zone (ft <sup>2</sup> )	Total Area of Primary Sidelit Daylit Zone (ft <sup>2</sup> )	Total Area of Secondary Sidelit Daylit Zone (ft <sup>2</sup> )	Percent of Total Building Area in Affected Daylit Zones	Total Affected Area of Daylit Zones (ft <sup>2</sup> )
			WWR. Pitched roof with an unconditioned attic.						
RetailLarge	1	240,000	Big-box type Retail building with WWR - 12% and SRR-0.82%	Front Entry Area, Perimeter Zones	167,928	4,621	2,176	71.90%	172,549
RetailMixed Use	1	9,375	Retail building with WWR -10%. Roof is adiabatic	Front Entry Area	0	995	1,000	10.60%	995
RetailStand Alone	1	24,563	Similar to a Target or Walgreens.7% WWR on the front façade, none on other sides. SRR of 2.1%.	Retail Areas, Point Sale	16,743	1,550	1,459	6.90%	16,743
RetailStripMall	1	9,375	Strip Mall building with WWR -10%	Front Entry Space	0	995	1,000	10.60%	995
SchoolPrimary	1	24,413	Elementary school with WWR of 0.36	Lobby, Corridor, Cafeteria	0	8,504	7,813	34.80%	8,504
SchoolSecondary	2	210,866	High school with WWR of 35% and SRR 1.4%	All areas	34,551	33,340	30,952	32.20%	67,891
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR- 0.7%, SRR-5%	All Areas	45,117	539	421	92.20%	454,578

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using EnergyPlus 9.01 and 2022 Research Version of the California Building Energy Code Compliance (CBECC) software for commercial buildings (CBECC-Com). Since CBECC-Com does not allow for adjustment of the dimming fraction in daylighting controls, energy impacts were simulated by modifying the baseline EnergyPlus file generated by CBECC-Com and running the modified input file in EnergyPlus.

CBECC-Com generates two models based on user inputs: the Standard Design and the Proposed Design.<sup>12</sup> The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building. There is an existing Title 24, Part 6 requirement that covers the building system in question and applies to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24 requirements that specify the general lighting power shall reduce to 35 percent or less when illuminance in the space reaches 150 percent design illuminance.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 13 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume that the general lighting power is reduced to 10 percent instead of 35 percent in skylit and primary daylight areas. Continuous dimming controls have a fraction of rated power to fraction of rated light output that is a linear interpolation of the minimum power fraction at the minimum dimming light fraction to rated power (power fraction = 1.0) at full light output (CEC 2019).

Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2019 Title 24, Part 6 requirements.

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<sup>12</sup> CBECC-Res also creates a third model, the Reference Design, that represents a building similar to the Proposed Design, but with construction and equipment parameters that are minimally compliant with the 2006 International Energy Conservation Code (IECC). The Statewide CASE Team did not use the Reference Design for energy impacts evaluations.

**Table 13: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change**

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
All Prototypes	All	Minimum Input Power Fraction	0.35	0.10
All Prototypes	All	Minimum Light Output Fraction	0.35	0.10

CBECC-Com calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). As part of this process, CBECC-Com calculates how much daylight is available for the prototypes in each climate zone and adjusts the amount of power (based on dimming in response to available daylight). Therefore, the whole-building energy consumption is based on both the amount of time the electric lighting is on and much the electric light is dimmed in response to available daylight. It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). CBECC-Com also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV\$) and nominal dollars.

The energy impacts of the proposed code change vary by climate zone. Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

Per-unit energy impacts for nonresidential buildings are presented as savings per square foot of total building floor area. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the entire floor area of the prototype building.<sup>13</sup> This step allows for an easier comparison of savings across different building types and enables calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

#### **4.2.2 Statewide Energy Savings Methodology**

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission n.d.). The Statewide Construction Forecasts estimate new

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<sup>13</sup> For the 2019 code cycle, the Statewide CASE Team presented savings per square foot of daylit space. For the 2022 code cycle, the Statewide CASE Team is presenting savings per square foot of total building floor area to be consistent with all other proposed changes for this code cycle.

construction occurring in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023 that the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The building types used in the construction forecast, Building Type ID, are not identical to the prototypical building types available in CBECC-Com. The Energy Commission provided guidance on which prototypical buildings to use for each Building Type ID when calculating statewide energy impacts. Table 14 presents the prototypical buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

**Table 14: Nonresidential Building Types and Associated Prototype Weighting**

<b>Building Type ID from Statewide Construction Forecast</b>	<b>Building Prototype for Energy Modeling</b>	<b>Weighting Factors for Statewide Impacts Analysis</b>
Small Office	OfficeSmall	100%
Large Office	OfficeMedium	50%
Large Office	OfficeLarge	50%
Restaurant	RestaurantFastFood	100%
Retail	RetailStandAlone	10%
Retail	RetailLarge	75%
Retail	RetailStripMall	5%
Retail	RetailMixedUse	10%
Grocery Store	Grocery	100%
Non-Refrigerated Warehouse	Warehouse	100%
Refrigerated Warehouse	RefrigWarehouse	N/A
Schools	SchoolPrimary	60%
Schools	SchoolSecondary	40%
Colleges	OfficeSmall	5%
Colleges	OfficeMedium	15%
Colleges	OfficeMediumLab	N/A
Colleges	PublicAssembly	5%
Colleges	SchoolSecondary	30%
Colleges	ApartmentHighRise	25%
Hospitals <sup>a</sup>	Hospital	100%
Hotel/Motels	HotelSmall	100%

### 4.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per square foot of total building floorspace are presented in Table 15 and represent savings from new construction and alterations/additions. This table presents the average impacts across all prototypical buildings that were included in the analysis. See Appendix H for results from each prototypical building independently. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. The average per-unit savings for the first-year electricity and peak demand reductions are expected to range from 0.09 to 0.11 kWh/yr depending on climate zone.

**Table 15: First-Year Energy Impacts Per Square Foot – Average of All Prototype Building**

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/ft2)	TDV Energy Savings (TDV kBtu/yr)
1	0.09	0.00	-0.00	1.16
2	0.09	0.00	-0.00	1.73
3	0.09	0.00	-0.00	1.82
4	0.09	0.00	-0.00	1.69
5	0.09	0.00	-0.00	1.61
6	0.10	0.00	-0.00	1.91
7	0.09	0.00	-0.00	1.80
8	0.10	0.00	-0.00	2.17
9	0.09	0.00	-0.00	2.17
10	0.09	0.00	-0.00	2.07
11	0.09	0.00	-0.00	1.89
12	0.09	0.00	-0.00	1.76
13	0.10	0.00	-0.00	2.22
14	0.10	0.00	-0.00	2.27
15	0.11	0.00	-0.00	2.64
16	0.09	0.00	-0.00	1.29

## 5. Cost and Cost Effectiveness

### 5.1 Energy Cost Savings Methodology

As of the Draft CASE Report's date of publication, the Energy Commission has not released the final 2022 TDV factors that are used to evaluate TDV energy savings and cost effectiveness. The energy and cost analysis presented in this report used the TDV factors that are consistent with the TDV factors presented during the Energy Commission's March 27, 2020 workshop on compliance metrics (California Energy Commission 2019). The electricity TDV factors include the 15 percent retail adder and the natural gas TDV factors include the impact of methane leakage on the building site. The electricity TDV factors used in the energy savings analyses were obtained via email from Energy and Environmental Economics, Inc. (E3), the contractor that is developing the 2022 TDV factors for the Energy Commission, in a spreadsheet titled "Electric TDVs 2022 - 15 pct Retail Adj Scaled by Avoided Costs.xlsx". The natural gas TDV factors used in the energy savings analyses were obtained via email from E3 in a spreadsheet titled "2022\_TDV\_Policy\_Compliant\_CH4Leak\_FlatRtlAdd\_20191210.xlsx". The electricity demand factors used in the energy savings analysis were obtained via email from E3 in a spreadsheet titled "2022 TDV Demand Factors.xlsx". The Energy Commission notified the Statewide CASE Team on April 21, 2020 that they were investigating further refinements to TDV factors using 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. It is anticipated that the 20-year GWP values will increase the TDV factors slightly. As a result, the TDV energy savings presented in this report are lower than the values that are expected if the final TDV use 20-year GWP values, and the proposed code changes will be more cost effective using the revised TDV. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

When the Energy Commission releases the final TDV factors, the Statewide CASE Team will consider the need to re-evaluate energy savings and cost-effectiveness analyses using the final TDV factors for the results that will be presented in the Final CASE Report.

The Energy Commission is developing a source energy metric (energy design rating or EDR 1) for the 2022 code cycle. As of the date this Draft CASE Report was published, the source energy metric has not been finalized and the Energy Commission has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years.

## 5.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in 2023 present value dollars in Table 16. This table presents the average impacts across all prototypical buildings that were included in the analysis. See Appendix H for results from each prototypical building independently. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

**Table 16: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – Average of All Prototype Building – New Construction and Alterations**

Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV\$)	15-Year TDV Natural Gas Cost Savings (2023 PV\$)	Total 15-Year TDV Energy Cost Savings (2023 PV\$)
1	\$0.15	-\$0.05	\$0.10
2	\$0.18	-\$0.03	\$0.15
3	\$0.19	-\$0.03	\$0.16
4	\$0.17	-\$0.02	\$0.15
5	\$0.17	-\$0.02	\$0.14
6	\$0.18	-\$0.01	\$0.17
7	\$0.17	-\$0.01	\$0.16
8	\$0.21	-\$0.01	\$0.19
9	\$0.21	-\$0.01	\$0.19
10	\$0.20	-\$0.01	\$0.18
11	\$0.19	-\$0.02	\$0.17
12	\$0.18	-\$0.02	\$0.16
13	\$0.22	-\$0.02	\$0.20
14	\$0.22	-\$0.02	\$0.20
15	\$0.24	-\$0.01	\$0.23
16	\$0.15	-\$0.04	\$0.12



### 5.3 Incremental First Cost

There are no incremental first cost of the proposed code changes. To evaluate the incremental first cost of a proposed measure, the Statewide CASE Team first determined the daylighting control component costs for both the current code requirements and the proposed code requirements.

The components of a daylighting control system include:

- Photocell;
- Daylighting logic controller; and
- Lamp power controller

The cost of the lamp is not included because the proposed code change does not impact the lamps or wattage requirements in the daylit space.

The photocell's function is to output a signal proportionate to the daylighting level in the space. The photocell equipment used to meet the current standard is also appropriate for the proposed measure. There is no increase in cost associated with the photocell for the proposed measure compared to the current standard.

The daylighting logic controller's function is to receive an input signal from the photocell and output an appropriate control signal to the lamp power controller. The daylighting logic controller equipment used to meet the current standard is also appropriate for the proposed measure. There is no increase in cost associated with the daylighting logic controller for the proposed measure compared to the current standard.

As discussed above in Section 3.2.1, LEDs would be a significant portion of the market when the 2022 standards take effect. As shown in Table 17 in the current code, LEDs are required to have dimming drivers that reduce lighting power to at least 10 percent of full power in the current standard. This means that the market would already be using lamp power controllers capable of dimming to 10 percent. Therefore, there is no cost increase for the lamp power controller for the proposed measure. Lamp power controllers that dim to 10 percent (i.e. dimming drivers for LEDs) would already have a market share greater than that used to justify the current standard, so requiring those controllers would not in general increase the cost of most projects.

Although the capability to dim to 10 percent from daylighting would be standard practice by the time the 2022 standards take effect, energy savings can still be claimed because the implementation of that capability is not a foregone conclusion without the adoption of the proposed requirement. Without a requirement to dim to 10 percent via daylighting controls, projects may choose to maintain higher levels of light in the space by dimming only to 35 percent, meeting the current requirements, even when there is sufficient daylight to dim to 10 percent and the multi-level controls capable of doing this are installed.

Although the change in lamp type is not included in the first cost of components, it may affect the technology used in the lamp power controller. The market share of different lamp types has changed since the analysis for the current standard was performed. The daylighting requirements adopted into the current standard were based on T8 fluorescent lamp fixtures (California Utilities Statewide Codes and Standards Team 2011). The cost-effectiveness analysis supporting these requirements was done in 2011. At that time T8 fluorescent lamps were approximately 45 percent of the commercial building market (Navigant Consulting, Inc. 2012). By 2021 LEDs are predicted to have 52 percent of the market (Pike Research 2019). Given that LEDs would have even more market share than T8 fluorescents had when they were used to justify an update to the standard, and this measure would largely affect new construction, it is judged appropriate to base the 2022 lamp power controller on LEDs.

The lamp power controller technology used to dim LEDs is different than that used to dim fluorescents. Fluorescents use dimming ballasts while LEDs use drivers. There is a cost difference associated with these two technologies, but it is not needed in the cost effectiveness analysis because LEDs with the capability to dim to 10 percent would already be standard practice.

In summary, there are not incremental first cost because:

- **Photocell:** there is no change in equipment from the current requirements.
- **Daylighting logic controllers:** there is no change in equipment from the current requirements.
- **Lamp power controllers:** lamp power controllers that dim to 10 percent would be standard practice when the 2022 standards take effect.

The Statewide CASE Team reviewed this assumption with stakeholders during the utility-sponsored stakeholder meetings and heard no objections to this assumption.

**Table 17: Table 130.1-A Multi-Level Lighting Controls and Uniformity Requirements**

<b>Luminaire Type</b>	<b>Minimum Required Control Steps (percent of full rated power<sup>a</sup>)</b>	<b>Uniform level of illuminance shall be achieved by:</b>
Line-voltage sockets except GU-24	Continuous dimming 10-100%	Continuous dimming 10-100%
Low-voltage incandescent systems	" "	" "
LED luminaires and LED source systems	" "	" "
GU-24 rated for LED	" "	" "
GU-24 sockets rated for fluorescent > 20 watts	Continuous dimming 20-100%	Continuous dimming 20-100%
Pin-based compact fluorescent > 20 watts <sup>b</sup>	" "	" "
GU-24 sockets rated for fluorescent ≤ 20 watts	Minimum one step between 30-70%	<ul style="list-style-type: none"> <li>• Stepped dimming; or</li> <li>• Continuous dimming; or</li> <li>• Switching alternate lamps in a luminaire.</li> </ul>
Pin-based compact fluorescent ≤ 20 watts <sup>b</sup>	" "	" "
Linear fluorescent and U-bent fluorescent ≤ 13 watts	" "	" "
Linear fluorescent and U-bent fluorescent > 13 watts	Minimum one step in each range: <ul style="list-style-type: none"> <li>• 20-40%</li> <li>• 50-70%</li> <li>• 75-85%</li> <li>• 100%</li> </ul>	<ul style="list-style-type: none"> <li>• Stepped dimming; or</li> <li>• Continuous dimming; or</li> <li>• Switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire illuminating the same area and in the same manner.</li> </ul>
Track Lighting	Minimum one step between 30 – 70%	<ul style="list-style-type: none"> <li>• Step dimming; or</li> <li>• Continuous dimming; or</li> <li>• Separately switching circuits in multi-circuit track with a minimum of two circuits.</li> </ul>
HID > 20 watts	" "	" "
Induction > 25 watts	" "	" "
Other light sources	" "	" "

a. Full rated input power of ballast and lamp, corresponding to maximum ballast factor.

b. Includes only pin based lamps: twin tube, multiple twin tube, and spiral lamps

**EXCEPTION 1 to Table 130.1-A Minimum Required Control Steps:** Classrooms with a connected general lighting load of 0.7 watts per square feet or less shall have a minimum of one control step between 30-70 percent of full rated power, regardless of luminaire type.

**EXCEPTION 2 to Table 130.1-A Minimum Required Control Steps:** Library stack aisles, aisle ways

and open areas in warehouses, parking garages, parking areas, loading and unloading areas, stairwells, and corridors shall have a minimum of one control step between 20-60 percent of full rated power, regardless of luminaire type.

## 5.4 Incremental Maintenance and Replacement Costs

There are no incremental maintenance or replacement costs associated with this measure. A control system that is capable to reduce lighting power to 35 percent (current code) and 10 percent (proposed code) requires the same maintenance and replacements. As such, there are no incremental costs associated with the proposed code change.

The Statewide CASE Team reviewed this assumption with stakeholders during the utility-sponsored stakeholder meetings and heard no objections to this assumption.

## 5.5 Cost Effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis.

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings were also included in the evaluation. Design costs were not included, nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

As discussed above, there are no costs associated with the proposed code changes. Since reducing lighting power to 10 percent yields energy cost savings in all building types and climate zones, the proposed code change has an infinite B/C ratio in all climate zones. See the energy cost savings (benefit) of the proposed code change by building type and climate zone in Appendix H.

## 6. First-Year Statewide Impacts

### 6.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 4.3, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

The Statewide CASE Team assumed that the renovation rate of lighting fixtures in existing building stock is ten percent per year. This assumption is based on the U.S. DOE's lighting market model, which "covers all upgrades/retrofits and renovations, regardless of their impetus, representing replacements that occur prior to the failure of the existing lighting fixture" (Department of Energy 2016).

The current energy code (2019 Title 24, Part 6, Section 141.0 I and J) offers three options to comply with the nonresidential lighting alteration requirements. Only one of the three available compliance options, referred to as "85-100 percent of LPD allowance" in this report, requires automatic daylighting controls.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Per-unit energy savings were normalized area, the results are scaled to the statewide affected floor stock of considered building types.

Table 18 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 19 presents the first-year statewide energy and energy cost savings from alterations to buildings by climate zone.

Table 20 presents first-year statewide savings from new construction, additions, and alterations.

**Table 18: Statewide Energy and Energy Cost Impacts – New Construction**

<b>Climate Zone</b>	<b>Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)</b>	<b>First-Year<sup>a</sup> Electricity Savings (GWh)</b>	<b>First-Year Peak Electrical Demand Reduction (MW)</b>	<b>First-Year Natural Gas Savings (million therms)</b>	<b>15-Year Present Valued Energy Cost Savings (PV\$ million in 2023)</b>
1	0.61	0.05	0.00	-0.00	\$0.06
2	3.62	0.33	0.00	-0.00	\$0.58
3	17.15	1.51	0.01	-0.02	\$2.66
4	8.83	0.73	0.00	-0.01	\$1.39
5	1.71	0.15	0.00	-0.00	\$0.25
6	11.89	1.10	-0.01	-0.00	\$1.69
7	8.82	0.85	0.00	-0.00	\$1.55
8	17.11	1.58	0.00	-0.01	\$3.13
9	28.13	2.64	0.02	-0.01	\$5.47
10	15.80	1.69	0.01	-0.01	\$3.49
11	3.31	0.33	0.00	-0.00	\$0.63
12	18.34	1.69	0.00	-0.02	\$3.02
13	6.48	0.65	0.00	-0.01	\$1.28
14	3.68	0.37	0.00	-0.00	\$0.77
15	2.25	0.25	0.00	-0.00	\$0.52
16	1.16	0.11	0.00	-0.00	\$0.15
<b>TOTAL</b>	<b>148.89</b>	<b>14.04</b>	<b>0.05</b>	<b>-0.09</b>	<b>\$26.64</b>

a. First-year savings from all buildings completed statewide in 2023.

**Table 19: Statewide Energy and Energy Cost Impacts – Alterations**

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023	First-Year <sup>a</sup> Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (PV\$ million in 2023)
1	1.84	0.15	0.00	-0.00	\$0.18
2	10.96	1.00	0.00	-0.01	\$1.79
3	51.29	4.56	0.03	-0.05	\$8.06
4	26.32	2.22	0.00	-0.02	\$4.21
5	5.20	0.46	0.00	-0.00	\$0.75
6	38.90	3.69	-0.03	-0.01	\$5.70
7	28.69	2.78	0.01	-0.01	\$5.02
8	55.48	5.26	0.01	-0.02	\$10.41
9	89.39	8.63	0.05	-0.04	\$17.84
10	56.32	6.10	0.03	-0.03	\$12.57
11	10.49	1.06	0.00	-0.01	\$2.01
12	55.01	5.09	0.01	-0.05	\$9.11
13	20.43	2.09	0.01	-0.02	\$4.08
14	12.81	1.32	0.01	-0.01	\$2.74
15	7.84	0.88	0.01	-0.00	\$1.84
16	3.94	0.38	0.00	-0.01	\$0.51
<b>TOTAL</b>	<b>474.92</b>	<b>45.66</b>	<b>0.16</b>	<b>-0.28</b>	<b>\$86.83</b>

a. First-year savings from all buildings completed statewide in 2023.

**Table 20: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions**

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	15-Year Present Valued Energy Cost Savings (PV\$ million in 2023)
New Construction	14	0.05	-0.09	26.6
Additions and Alterations	46	0.16	-0.28	86.8
<b>TOTAL</b>	<b>60</b>	<b>0.21</b>	<b>-0.37</b>	<b>113.47</b>

a. First-year savings from all alterations completed statewide in 2023.



## 6.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard goal of 33 percent renewable electricity generation by 2020.<sup>14</sup> Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions.

Table 21 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 25,217 metric tonnes of carbon dioxide equivalents (metric tonnes CO<sub>2</sub>e) would be avoided.

**Table 21: First-Year Statewide GHG Emissions Impacts**

<b>Measure</b>	<b>Electricity Savings<sup>a</sup> (GWh/yr)</b>	<b>Reduced GHG Emissions from Electricity Savings<sup>a</sup> (Metric Tonnes CO<sub>2</sub>e)</b>	<b>Natural Gas Savings<sup>a</sup> (million therms/yr)</b>	<b>Reduced GHG Emissions from Natural Gas Savings<sup>a</sup> (Metric Tonnes CO<sub>2</sub>e)</b>	<b>Total Reduced CO<sub>2</sub>e Emissions<sup>a,b</sup> (Metric Tonnes CO<sub>2</sub>e)</b>
Daylighting Dimming to 10%	45.64	10,970	-0.21	-1,118	9,852

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO<sub>2</sub>e/GWh and 5,454.4 MTCO<sub>2</sub>e/million therms.

<sup>14</sup> When evaluating the impact of increasing the Renewable Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020, the 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.

### **6.3 Statewide Water Use Impacts**

The proposed code change would not result in on-site water savings. The reduction in electricity use would conserve water at thermoelectric power plants that use open loop systems for their water. These water savings are not yet considered pertinent for CASE proposals.

### **6.4 Statewide Material Impacts**

As discussed in Section 3.2 there would be no equipment change necessary to meet the proposed measure's requirements. In addition, dimming systems that would be most common for providing dimming to 10 percent would be 0-10 VDC and DALI. 0-10 VDC is already the main technology for LED lighting drivers (Heraldkeeper 2019) and for smart devices, DALI currently has the greatest market share (Evangeline 2018). Therefore, no significant change in material use is expected because the same equipment that is currently being used would be used with the proposed measure.

### **6.5 Other Non-Energy Impacts**

The Statewide CASE Team does not anticipate any other non-energy impacts.

## 7. Proposed Revisions to Code Language

### 7.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~striketroughs~~ (deletions). Code language that has been moved from one location to another without modifications is marked with blue underlining (new location) and ~~striketroughs~~ (old location).

### 7.2 Standards

#### SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

(d) **Automatic Daylighting Controls.** The general lighting in skylit daylit zones and primary sidelit daylit zones, as well as the general lighting in the combined primary and secondary sidelit daylit zones in parking garages, shall provide controls that automatically adjust the power of the installed lighting up and down to keep the total light level stable as the amount of incoming daylight changes. For skylight located in an atrium, the skylit daylit zone ~~definition~~ shall apply to the floor area directly under the atrium and the top floor area directly adjacent to the atrium.

3. The automatic daylighting controls shall:

- C. For areas other than parking garages, ensure that when the daylight illuminance is greater than 150 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be reduced by a minimum of 90 ~~65~~ percent; and

(e) Automatic Daylighting Controls in Secondary Daylit Zones. All luminaires providing general lighting that is in, or partially in a Secondary Sidelit Daylit Zone, and that is not in a Primary Sidelit Daylit Zone shall:

1. Be controlled independently from all other luminaires by automatic daylighting controls that meet the applicable requirements of Section 110.9; and
2. Be controlled in accordance with the applicable requirements in Section 130.1(d); and
3. All Secondary Sidelit Daylit Zones shall be shown on the plans submitted to the enforcing agency.

**EXCEPTION 1 to Section ~~140.6(d)~~ 130.1(e):** Luminaires in Secondary Sidelit Daylit Zone(s) in an enclosed space in which the combined total general lighting power in Secondary Daylit Zone(s) is less than 120 watts, or where the combined total general lighting power in Primary and Secondary Daylit Zone(s) is less than 240 watts.

**EXCEPTION 2 to Section ~~140.6(d)~~ 130.1(e):** Luminaires in parking garages complying with Section 130.1(d)3.

**EXCEPTION 3 to Section ~~140.6(d)~~ 130.1(e):** Areas adjacent to vertical glazing below an overhang, where there is no vertical glazing above the overhang and where the ratio of the

overhang projection to the overhang rise is greater than 1.5 for South, East and West orientations, or where the ratio of the overhang projection to the overhang rise is greater than 1 for North orientations.

EXCEPTION 4 to Section ~~140.6(d)~~ 130.1(e): Rooms that have a total glazing area of less than 24 square feet, or parking garage areas with a combined total of less than 36 square feet of glazing or opening.

EXCEPTION 5 to Section ~~140.6(d)~~ 130.1(e): Luminaires in sidelit daylit zones in retail merchandise sales and wholesale showroom areas.

## **SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING**

~~(d) Automatic Daylighting Controls in Secondary Daylit Zones. All luminaires providing general lighting that is in, or partially in a Secondary Sidelit Daylit Zone, and that is not in a Primary Sidelit Daylit Zone shall:~~

- ~~1. Be controlled independently from all other luminaires by automatic daylighting controls that meet the applicable requirements of Section 110.9; and~~
- ~~2. Be controlled in accordance with the applicable requirements in Section 130.1(d); and~~
- ~~3. All Secondary Sidelit Daylit Zones shall be shown on the plans submitted to the enforcing agency.~~

~~EXCEPTION 1 to Section 140.6(d): Luminaires in Secondary Sidelit Daylit Zone(s) in an enclosed space in which the combined total general lighting power in Secondary Daylit Zone(s) is less than 120 watts, or where the combined total general lighting power in Primary and Secondary Daylit Zone(s) is less than 240 watts.~~

~~EXCEPTION 2 to Section 140.6(d): Luminaires in parking garages complying with Section 130.1(d)3.~~

~~EXCEPTION 3 to Section 140.6(d): Areas adjacent to vertical glazing below an overhang, where there is no vertical glazing above the overhang and where the ratio of the overhang projection to the overhang rise is greater than 1.5 for South, East and West orientations, or where the ratio of the overhang projection to the overhang rise is greater than 1 for North orientations.~~

~~EXCEPTION 4 to Section 140.6(d): Rooms that have a total glazing area of less than 24 square feet, or parking garage areas with a combined total of less than 36 square feet of glazing or opening.~~

~~EXCEPTION 5 to Section 140.6(d): Luminaires in sidelit daylit zones in retail merchandise sales and wholesale showroom areas.~~

...

**TABLE 140.6-A LIGHT POWER ADJUSTMENT FACTORS (PAF)**

TYPE OF CONTROL	TYPE OF AREA		FACTOR
a. To qualify for any of the Power Adjustment Factors in this table, the installation shall comply with the applicable requirements in Section 140.6(a)2 b. Only one PAF may be used for each qualifying luminaire unless combined below. c. Lighting controls that are required for compliance with Part 6 shall not be eligible for a PAF			
1. Daylight Dimming plus OFF Control	Luminaires in skylit daylit zone or primary sidelit daylit zone		<del>0.4</del> <u>0.03</u>
2. Occupant Sensing Controls in Large Open Plan Offices	In open plan offices > 250 square feet: One sensor controlling an area that is:	No larger than 125 square feet	0.40
		From 126 to 250 square feet	0.30
		From 251 to 500 square feet	0.20
3. Institutional Tuning	Luminaires in non-daylit areas. Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.		0.10
	Luminaires in daylit areas. Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.		0.05
4. Demand Responsive Control	All building types of 10,000 square feet or smaller. Luminaires that qualify for other PAFs in this table may also qualify for this demand responsive control PAF		0.05
5. Clerestory Fenestration	Luminaires in daylit areas adjacent to the clerestory. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.		0.05
6. Horizontal Slats	Luminaires in daylit areas adjacent to vertical fenestration with interior or exterior horizontal slats. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.		0.05
7. Light Shelves	Luminaires in daylit areas adjacent to clerestory fenestration with interior or exterior light shelves. This PAF may be combined with the PAF for clerestory fenestration. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF		0.10

## 7.3 Reference Appendices

### NA 7.6.1

**DAYLIGHT ILLUMINANCE** is the areal density of luminous flux from the sun at a point onto the interior area of a building.

**DESIGN ILLUMINANCE** is the areal density of luminous flux on an area where the source is the lighting system for the space.

These definitions are adapted from the IES definition for illuminance.

#### **NA 7.6.1.2.1 Continuous Dimming Control Systems**

(e) Full daylight test. Simulate or provide bright conditions. Verify and document the following:

1. Lighting power reduction is at least ~~90~~65 percent under fully dimmed conditions and light output is stable with no discernable flicker.

#### **NA 7.6.1.2.2 Stepped Switching or Stepped Dimming Control Systems**

(c) Full daylight test. Simulate or provide bright conditions. Verify and document the following:

1. 1. Lighting power reduction of controlled luminaires is at least ~~90~~65 percent.

## **7.4 ACM Reference Manual**

### **5.4.5 Daylighting Control**

This group of building descriptors is applicable for spaces that have daylighting controls or daylighting control requirements.

California prescribes a modified version of the split flux daylighting methods to be used for compliance. This is an **internal daylighting method** because the calculations are automatically performed by the simulation engine. For top-lighted or sidelit daylit areas, California compliance prescribes an internal daylighting model consistent with the split flux algorithms used in many simulation programs. With this method the simulation model has the capability to model the daylighting contribution for each hour of the simulation and make an adjustment to the lighting power for each hour, taking into account factors such as daylighting availability, geometry of the space, daylighting aperture, control type, and the lighting system. The assumption is that the geometry of the space, the reflectance of surfaces, the size and configuration of the daylight apertures, and the light transmission of the glazing are taken from other building descriptors.

For daylight control using a simplified geometry approach, daylight control for both the primary daylit zone (mandatory) and secondary daylit zone (~~prescriptive~~ mandatory) must be indicated on the compliance forms. If the simplified geometry approach is used and the visible transmittance of fenestration does not meet prescriptive requirements, the standard design lighting power is reduced by 20 percent as a penalty. See Interior Lighting.

Minimum Dimming Power Fraction	
<i>Applicability</i>	Daylit spaces
<i>Definition</i>	The minimum power fraction when controlled lighting is fully dimmed. Minimum power fraction = minimum power / full rated power.
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed <del>., specified from luminaire type (not a user input)</del>
<i>Standard Design</i>	Standard design uses continuous dimming control with a minimum dimming power fraction of <del>0.1 from Table 8: Standard Design Power/Light Output Fraction. Where the controlled luminaire type, input by the user, determines the minimum dimming power fraction.</del>
<i>Standard Design: Existing Buildings</i>	Same as for new construction when skylights are added/replaced, and general light is altered.

Minimum Dimming Light Fraction	
<i>Applicability</i>	Daylighting and dimming controls
<i>Definition</i>	The minimum light output when controlled lighting is fully dimmed. Minimum light fraction = minimum light output / rated light output.
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed
<i>Standard Design</i>	Standard design uses continuous dimming control with a minimum dimming light fraction <del>0.1 from Table 8: Standard Design Power/Light Output Fraction. Where the controlled luminaire type, input by the user, determines the minimum dimming power fraction.</del>
<i>Standard Design: Existing Buildings</i>	Same as for new construction when skylights are added/replaced, and general light <del>ing</del> is altered.

## 7.5 Compliance Manuals

Chapter 5.1.1 of the Nonresidential Compliance Manual would need to be revised. It would be updated to note that the minimum reduction of the general lighting power in daylight zones was adjusted from 65 percent to 90 percent. It would also note that automatic daylighting controls for SDZs are now mandatory instead of prescriptive.

Chapter 5.4.4 of the Nonresidential Compliance Manual would need to be revised. It would need to be updated to note that automatic daylighting controls for SDZs are mandatory and not prescriptive. This language would also need to move from Chapter 5.5.3 to Chapter 5.4.4.

Chapter 5.4 of the Nonresidential Compliance Manual would need to be revised. It would be updated to note that the minimum reduction of the general lighting power in



daylight zones was adjusted from 65 percent to 90 percent. The specific changes would occur in Chapters 5.4.4.4 and 5.4.4.5.

Chapter 5.5 of the Nonresidential Compliance Manual would need to be revised. It would be updated to note that the minimum reduction of the general lighting power in daylight zones was adjusted from 65 percent to 90 percent. The specific change would occur in example 5-7.

Chapter 5.10 of the Nonresidential Compliance Manual would need to be revised. It would be updated to note that the minimum reduction of the general lighting power in daylight zones was adjusted from 65 percent to 90 percent. The specific change would occur in Chapter 5.10.3.3.

Chapter 13.4 of the Nonresidential Compliance Manual would need to be revised. It would be updated to note that the minimum reduction of the general lighting power in daylight zones was adjusted from 65 percent to 90 percent. The specific change would occur in Chapter 13.4.3.

## 7.6 Compliance Documents

Compliance documents that would need to be updated are listed as follows:

- NRCA-LTI-03 Automatic Daylighting Controls
  - Rated power should be 10 percent or less when the luminaire is dimmed
- NRCC-LTI-E
  - Section H Indoor Lighting Controls should specify for Daylight dimming to 10 percent

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## Appendix A: Statewide Savings Methodology

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards would be in effect (2023). The projected nonresidential new construction forecast that would be impacted by the proposed code change in 2023 is presented in Table 23. The projected nonresidential existing statewide building stock that would be impacted by the proposed code change as a result of additions and alterations in 2023 is presented in Table 24. This section describes how the Statewide CASE Team developed these estimates.

The Energy Commission Building Standards Office provided the nonresidential construction forecast, which is available for public review on the Energy Commission's website. This table also identifies the prototypical buildings that were used to model the energy use of the proposed code changes. This mapping was required because the building types the Energy Commission defined in the construction forecast are not identical to the prototypical building types that the Energy Commission requested that the Statewide CASE Team use to model energy use. This mapping is consistent with the mapping that the Energy Commission used in the Final Impacts Analysis for the 2019 code cycle (California Energy Commission 2018).

The Energy Commission's forecast allocated 19 percent of the total square footage of new construction in 2023 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings would be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types so that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, would remain constant. See Table 24 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

After the miscellaneous floorspace was redistributed, the Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. Table 25 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal. If the assumed percentage is non-zero, but less than 100 percent, it is an indication that no buildings would be impacted by the proposal. Table 26 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone.

**Table 22: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2023 (New Construction), by Climate Zone and Building Type (Million Square Feet)**

Climate Zone	Nonresidential Prototype (million square feet)													
	Assembly	Grocery	Office Large	Office Medium	Office Small	RestaurantFast Food	Retail Large	Retail Mixed Use	Retail Stand Alone	Retail Strip Mall	School Primary	School Secondary	Warehouse	Total NR
1	0.00	0.04	0.07	0.08	0.05	0.02	0.10	0.01	0.01	0.01	0.04	0.03	0.10	0.61
2	0.01	0.21	0.43	0.46	0.27	0.12	0.60	0.08	0.08	0.04	0.22	0.21	0.58	3.62
3	0.04	0.89	2.42	2.55	0.98	0.47	2.72	0.36	0.36	0.18	0.89	0.85	3.00	17.15
4	0.02	0.45	1.27	1.34	0.49	0.24	1.39	0.19	0.19	0.09	0.45	0.43	1.54	8.83
5	0.00	0.10	0.22	0.24	0.11	0.05	0.28	0.04	0.04	0.02	0.09	0.09	0.29	1.71
6	0.02	0.65	1.68	1.74	0.70	0.46	1.92	0.26	0.26	0.13	0.49	0.46	2.29	11.89
7	0.02	0.54	0.94	1.00	0.96	0.30	1.35	0.18	0.18	0.09	0.52	0.47	1.35	8.82
8	0.03	0.91	2.51	2.61	0.92	0.67	2.76	0.37	0.37	0.18	0.67	0.64	3.29	17.11
9	0.06	1.39	4.65	4.83	1.49	1.12	4.28	0.57	0.57	0.29	0.89	0.96	5.23	28.13
10	0.03	0.98	0.95	1.04	1.27	0.82	2.67	0.36	0.36	0.18	0.95	0.82	4.34	15.80
11	0.00	0.24	0.20	0.23	0.34	0.11	0.54	0.07	0.07	0.04	0.25	0.22	0.79	3.31
12	0.04	1.01	1.97	2.09	1.77	0.51	2.92	0.39	0.39	0.19	1.03	0.92	3.91	18.34
13	0.02	0.51	0.31	0.36	0.74	0.24	1.15	0.15	0.15	0.08	0.55	0.47	1.37	6.48
14	0.00	0.22	0.33	0.35	0.25	0.18	0.63	0.08	0.08	0.04	0.19	0.17	0.93	3.68
15	0.00	0.16	0.10	0.11	0.24	0.09	0.36	0.05	0.05	0.02	0.13	0.11	0.67	2.25
16	0.00	0.08	0.08	0.09	0.10	0.05	0.20	0.03	0.03	0.01	0.07	0.06	0.28	1.16
<b>TOTAL</b>	<b>0.33</b>	<b>8.39</b>	<b>18.14</b>	<b>19.11</b>	<b>10.68</b>	<b>5.44</b>	<b>23.86</b>	<b>3.18</b>	<b>3.18</b>	<b>1.59</b>	<b>7.44</b>	<b>6.91</b>	<b>29.95</b>	<b>148.89</b>



**Table 23: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2023 (Alterations), by Climate Zone and Building Type (Million Square Feet)**

Climate Zone	Nonresidential Prototype (million square feet)													
	Assembly	Grocery	Office Large	Office Medium	Office Small	RestaurantFast Food	Retail Large	Retail Mixed Use	Retail Stand Alone	Retail Strip Mall	School Primary	School Secondary	Warehouse	Total NR
1	0.01	0.10	0.23	0.25	0.14	0.05	0.29	0.04	0.04	0.02	0.13	0.12	0.29	1.85
2	0.04	0.61	1.37	1.48	0.84	0.30	1.70	0.23	0.23	0.11	0.77	0.73	1.72	10.96
3	0.15	2.49	7.50	7.96	3.06	1.23	7.58	1.01	1.01	0.51	3.19	3.05	8.73	51.29
4	0.08	1.26	3.92	4.16	1.53	0.62	3.87	0.52	0.52	0.26	1.62	1.55	4.45	26.32
5	0.02	0.27	0.72	0.76	0.34	0.13	0.80	0.11	0.11	0.05	0.34	0.32	0.85	5.20
6	0.10	2.07	5.08	5.37	2.25	1.37	6.13	0.82	0.82	0.41	2.17	2.04	7.80	38.90
7	0.08	1.75	3.29	3.53	2.93	0.87	4.39	0.59	0.59	0.29	1.70	1.61	4.41	28.69
8	0.14	2.91	7.52	7.93	2.96	1.98	8.75	1.17	1.17	0.58	3.02	2.84	11.10	55.48
9	0.25	4.40	13.25	14.01	4.67	3.27	13.43	1.79	1.79	0.90	4.48	4.50	17.36	89.39
10	0.13	3.47	3.40	3.78	4.17	2.72	9.62	1.28	1.28	0.64	3.55	3.13	16.10	56.32
11	0.03	0.74	0.65	0.74	1.02	0.29	1.67	0.22	0.22	0.11	0.86	0.76	2.63	10.46
12	0.14	3.02	6.01	6.43	4.95	1.40	8.64	1.15	1.15	0.58	3.60	3.24	11.50	55.01
13	0.06	1.58	0.95	1.13	2.25	0.66	3.53	0.47	0.47	0.24	1.98	1.69	4.37	20.43
14	0.03	0.76	1.03	1.12	0.82	0.58	2.18	0.29	0.29	0.15	0.80	0.71	3.39	12.81
15	0.01	0.57	0.33	0.36	0.78	0.28	1.29	0.17	0.17	0.09	0.48	0.39	2.45	7.84
16	0.01	0.26	0.26	0.29	0.32	0.16	0.67	0.09	0.09	0.04	0.29	0.25	1.00	3.94
<b>TOTAL</b>	<b>1.27</b>	<b>26.28</b>	<b>55.51</b>	<b>59.31</b>	<b>33.03</b>	<b>15.93</b>	<b>74.53</b>	<b>9.94</b>	<b>9.94</b>	<b>4.97</b>	<b>29.00</b>	<b>26.93</b>	<b>98.16</b>	<b>474.92</b>

**Table 24: Example of Redistribution of Miscellaneous Category - 2023 New Construction in Climate Zone 1**

<b>Building Type</b>	<b>2020 Forecast (Million Square Feet) [A]</b>	<b>Distribution Excluding Miscellaneous Category [B]</b>	<b>Redistribution of Miscellaneous Category (Million Square Feet) [C] = B × [D = 0.145]</b>	<b>Revised 2020 Forecast (Million Square Feet) [E] = A + C</b>
Small Office	0.036	7%	0.010	0.046
Large Office	0.114	21%	0.031	0.144
Restaurant	0.015	3%	0.004	0.020
Retail	0.107	20%	0.029	0.136
Grocery Store	0.029	5%	0.008	0.036
Non-Refrigerated Warehouse	0.079	15%	0.021	0.101
Refrigerated Warehouse	0.006	1%	0.002	0.008
Schools	0.049	9%	0.013	0.062
Colleges	0.027	5%	0.007	0.034
Hospitals	0.036	7%	0.010	0.046
Hotel/Motels	0.043	8%	0.012	0.055
Miscellaneous [D]	0.145	---	0.000	0.145
<b>TOTAL</b>	<b>0.686</b>	<b>100%</b>	<b>0.147</b>	<b>0.83370</b>

**Table 25: Percent of Floorspace Impacted by Proposed Measure, by Building Type**

Building Type Building Sub-type	Composition of Building Type by Sub-types <sup>a</sup>	Percent of Square Footage Impacted <sup>b</sup>	
		New Construction	Existing Building Stock (Alterations) <sup>c</sup>
Small Office	N/A	100%	7%
Restaurant	N/A	100%	7%
Retail	N/A	100%	7%
Stand-Alone Retail	10%	100%	7%
Large Retail	75%	100%	7%
Strip Mall	5%	100%	7%
Mixed-Use Retail	10%	100%	7%
Food <sup>d</sup>	N/A	100%	0%
Non-Refrigerated Warehouse	N/A	100%	7%
Refrigerated Warehouse	N/A	0%	0%
Schools	N/A	100%	7%
Small School	60%	100%	7%
Large School	40%	100%	7%
College	N/A	100%	7%
Small Office	5%	100%	7%
Medium Office	15%	100%	7%
Medium Office/Lab	N/A	N/A	N/A
Public Assembly	5%	100%	7%
Large School	30%	100%	7%
High-Rise Apartment	25%	100%	7%
Hospital <sup>e</sup>	N/A	0%	0%
Hotel/Motel	N/A	100%	7%
Offices	N/A	100%	7%
Medium Office	50%	100%	7%
Large Office	50%	100%	7%

- Presents the assumed composition of the main building type category by the building subtypes. All 2022 CASE Reports assumed the same percentages of building subtypes.
- When the building type is composed of multiple subtypes, the overall percentage for the main building category was calculated by weighing the contribution of each subtype.
- Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.
- The proposed code change will apply to the food building category. The Statewide CASE Team will be adding impacts from the food building category for the Final CASE Report.
- The proposed code change will apply to the hospital building category. The Statewide CASE Team will be adding impacts from the food building category for the Final CASE Report.

**Table 26: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone**

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations) <sup>a</sup>
1	100%	100%
2	100%	100%
3	100%	100%
4	100%	100%
5	100%	100%
6	100%	100%
7	100%	100%
8	100%	100%
9	100%	100%
10	100%	100%
11	100%	100%
12	100%	100%
13	100%	100%
14	100%	100%
15	100%	100%
16	100%	100%

- a. Percent of existing floorspace that would be altered during the first year the 2022 standards are in effect.

## Appendix B: Embedded Electricity in Water Methodology

The proposed code change would not result in on-site water savings. The reduction in electricity use would conserve water at thermoelectric power plants that use open loop systems for their water. These water savings are not yet considered pertinent for CASE proposals.

## Appendix C: Environmental Impacts Methodology

### Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric tonnes CO<sub>2</sub>e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO<sub>2</sub>e/MWh for the WECC CAMX subregion. This value was converted to metric tonnes/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO<sub>2</sub> (Carbon Dioxide), 0.64 pounds of N<sub>2</sub>O (Nitrous Oxide) and 2.3 pounds of CH<sub>4</sub> (Methane). The emission value for N<sub>2</sub>O assumed that low NO<sub>x</sub> burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N<sub>2</sub>O and CH<sub>4</sub> were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N<sub>2</sub>O and CH<sub>4</sub> are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tonnes per million therms.

### GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). As of the Draft CASE Report's date of publication, the Energy Commission has not released the final TDV factors. The Final CASE Report will show the monetary value of avoided GHG emissions using assumptions that align with those used for the 2022 TDV factors.

## **Water Use and Water Quality Impacts Methodology**

There are no water impacts from the proposed code change.



# Appendix D: California Building Energy Code Compliance (CBECC) Software Specification

CBECC-Com software developers would use the information from this document to implement the proposed software change. Once the software change is implemented, the software would be tested and verified using the test procedure and reference results provided in the Simulation Engine Inputs section of this appendix.

The Energy Commission requires a beta version of CBECC software to be released at least one year prior to the effective date of the California Energy Code. The 2022 code would take effect January 1, 2023. Therefore, the beta version of the CBECC software must be released no later than January 1, 2022. The Statewide CASE Team would provide this appendix to the CBECC development teams at least 20 months prior to the anticipated effective date of the 2022 code to allow sufficient time for the development and testing of the software changes. Therefore, the Statewide CASE Team would provide this document to the CBECC development teams no later than May 1, 2021.

## Introduction

The purpose of this appendix is to present proposed revisions to CBECC for commercial buildings (CBECC-Com) along with the supporting documentation that the Energy Commission staff, and the technical support contractors would need to approve and implement the software revisions.

## Technical Basis for Software Change

Daylighting systems that dim to 10 percent are available and ready for the wide adoption as discussed in Section 3.2. Changing the Standard Design to have daylighting systems that dim to 10 percent would match the proposed mandatory requirement and ensure any penalties or credits that vary from this feature in the Proposed Design.

## Description of Software Change

### Background Information for Software Change

Daylighting systems lower the lighting system power in response to adequate daylight available from a space's fenestration. Daylighting is already a design feature in CBECC-Com and in particular the Standard Design follows the mandatory and prescriptive requirements for daylighting in Title 24, Part 6. Daylighting systems that dim to 10 percent are available and ready for wide adoption as discussed in Section 3.2. The Statewide CASE Team recommends that the Standard Design of CBECC-Com have

daylighting systems that dim to 10 percent to match the proposed mandatory requirement. This ensures any energy penalties or credits that vary from this feature in the Proposed Design are applied.

### **Existing CBECC-Com Modeling Capabilities**

The CBECC-Com values for minimum lighting power fraction and the minimum lighting fraction at that power are translated into EnergyPlus without modification and are used in EnergyPlus's split flux algorithm. The split flux algorithm first determines the level of daylight available. It then determines how much electric lighting is necessary to supplement the daylight such that the total lighting meets the illumination setpoint. If the illumination setpoint can be met by daylight alone, the minimum power fraction dictates a minimum amount of power the lighting system still uses. In practical terms, this lighting power represents the fact that electric lights are not completely off. For any electric lighting power in between full power and the minimum power fraction, the ACM has algorithms to determine the lighting power for both the Proposed and Standard Designs.

Currently, the Standard Design minimum lighting fraction is 0.20 at a power of 0.20. Note that this is different than the ACM which specifies that the Standard Design's minimum lighting and power fraction shall be determined by the luminaire type per the ACM's Table 8 and varies from 0.1 to 0.5. Both of these differ from the 0.35 minimum power fraction as listed in the mandatory daylighting requirements, Section 130.0(d)3.C of Title 24, Part 6.

For the Proposed Design, CBECC-Com determines the minimum lighting and power fraction by the luminaire type per the ACM's Table 8. This currently allows violation of the current mandatory requirement, allowing minimum dimming power fractions greater than 35 percent.

To match the proposed mandatory requirement, the Standard Design minimum lighting and power fraction would need to be reduced to 10 percent. In addition, the Proposed Design would need to be as-designed so that proper credits are applied where the Proposed Design is lower than the Standard Design. The Proposed Design can never have a minimum power fraction greater than the Standard Design as this would violate the proposed mandatory measure.

Currently CBECC-Com's Standard Design minimum lighting fraction is 0.20 at a power of 0.20. This is different than the ACM which specifies that the Standard Design's minimum lighting and power fraction shall be determined by the luminaire type per the ACM's Table 8 which varies from 0.1 to 0.5. Both of these differ from the 0.35 minimum power fraction as required by the mandatory daylighting requirements, Section 130.0(d)3.C of Title 24, Part 6.

For the Proposed Design, CBECC-Com determines the minimum lighting and power fraction by the luminaire type per the ACM's Table 8. This currently allows violation of the current mandatory requirement, allowing minimum dimming power fractions greater than 35 percent.

To match the proposed mandatory requirement the Standard Design minimum lighting and power fraction would need to be reduced to 10 percent. In addition, the Proposed Design would need to match the design so that proper credits are applied where the Proposed Design is lower than the Standard Design. The Proposed Design can never have a minimum power fraction greater than the proposed mandatory measure's 0.1.

### Summary of Proposed Revisions to CBECC-Com

To correctly calculate credits or penalties from the as-designed minimum power fraction, it is proposed that the Standard Design minimum light and power fraction be reduced to 0.1 and 0.1, respectively. This follows the proposed measure's revisions to the mandatory daylighting controls. The ACM should also be revised as detailed in Section 7.4 to reflect this change and fix the current inconsistency between the ACM and CBECC-Com.

The Proposed Design's minimum lighting and power fraction should be the minimum lighting and power fraction as it is in the construction documents. This fixes the current inconsistency between the ACM and CBECC-Com and should be done whether or not the proposed measure's dimming to 10 percent is adopted.

The translation of the minimum lighting and power fraction into EnergyPlus would not change, nor would any additional inputs or outputs be required.

### User Inputs to CBECC-Com

The user input fields necessary to implement this measure already exist in CBECC-Com, but they are not editable. Table 27 lists the necessary changes.

**Table 27: Modified User Inputs Relevant to Daylight Dimming to 10 Percent**

Input Screen	Variable Name	Data Type	Units	User Editable	Recommended Label
Luminaire Data	MinDimPwrFrac	Decimal	None	<u>Yes</u>	N/A
Luminaire Data	MinDimLtgFrac	Decimal	None	<u>Yes</u>	N/A

## **Simulation Engine Inputs**

### **EnergyPlus**

The existing algorithms for translation are sufficient for the proposed measure. No changes are needed.

### **Calculated Values, Fixed Values, and Limitations**

The existing algorithms for calculations, fixed values and limitations are sufficient for the proposed measure. No changes are needed.

## **Simulation Engine Output Variables**

The existing algorithms for calculations, fixed values and limitations are sufficient for the proposed measure. No changes are needed.

## **Compliance Report**

The existing compliance reports are sufficient for the proposed measure. No changes are needed.

## **Compliance Verification**

The existing compliance verification processes are sufficient for the proposed measure. No changes are needed.

## **Testing and Confirming CBECC-Com Modeling**

The existing testing and confirmation process are sufficient for the proposed measure. No changes are needed.

## **Description of Changes to ACM Reference Manual**

This information is available in Section 7.4.

## Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. Table 28 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in Table 28 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

The compliance process would not need any significant change to the workflow. The proposed modification requires no new tasks. Currently market actors (e.g., designers, engineers, plan examiners) must include daylighting dimming that dims to at least 35 percent, exemptions excluded. The proposed measure involves identical workflow but to verify that the general lighting dims to 10 percent or lower.

ATTs would follow adjusted testing methods to verify the system is capable of dimming to 10 percent instead of 35 percent. Nothing else within the test procedure is expected to change.

**Table 28: Roles of Market Actors in the Proposed Compliance Process**

<b>Market Actor</b>	<b>Task(s) In Compliance Process</b>	<b>Objective(s) in Completing Compliance Tasks</b>	<b>How Proposed Code Change Could Impact Work Flow</b>	<b>Opportunities to Minimize Negative Impacts of Compliance Requirement</b>
Lighting Designer	<ul style="list-style-type: none"> <li>• Identify relevant requirements and/or compliance path.</li> <li>• Perform required calculations by space to confirm compliance.</li> <li>• Coordinate design with other team members (Contractor/Installer/Engineers)</li> <li>• Complete compliance document for permit application.</li> <li>• Review submittals during construction.</li> <li>• Coordinate with commissioning agent/ATT as necessary.</li> </ul>	Clearly communicate system requirements to constructors.	Should not significantly impact workflow.	Clear communication on sensor placement and operation to construction.
Installer	<ul style="list-style-type: none"> <li>• Identify relevant requirements.</li> <li>• Confirm data on documents is compliant.</li> <li>• Confirm plans/specifications match data on documents.</li> <li>• Provide correction comments if necessary.</li> </ul>	<ul style="list-style-type: none"> <li>• Quickly and easily determine requirements based on scope.</li> <li>• Quickly and easily determine if data in documents meets requirements.</li> <li>• Quickly and easily determine if plans/specs match documents.</li> <li>• Quickly and easily provide correction comments that would resolve issue.</li> </ul>	Should not significantly impact workflow.	Record compliance on documents in a way easily compared to plans.
ATT	Identify photosensors function properly and lighting power reduces to 10 percent or more.	Verify photosensors work properly and lighting power reduces to 10 percent or more.	Should not significantly impact workflow.	Assessing plans and determine whether distance method or time-sensitive illuminance method is the appropriate depending on the project.

## Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this Draft CASE Report are generally supported. Stakeholders provided valuable feedback on draft analyses and helped to identify and address challenges to adoption including cost effectiveness, market barriers, technical barriers, compliance and enforcement challenges, or potential impacts on human health or the environment. Some stakeholders also provided data that the Statewide CASE Team used to support analyses.

### Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asked for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for Daylighting via webinar which was part of the greater lighting stakeholder meeting.

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Utility-Sponsored Stakeholder Meeting	Thursday, September 12, 2019	<a href="https://title24stakeholders.com/event/nonresidential-indoor-lighting-utility-sponsored-stakeholder-meeting/">https://title24stakeholders.com/event/nonresidential-indoor-lighting-utility-sponsored-stakeholder-meeting/</a>
Second Round of Utility-Sponsored Stakeholder Meeting	Tuesday, March 3, 2020	<a href="https://title24stakeholders.com/event/lighting-utility-sponsored-stakeholder-meeting-2/">https://title24stakeholders.com/event/lighting-utility-sponsored-stakeholder-meeting-2/</a>



The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from March to May 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost-effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from [info@title24stakeholders.com](mailto:info@title24stakeholders.com). One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page<sup>15</sup> (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive outreach to stakeholders identified in initial work plans who had not yet opted in to the listserv. Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

## Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email, phone, and in person at industry events with numerous stakeholders when developing this report. The Statewide CASE Team conducted outreach to manufacturers, contractors, designers, and ATTs). Specifically, the Statewide CASE Team asked over three dozen manufacturers, contractors, designers and other stakeholders for their feedback daylight harvesting<sup>16</sup> when attending LightFair 2019, Strategies in Light, Design Light Expo, and LightShow West. The Statewide CASE Team also worked with California Lighting

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<sup>15</sup> Title 24 Stakeholders' LinkedIn page can be found here <https://www.linkedin.com/showcase/title-24-stakeholders/>.

<sup>16</sup> Daylight harvesting refers to strategies for using daylighting to offset the amount of electric lighting needed. Daylight dimming plus OFF is an example of a daylight harvesting strategy.

Technology Center (CLTC) who conducted research and stakeholder outreach, including discussions with the California Energy Alliance.<sup>17</sup> Finally, the Statewide CASE Team conducted a survey of ATTs, which is described below.

## Survey

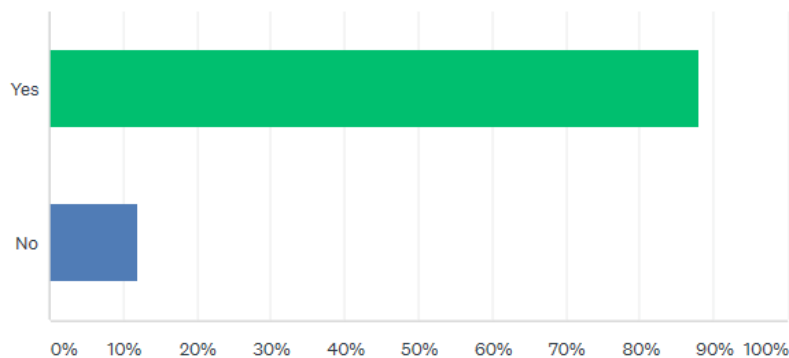
The Statewide CASE Team coordinated with the California Lighting Technology Center (CLTC) and the California Energy Alliance to develop and distribute a survey to ATTs that included questions on daylight dimming to 10 percent, along with other daylighting measures. The results of this survey are shown below.

### Question 1

Have you completed lighting controls acceptance tests for automatic daylighting controls?

Have you completed lighting controls acceptance tests for automatic daylighting controls?

Answered: 143 Skipped: 52



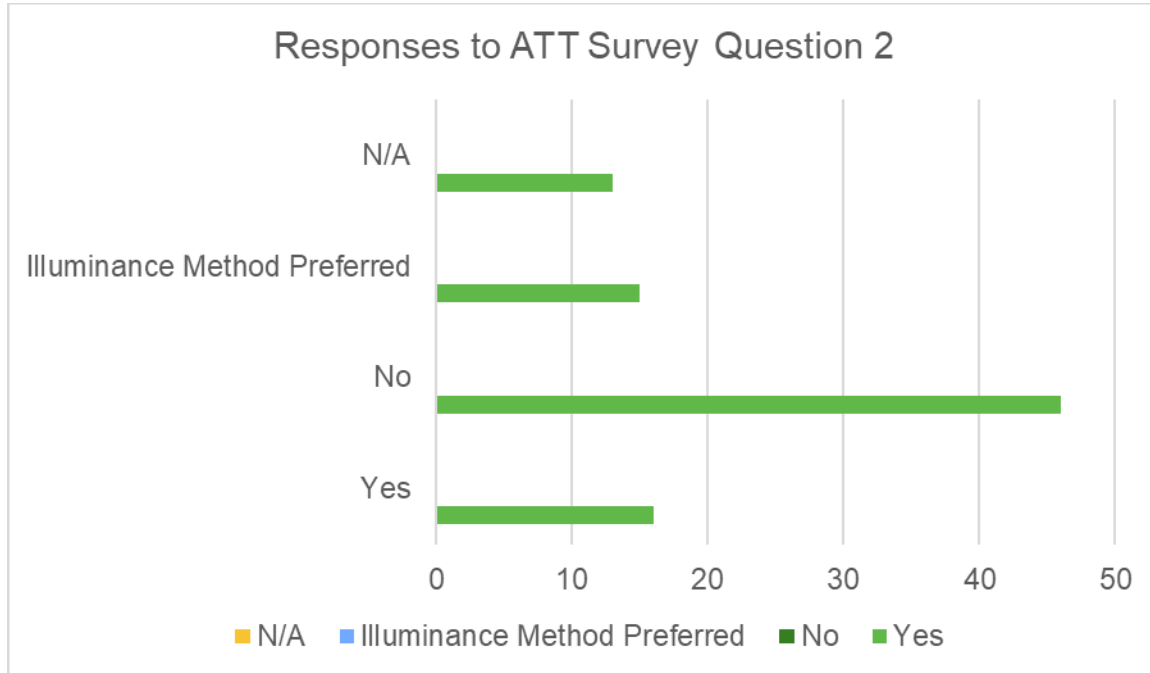
ANSWER CHOICES	RESPONSES	
Yes	88.11%	126
No	11.89%	17
Total Respondents: 143		

**Figure 1: Daylighting Question 1 from ATT Survey.**

<sup>17</sup> California Energy Alliance's website can be found here: <https://caenergyalliance.org/>.

## Question 2

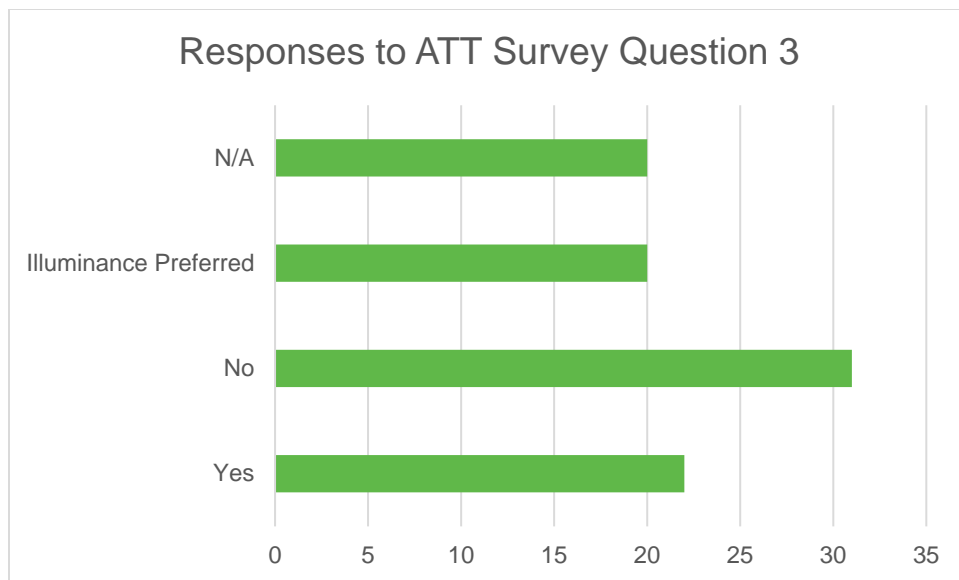
If the acceptance test procedure requires physical testing to verify and document the lighting power reduction of 90%, would it change the way in which you conduct the test? For example, would it impact whether you used the illuminance method or distance method for completing the tests?



**Figure 2: Response to ATT Survey Question 2.**

## Question 3

Is there any significant difference in time it takes to complete a daylighting controls acceptance test when using the illuminance test method as opposed to the distance method?



**Figure 3: Response to Acceptance Test Technician survey question 3.**

## Appendix G: Nominal Savings Tables

This appendix will be included for the Final CASE Report.

In Section 5, the energy cost savings of the proposed code changes over the 15-year period of analysis are presented in 2023 present value dollars.

This appendix will present energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis but the time value of money is not included so the results are not discounted.

## Appendix H: Per Unit Energy and Cost Results by Prototypical Building

The tables below present energy savings per square foot for each prototypical building modeled and the 15-year energy cost savings associated with energy savings in 2023 present value dollars.

**Table 29: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Small Hotel Prototype Building**

Climate Zone	Electricity Savings (kWh/ft <sup>2</sup> )	Peak Electricity Demand Reductions (kW/ft <sup>2</sup> )	Natural Gas Savings (therms/ft <sup>2</sup> )	TDV Energy Savings (TDV kBtu/ft <sup>2</sup> )	15-Year TDV Electricity Cost Savings (2023 PV\$)	15-Year TDV Natural Gas Cost Savings (2023 PV\$)	Total 15-Year TDV Energy Cost Savings (2023 PV\$)
1	0.01	0.00	-0.00	0.11	\$0.01	\$0.00	\$0.01
2	0.01	0.00	-0.00	0.18	\$0.02	\$0.00	\$0.02
3	0.01	0.00	-0.00	0.15	\$0.02	\$0.00	\$0.01
4	0.01	0.00	-0.00	0.20	\$0.02	\$0.00	\$0.02
5	0.01	0.00	-0.00	0.15	\$0.01	\$0.00	\$0.01
6	0.01	0.00	-0.00	0.23	\$0.02	\$0.00	\$0.02
7	0.01	0.00	-0.00	0.20	\$0.02	\$0.00	\$0.02
8	0.01	0.00	-0.00	0.26	\$0.02	\$0.00	\$0.02
9	0.01	0.00	-0.00	0.27	\$0.02	\$0.00	\$0.02
10	0.01	0.00	-0.00	0.26	\$0.02	\$0.00	\$0.02
11	0.01	0.00	-0.00	0.16	\$0.02	\$0.00	\$0.01
12	0.01	0.00	-0.00	0.19	\$0.02	\$0.00	\$0.02
13	0.01	0.00	-0.00	0.21	\$0.02	\$0.00	\$0.02
14	0.01	0.00	-0.00	0.21	\$0.02	\$0.00	\$0.02
15	0.01	0.00	-0.00	0.23	\$0.02	\$0.00	\$0.02
16	0.01	0.00	-0.00	0.14	\$0.01	\$0.00	\$0.01

**Table 30: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Large Office**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.05	0.00	-0.00	0.80	\$0.08	-\$0.01	\$0.07
2	0.05	0.00	-0.00	1.19	\$0.11	-\$0.00	\$0.11
3	0.05	0.00	-0.00	1.09	\$0.10	-\$0.00	\$0.10
4	0.05	0.00	-0.00	1.29	\$0.11	-\$0.00	\$0.11
5	0.05	0.00	-0.00	1.01	\$0.09	-\$0.00	\$0.09
6	0.05	0.00	-0.00	1.28	\$0.11	-\$0.00	\$0.11
7	0.05	0.00	-0.00	1.15	\$0.10	-\$0.00	\$0.10
8	0.05	0.00	-0.00	1.41	\$0.12	-\$0.00	\$0.13
9	0.06	0.00	-0.00	1.45	\$0.13	-\$0.00	\$0.13
10	0.06	0.00	-0.00	1.39	\$0.12	-\$0.00	\$0.12
11	0.05	0.00	-0.00	1.19	\$0.11	-\$0.00	\$0.11
12	0.05	0.00	-0.00	1.19	\$0.11	-\$0.00	\$0.11
13	0.05	0.00	-0.00	1.26	\$0.11	-\$0.00	\$0.11
14	0.06	0.00	-0.00	1.40	\$0.13	-\$0.00	\$0.12
15	0.06	0.00	-0.00	1.41	\$0.12	-\$0.00	\$0.13
16	0.05	0.00	-0.00	0.97	\$0.09	-\$0.01	\$0.09



**Table 31: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Medium Office Prototype Building**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.07	0.00	-0.00	1.02	\$0.11	-\$0.02	\$0.09
2	0.08	0.00	-0.00	1.68	\$0.16	-\$0.01	\$0.15
3	0.07	0.00	-0.00	1.51	\$0.14	-\$0.01	\$0.13
4	0.08	0.00	-0.00	1.78	\$0.16	-\$0.01	\$0.16
5	0.08	0.00	-0.00	1.41	\$0.13	-\$0.01	\$0.13
6	0.08	0.00	-0.00	1.91	\$0.17	-\$0.00	\$0.17
7	0.08	0.00	-0.00	1.72	\$0.15	-\$0.00	\$0.15
8	0.08	0.00	-0.00	2.08	\$0.19	-\$0.00	\$0.19
9	0.08	0.00	-0.00	2.12	\$0.19	-\$0.00	\$0.19
10	0.08	0.00	-0.00	2.00	\$0.18	-\$0.00	\$0.18
11	0.08	0.00	-0.00	1.76	\$0.17	-\$0.01	\$0.16
12	0.08	0.00	-0.00	1.70	\$0.16	-\$0.01	\$0.15
13	0.08	0.00	-0.00	1.89	\$0.17	-\$0.01	\$0.17
14	0.08	0.00	-0.00	2.17	\$0.20	-\$0.01	\$0.19
15	0.09	0.00	-0.00	2.12	\$0.19	-\$0.00	\$0.19
16	0.07	0.00	-0.00	1.28	\$0.13	-\$0.02	\$0.11

**Table 32: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Small Office Prototype Building**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/ft<sup>2</sup>)</b>	<b>Peak Electricity Demand Reductions (kW/ft<sup>2</sup>)</b>	<b>Natural Gas Savings (therms/ft<sup>2</sup>)</b>	<b>TDV Energy Savings (TDV kBtu/ft<sup>2</sup>)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.11	0.00	-0.00	1.86	\$0.20	-\$0.03	\$0.17
2	0.12	0.00	-0.00	2.57	\$0.24	-\$0.02	\$0.23
3	0.12	0.00	-0.00	2.60	\$0.24	-\$0.01	\$0.23
4	0.12	0.00	-0.00	2.75	\$0.25	-\$0.01	\$0.24
5	0.12	0.00	-0.00	2.49	\$0.23	-\$0.01	\$0.22
6	0.12	0.00	-0.00	2.87	\$0.26	-\$0.00	\$0.26
7	0.12	0.00	-0.00	2.72	\$0.24	-\$0.00	\$0.24
8	0.14	0.00	-0.00	3.52	\$0.32	-\$0.00	\$0.31
9	0.13	0.00	-0.00	3.31	\$0.30	-\$0.00	\$0.29
10	0.12	0.00	-0.00	3.02	\$0.27	-\$0.01	\$0.27
11	0.12	0.00	-0.00	2.54	\$0.24	-\$0.01	\$0.23
12	0.12	0.00	-0.00	2.57	\$0.24	-\$0.01	\$0.23
13	0.12	0.00	-0.00	2.84	\$0.27	-\$0.01	\$0.25
14	0.13	0.00	-0.00	3.18	\$0.30	-\$0.01	\$0.28
15	0.14	0.00	-0.00	3.53	\$0.32	-\$0.00	\$0.31
16	0.11	0.00	-0.00	2.04	\$0.21	-\$0.03	\$0.18

**Table 33: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Fast Food Restaurant**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.13	0.00	-0.00	1.71	\$0.26	-\$0.11	\$0.15
2	0.15	0.00	-0.00	3.28	\$0.35	-\$0.06	\$0.29
3	0.15	0.00	-0.00	2.87	\$0.32	-\$0.06	\$0.26
4	0.16	0.00	-0.00	3.66	\$0.37	-\$0.04	\$0.33
5	0.15	0.00	-0.00	2.80	\$0.30	-\$0.06	\$0.25
6	0.16	0.00	-0.00	3.63	\$0.35	-\$0.02	\$0.32
7	0.16	0.00	-0.00	3.37	\$0.32	-\$0.02	\$0.30
8	0.16	0.00	-0.00	4.15	\$0.39	-\$0.02	\$0.37
9	0.17	0.00	-0.00	4.09	\$0.39	-\$0.03	\$0.36
10	0.16	0.00	-0.00	3.91	\$0.38	-\$0.03	\$0.35
11	0.16	0.00	-0.00	3.62	\$0.37	-\$0.05	\$0.32
12	0.16	0.00	-0.00	3.59	\$0.37	-\$0.05	\$0.32
13	0.16	0.00	-0.00	3.84	\$0.38	-\$0.04	\$0.34
14	0.17	0.00	-0.00	3.98	\$0.40	-\$0.04	\$0.35
15	0.17	0.00	-0.00	4.35	\$0.40	-\$0.01	\$0.39
16	0.16	0.00	-0.00	2.62	\$0.31	-\$0.08	\$0.23

**Table 34: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Large Retail**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.08	0.00	-0.00	1.02	\$0.13	-\$0.04	\$0.09
2	0.10	0.00	-0.00	2.09	\$0.20	-\$0.01	\$0.19
3	0.09	0.00	-0.00	2.18	\$0.21	-\$0.01	\$0.19
4	0.07	0.00	-0.00	1.73	\$0.16	-\$0.01	\$0.15
5	0.09	0.00	-0.00	1.97	\$0.19	-\$0.01	\$0.18
6	0.09	0.00	-0.00	-0.67	-\$0.05	-\$0.00	-\$0.06
7	0.12	0.00	-0.00	2.41	\$0.22	-\$0.00	\$0.21
8	0.09	0.00	-0.00	1.16	\$0.11	-\$0.00	\$0.10
9	0.11	0.00	-0.00	2.11	\$0.19	-\$0.01	\$0.19
10	0.12	0.00	-0.00	3.34	\$0.30	-\$0.01	\$0.30
11	0.11	0.00	-0.00	3.23	\$0.30	-\$0.01	\$0.29
12	0.08	0.00	-0.00	1.68	\$0.16	-\$0.01	\$0.15
13	0.09	0.00	-0.00	2.13	\$0.20	-\$0.01	\$0.19
14	0.09	0.00	-0.00	2.32	\$0.21	-\$0.01	\$0.21
15	0.10	0.00	-0.00	2.49	\$0.22	-\$0.00	\$0.22
16	0.09	0.00	-0.00	1.51	\$0.17	-\$0.03	\$0.13

**Table 35: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Mixed-use Retail**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.05	0.00	-0.00	0.82	\$0.09	-\$0.01	\$0.07
2	0.05	0.00	-0.00	0.74	\$0.07	-\$0.01	\$0.07
3	0.06	0.00	-0.00	4.10	\$0.37	-\$0.01	\$0.37
4	0.06	0.00	-0.00	1.25	\$0.12	-\$0.00	\$0.11
5	0.05	0.00	-0.00	0.96	\$0.09	-\$0.00	\$0.09
6	0.06	0.00	-0.00	1.25	\$0.11	-\$0.00	\$0.11
7	0.06	0.00	-0.00	1.43	\$0.13	-\$0.00	\$0.13
8	0.07	0.00	-0.00	1.49	\$0.13	-\$0.00	\$0.13
9	0.05	0.00	-0.00	1.16	\$0.11	-\$0.00	\$0.10
10	0.05	0.00	-0.00	1.17	\$0.11	-\$0.00	\$0.10
11	0.05	0.00	-0.00	0.75	\$0.07	-\$0.01	\$0.07
12	0.05	0.00	-0.00	0.90	\$0.09	-\$0.01	\$0.08
13	0.04	0.00	-0.00	0.79	\$0.08	-\$0.01	\$0.07
14	0.05	0.00	-0.00	1.04	\$0.10	-\$0.01	\$0.09
15	0.07	0.00	-0.00	1.49	\$0.13	\$0.00	\$0.13
16	0.04	0.00	-0.00	0.63	\$0.07	-\$0.02	\$0.06

**Table 36: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Stand Alone Retail**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.18	0.00	-0.00	2.09	\$0.28	-\$0.09	\$0.19
2	0.16	0.00	-0.00	2.45	\$0.24	-\$0.03	\$0.22
3	0.14	0.00	-0.00	1.46	\$0.15	-\$0.02	\$0.13
4	0.11	0.00	-0.00	0.83	\$0.09	-\$0.02	\$0.07
5	0.20	0.00	-0.00	3.48	\$0.34	-\$0.03	\$0.31
6	0.23	0.00	-0.00	5.83	\$0.53	-\$0.01	\$0.52
7	0.26	0.00	-0.00	6.25	\$0.57	-\$0.01	\$0.56
8	0.17	0.00	-0.00	4.25	\$0.39	-\$0.01	\$0.38
9	0.13	0.00	-0.00	3.57	\$0.33	-\$0.01	\$0.32
10	0.12	0.00	-0.00	1.74	\$0.17	-\$0.02	\$0.15
11	0.12	0.00	-0.00	1.91	\$0.19	-\$0.02	\$0.17
12	0.16	0.00	-0.00	2.48	\$0.24	-\$0.02	\$0.22
13	0.17	0.00	-0.00	5.03	\$0.46	-\$0.02	\$0.45
14	0.16	0.00	-0.00	4.25	\$0.40	-\$0.02	\$0.38
15	0.23	0.00	-0.00	6.19	\$0.56	-\$0.00	\$0.55
16	0.12	0.00	-0.00	1.49	\$0.19	-\$0.06	\$0.13

**Table 37: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Strip Mall Retail**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.05	0.00	-0.00	0.69	\$0.08	-\$0.02	\$0.06
2	0.04	0.00	-0.00	0.55	\$0.06	-\$0.01	\$0.05
3	0.05	0.00	-0.00	0.88	\$0.09	-\$0.01	\$0.08
4	0.05	0.00	-0.00	0.85	\$0.08	-\$0.01	\$0.08
5	0.06	0.00	-0.00	0.98	\$0.09	-\$0.01	\$0.09
6	0.05	0.00	-0.00	0.99	\$0.09	-\$0.00	\$0.09
7	0.06	0.00	-0.00	1.80	\$0.16	-\$0.00	\$0.16
8	0.05	0.00	-0.00	1.18	\$0.11	-\$0.00	\$0.10
9	0.04	0.00	-0.00	0.77	\$0.07	-\$0.00	\$0.07
10	0.03	0.00	-0.00	1.32	\$0.12	-\$0.00	\$0.12
11	0.05	0.00	-0.00	0.97	\$0.10	-\$0.01	\$0.09
12	0.05	0.00	-0.00	0.77	\$0.08	-\$0.01	\$0.07
13	0.06	0.00	-0.00	1.25	\$0.12	-\$0.01	\$0.11
14	0.05	0.00	-0.00	1.03	\$0.10	-\$0.01	\$0.09
15	0.05	0.00	-0.00	1.05	\$0.10	-\$0.00	\$0.09
16	0.04	0.00	-0.00	0.56	\$0.07	-\$0.02	\$0.05



**Table 38: Energy Impacts Per Square Foot and 15-Year Energy Cost Savings – Primary School**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.13	0.00	-0.00	1.93	\$0.23	-\$0.06	\$0.17
2	0.17	0.00	-0.00	3.71	\$0.37	-\$0.04	\$0.33
3	0.18	0.00	-0.00	3.80	\$0.38	-\$0.04	\$0.34
4	0.15	0.00	-0.00	3.39	\$0.32	-\$0.02	\$0.30
5	0.15	0.00	-0.00	2.95	\$0.29	-\$0.02	\$0.26
6	0.16	0.00	-0.00	3.59	\$0.33	-\$0.01	\$0.32
7	0.16	0.00	-0.00	3.44	\$0.31	-\$0.01	\$0.31
8	0.16	0.00	-0.00	3.74	\$0.34	-\$0.01	\$0.33
9	0.16	0.00	-0.00	3.97	\$0.36	-\$0.01	\$0.35
10	0.16	0.00	-0.00	3.69	\$0.34	-\$0.01	\$0.33
11	0.15	0.00	-0.00	3.35	\$0.33	-\$0.03	\$0.30
12	0.15	0.00	-0.00	3.13	\$0.31	-\$0.03	\$0.28
13	0.16	0.00	-0.00	3.61	\$0.35	-\$0.03	\$0.32
14	0.16	0.00	-0.00	3.90	\$0.37	-\$0.03	\$0.35
15	0.17	0.00	-0.00	4.26	\$0.38	-\$0.00	\$0.38
16	0.15	0.00	-0.00	2.53	\$0.28	-\$0.06	\$0.22

**Table 39: First-Year Energy Impacts Per Square Foot – Secondary School**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.08	0.00	-0.00	1.08	\$0.13	-\$0.03	\$0.10
2	0.08	0.00	-0.00	1.68	\$0.17	-\$0.02	\$0.15
3	0.08	0.00	-0.00	1.49	\$0.15	-\$0.02	\$0.13
4	0.08	0.00	-0.00	1.68	\$0.16	-\$0.01	\$0.15
5	0.09	0.00	-0.00	1.45	\$0.15	-\$0.02	\$0.13
6	0.09	0.00	-0.00	1.91	\$0.18	-\$0.01	\$0.17
7	0.09	0.00	-0.00	1.73	\$0.17	-\$0.01	\$0.15
8	0.09	0.00	-0.00	2.16	\$0.20	-\$0.01	\$0.19
9	0.09	0.00	-0.00	2.22	\$0.21	-\$0.01	\$0.20
10	0.09	0.00	-0.00	2.08	\$0.19	-\$0.01	\$0.19
11	0.09	0.00	-0.00	1.72	\$0.17	-\$0.01	\$0.15
12	0.09	0.00	-0.00	1.70	\$0.16	-\$0.01	\$0.15
13	0.11	0.00	-0.00	2.28	\$0.22	-\$0.01	\$0.20
14	0.09	0.00	-0.00	2.19	\$0.21	-\$0.01	\$0.20
15	0.10	0.00	-0.00	2.22	\$0.20	-\$0.01	\$0.20
16	0.08	0.00	-0.00	1.29	\$0.14	-\$0.02	\$0.11

**Table 40: First-Year Energy Impacts Per Square Foot – Warehouse**

<b>Climate Zone</b>	<b>Electricity Savings (kWh/yr)</b>	<b>Peak Electricity Demand Reductions (kW)</b>	<b>Natural Gas Savings (therms/ft2)</b>	<b>TDV Energy Savings (TDV kBtu/yr)</b>	<b>15-Year TDV Electricity Cost Savings (2023 PV\$)</b>	<b>15-Year TDV Natural Gas Cost Savings (2023 PV\$)</b>	<b>Total 15-Year TDV Energy Cost Savings (2023 PV\$)</b>
1	0.14	0.00	-0.01	1.31	\$0.23	-\$0.12	\$0.12
2	0.14	0.00	-0.00	2.49	\$0.28	-\$0.06	\$0.22
3	0.14	0.00	-0.00	2.20	\$0.26	-\$0.06	\$0.20
4	0.14	0.00	-0.00	2.67	\$0.29	-\$0.05	\$0.24
5	0.14	0.00	-0.00	2.19	\$0.25	-\$0.05	\$0.20
6	0.14	0.00	-0.00	2.77	\$0.28	-\$0.03	\$0.25
7	0.14	0.00	-0.00	2.56	\$0.26	-\$0.03	\$0.23
8	0.14	0.00	-0.00	3.19	\$0.31	-\$0.03	\$0.28
9	0.14	0.00	-0.00	3.23	\$0.32	-\$0.03	\$0.29
10	0.14	0.00	-0.00	3.02	\$0.30	-\$0.03	\$0.27
11	0.14	0.00	-0.00	2.48	\$0.28	-\$0.06	\$0.22
12	0.14	0.00	-0.00	2.63	\$0.29	-\$0.05	\$0.23
13	0.14	0.00	-0.00	2.70	\$0.29	-\$0.05	\$0.24
14	0.15	0.00	-0.00	3.08	\$0.33	-\$0.05	\$0.27
15	0.15	0.00	-0.00	3.18	\$0.30	-\$0.02	\$0.28
16	0.14	0.00	-0.00	1.70	\$0.24	-\$0.09	\$0.15