Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code

Nonresidential Indoor Lighting

2022-NR-LIGHT2-D **|** Nonresidential Lighting **|** July 2020 DRAFT CASE REPORT

Prepared by Energy Solutions

Please submit comments to info@title24stakeholders.com by August 14, 2020.

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Executive Summary

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2. *Do the calculations estimating energy savings from the addition of occupancy sensors to control zones no greater than 600 square feet (ft^2) in large offices appear to be correct?*
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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 Draft CASE Report is to present a code change proposal for multi-zone occupancy sensing in large offices and lighting power densities. The report contains pertinent information supporting the code change.

Measure Description

Background Information

Multi-zone Occupancy Sensing in Large Offices

Currently, occupant sensing control requirements for office spaces greater than 250 ft^2 are not mandatory in Title 24, Part 6. Shut-off options include time-switch controls and an occupancy sensor without coverage area limits. The Power Adjustment Factors (PAFs) from the 2013 Title 24, Part 6 code cycle enable a pathway for utilizing occupancy controls with varying control zone sizes.

This proposal aligns with the 2018 International Energy Conservation Code (IECC) C405.2.1.3 Open Plan Office Control which mandates a maximum 600 ft^2 control zone size and specifies that all control zones shall be switched separately, lights shall automatically turn off all control zones within 20 minutes of all occupants leaving the space, and that each control zone must reduce lighting by at least 80 percent power, or switch off, within 20 minutes of occupants leaving a control zone.

This measure would save energy through two main mechanisms: (1) reducing the full load hours of operation on the lighting system in large offices, and (2) enabling HVAC occupied standby mode in large office spaces, and therefore reducing energy usage from HVAC systems. HVAC occupied standby resets thermostat setpoints and shuts off ventilation air to a zone when the entire space is unoccupied. The energy savings calculations, as found in Section 2.3, estimate 0.940 $kWh/ft^2/yr$ in per-unit savings.

Technology to implement this code change is already readily available in the market. Most occupancy sensors control the lights digitally through either a room controller or a networked lighting control system. The occupancy sensors are configurable in terms of their associations with the luminaires and/or control zones. By using software, and occasionally hardware, different sensors can be configured to monitor and work with different control zones and control zone sizes. As such, control zones can be easily programmed, added, and rearranged at the control panel or remotely through computer, and even mobile phone applications, rather than rewiring and ladders.

Another popular control implementation is luminaire level lighting control (LLLC), where sensors are an integral part of the luminaires, so each luminaire would have its own sensor. This luminaire and sensor configuration would increase the granularity of the control area as each on-board sensor controls an individual luminaire independently. With LLLCs, the luminaires may also be networked together to coordinate with each other and act as a single, larger zone if that would be the desired lighting design.

Lighting Power Densities

This measure proposes to update the allowable lighting power density (LPD) values (watts of lighting per square foot of room floor area) based on a re-analysis of LPDs with improved tools and changes to the products available in the market. The Statewide CASE Team updated LPD values during the 2019 Title 24, Part 6 code cycle to reflect an all LED (light emitting diode) baseline. During this code cycle for the 2022 standards, the Statewide CASE Team is refining this previous work by updating previous models and accounting for advancing technology. Specifically, the Statewide CASE Team has found efficacy increases over the last three years for luminaires with high color rendering index (CRI) LED sources, color tuning, and dim-to-warm controllability. Likewise, the Statewide CASE Team has updated models based on revisiting IES recommended practice and IES Standards. The Inverse Lumen Method lighting power density model has been improved to provide a more accurate estimate of required lighting power. This allows the Statewide CASE Team to use proposed LPDs that more closely match the results of the model as there is less error in the calculations. Improvements includes:

- Detailed documentation of the target illuminance values used for the general, task, supplemental and wall wash systems and references to the various IES recommended practices.
- Direct use of the zonal lumens extracted from the IES-LM-63 formatted photometric files of luminaires to calculate the coefficients of utilization for the luminaires for any combination of room reflectance and rectangular room geometry.
- Direct use of manufacturer lamp lumen depreciation values
- Implementation of the luminaire dirt depreciation model from IES RP-36 specific to luminaire type and primary function area

The proposed LPD updates do not prevent sufficient light levels from being achieved. In addition to general lighting LPDs, there are several additional power allowances that all contribute to providing sufficient lighting power to ensure proper light levels are achievable. These assure there is sufficient light for task work, display, and ornamental lighting. There are also additional wattage allowances for a number of special needs and capabilities, such as additional lighting wattage for providing extra light to areas occupied by elderly or visually impaired.

The lighting power allowances for the complete building method (a weighted average of the general lighting power allowances for primary function areas in each building type) have also been updated. The tailored lighting power allowances have been slightly updated to account for the increased efficacy of high CRI lighting sources.

Proposed Code Change

The multi-zone occupancy sensing in large offices measure proposes a mandatory control requirement for nonresidential indoor lighting systems in “large” offices, defined as enclosed offices greater than 250 ft^2. This especially includes open office workstations, although the term “open office” itself is undefined in Title 24, Part 6. The proposed code change applies to all lighting, with an exception for under shelf or furniture-mounted supplemental task lighting. It impacts new construction, additions, and alterations.

The lighting power density measure proposes updates to the definitions, mandatory, and the prescriptive section of Title 24, Part 6. Definitions have been updated for clarification and readability. Additionally, the 50 watt and JA8 mandatory requirement for luminaires with line voltage lamp holders has been removed. In the prescriptive section, code language for calculation of adjusted indoor lighting power and luminaire classification and power adjustment has been updated for clarification and to reflect updated LPD values. Likewise, the LPD values in the tables for the Complete Building Method, Area Category Method, and Tailored Method have all been updated. These updates affect new construction, additions, and alterations. Not every building type is affected by the updates, but many have minor to moderate updates.

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

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Multi-zone Occupancy Sensing in Large Offices	Mandatory	130.1(c)6, 130.1(f), 140.6-A	Appendix NA7	Yes	NRCI-LTI-05-E, NRCC-LTI-E, NRCA-LTI-02-A
Lighting Power Densities	Mandatory, Prescriptive	100.1, 130.0(c), 140.6(a), 140.6(c)	None	Yes	None

Market Analysis and Regulatory Assessment

Multi-zone Occupancy Sensing in Large Offices

The market for occupancy sensors and lighting controls is well established in the United States (U.S.). Currently, the main market actors include lighting designers, electrical engineers, electrical contractors, distributors, manufacturer sales representatives and agencies, manufacturers, and lighting controls acceptance test technicians. Section 2.2.1 describes market actor core functions in detail.

Technology to implement this code change is readily available in California, as confirmed by research and interviews with stakeholders. Most occupancy sensors control the lighting digitally through either a room controller or a networked lighting control system. The occupancy sensors are configurable in terms of their associations with the luminaires and/or control zones by using software, and occasionally hardware. As such, control zones can be reprogrammed, added, and rearranged at the control panel or remotely through computer, and even mobile phone applications, rather than rewiring.

Luminaire level lighting control (LLLC), where sensors are an integral part of each luminaires, also offers options for implementation. This luminaire and sensor configuration can increase the granularity of the control area if each sensor makes control decisions independently. With LLLCs, the luminaires may also be networked together to coordinate with each other and act as a single, larger zone if that would be the desired lighting design.

If the proposed code change is adopted, market actors would need to utilize more occupancy sensors, a more granular control strategy, and potentially different equipment. A few stakeholders mentioned that when demand response is required for large buildings, digital systems are used and are already configurable to meet the proposed code change requirements. For this implementation, no additional equipment would be needed and would only require correctly programming controls to meet the requirement. Based on feedback from stakeholder outreach, manufacturers and lighting representatives would likely benefit due to increased sales and the design strategy would necessitate more work for electrical engineers and/or contractors to specify a code compliant control strategy. The design, installation, and compliance processes would likely benefit from increased communication between contractors, sales representatives, and designers. More details on stakeholder perspective can be found in Section 2.2.2.3.

The proposed code change would require a new acceptance test, for which proposed code language can be found in Section 2.6.3. Acceptance Test Technicians (ATT) perspectives were gathered and incorporated before drafting the acceptance test and after the first draft of the test was completed, as described in Section 2.1.5. Detailed survey responses and reviewer comments can be found in Sections 4.1.1.4 and 4.1.1.5.

This proposal also aligns with the 2018 IECC Section C405.2.1.3 Open Plan Office Control as both include mandatory requirements to have 600 ft^2 maximum sized control zones that switch separately, automatically turn off all control zones within 20 minutes of all occupants leaving the space, and reduce lighting by at least 80 percent power, or switch off, within 20 minutes of occupants leaving a control zone. Section 2.1.4.4 explains the difference in nomenclature between “open office” and “large office.”

Lighting Power Densities

The current market structure for indoor lighting sources has not changed significantly over the past three years. Lighting designers still develop lighting systems and specify fixture types, lumen output, and wattages. Contractors and electricians are responsible for obtaining products and installing lighting systems. While the market actors and technologies have not experienced much change, the efficacies and costs of products have. Almost all luminaires specified for new construction or major alterations make use of Light Emitting Diode (LED) technology. LED light sources are no longer a premium product but are the default product and as such the costs have been dropping. The Statewide CASE Team conducted research, spoke with manufacturers, and other stakeholders to gather data on increased efficacies and dropping costs.

Section 140.6 of Title 24, Part 6 includes existing requirements in for indoor LPDs. Indoor lighting in nonresidential buildings is limited by LPDs; the LPDs specify how much wattage for lighting is allowed in the different building and space types.

The proposed code change will would revise the existing 2019 Title 24, Part 6 LPD requirements. There is some overlap with the multi-zone occupancy sensing in large offices proposal since it also addresses requirements for interior lighting. Additionally, based on the findings for the large office controls proposal, the primary function area “open plan office” has been dropped and is replaced with “office > 250 ft^2”. This proposal does not recommend any structural changes to the LPD requirements; it only updates the LPD allowance values.

Cost Effectiveness

The proposed code change was found to be cost effective for all climate zones. The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 15-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratio for the multi-zone occupancy sensing in large offices measure is 1.71. See Section 2.4 for the corresponding methodology, assumptions, and results of the cost-effectiveness analysis.

The B/C ratio for the lighting power density measure varies by primary function area but overall, the measure saves both energy cost and first cost. As a result, the B/C ratio is infinite. Typically, it is expected that saving energy requires more costly lighting systems (incremental costs that are positive), and this was true in some cases. However, for many cases, the first cost stayed the same or decreased. In the situation where the first cost decreased or stayed the same, the B/C ratio is listed as “infinite.”

Examples of reduced or zero incremental cost include:

- Product efficacy has increased but cost has stayed the same or decreased, as has been the case with ornamental lighting. The high color rendering index (CRI) luminaires used for ornamental lighting have increased performance as compared to three years ago and often do not cost more.
- Updating the model which is now based on lower illuminance values than used in the 2019 code cycle. Not only did this result in energy savings, but the proposed lighting system also has fewer luminaires or uses lower output luminaires which results in either a first cost savings or an unchanged first cost (negative or zero incremental cost).

Detailed costing of the lighting systems used in the 2019 base case model and in the 2022 proposed case model are tabulated in Appendix S.

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 Sections 2.5 and 3.5 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Sections 2.3 and 3.3 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 (Millions of TDV kBtu)
Multi-zone Occupancy Sensing in Large Offices	**94.75**	**14.34**	**0.05**	**2,945**
New Construction	22.44	3.51	0.01	700
Additions and Alterations	72.32	10.83	0.04	2,245
Lighting Power Densities	109.1	27.8		2,946
New Construction	26.7	21.2	0	722
Additions and Alterations	82.4	6.5	0	2,224

The multi-zone occupancy sensing in large office measure energy analysis revealed a large savings potential for a typical office occupancy pattern, as described in Section 2.3. The energy savings are dependent on occupancy patterns and how the office is occupied geographically, as evenly distributed occupancy would save less energy than more clustered occupancy. The Statewide CASE Team captured this by modeling “best” and “worst” case scenarios. During modeling, the greatest energy savings potential occurred when an office was lightly or partially occupied, such as during off-business hours like the early morning or late afternoon hours when overtime workers or maintenance crews would be present.

Though the proposal updated values for all three compliance paths (Complete Building Method, Area Category Method and Tailored Method), statewide savings is based on the Area Category Method, as it is the most commonly used method used for determining lighting power compliance. Of the 78 primary function areas in the Area Category Method, the combined general lighting and additional lighting allowance LPDs in this proposal would increase in 8 function areas, decrease in 34 areas, and stay the same for 36 areas. Overall, the total savings are approximately a quarter that of the savings associated with LPD changes in the 2019 Title 24, Part 6 Standards. The small reduction in savings from this 2022 LPD proposal relative to the savings associated with the 2019 LPD proposal indicates that the changes proposed are relatively modest and are "fine tuning" of the changes that were proposed for the 2019 Title 24, Part 6 Standards.

Table 3 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect for both new construction and alterations. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in Section 2.5.2, and Section 3.5.2, 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 Tons CO2e/yr)	Annual Average Monetary Value of Avoided GHG Emissions ($2023/yr)
Multi-zone Occupancy Sensing in Large Offices	23,032	$690,950
Lighting Power Densities	15,171	$1,618,076
Total	**38,203**	**$2,309,026**

Water and Water Quality Impacts

This 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 Sections 2.1.5 and 3.1.5. Impacts that the proposed measure would have on market actors is described in Section 2.2.3, Section 3.2.3, and Appendix E. The key issues related to compliance and enforcement are summarized below:

Multi-zone Occupancy Sensing in Large Offices

- Complexity due to control integration required for lighting and mechanical systems.
  - Need for increased coordination between lighting design teams, mechanical design teams, lighting representatives, controls contractor, and lighting and mechanical ATTs.
- New acceptance test:
  - Need to allow for control zone overlap.
  - Need for verification of control zone size.
- Raising awareness of market actors that large offices would be required to comply with HVAC occupied standby controls integration.
- Potential loopholes:
  - ATTs could alter the sensors between lighting and mechanical acceptance testing such that the controls are non-compliant.
  - If an HVAC zone serves the large office as well as other spaces with occupancy, it would be exempt from the HVAC occupied standby initiation until all spaces within the HVAC zone had been unoccupied for more than five minutes as per Section 120.2(e)3 of the 2019 Standards.
  - The control zone size could be larger than the required 600 ft^2 maximum zone size.
  - If all of the lighting was specified as under shelf or furniture-mounted task lighting with no lighting on the ceiling, the large office would be exempt from the proposed code change.

Lighting Power Densities

This measure is not changing the structure of the lighting power allowances in Title 24, Part 6, but is updating the values applied to each primary function area of building types. Enforcement remains unchanged.

For areas where the LPDs are increasing, the lighting designer has more flexibility in design choices for that space.

For areas with lower LPDs, building designers would have less wattage to trade off with HVAC and envelope measures. This may result in designers (and others) needing to ensure their HVAC and envelope designs are more efficient as lighting power limitations would be more stringent. Revised LPDs that account for increases in LED efficacy help retain the structure of Title 24, Part 6 which designers need to judiciously select and locate luminaires to meet task illuminance levels.

However, for about half of the primary function areas, there is no change to the power allowance.

This proposal maintains the status quo for lighting power allowance enforcement.

Field Verification and Acceptance Testing

The multi-zone occupancy sensing in large offices measure proposes a new acceptance testing requirement that confirms lighting is required to dim by at least 80 percent of full power when control zones are unoccupied, that all lights are off when the entire room is unoccupied, and that control zone sizes are no greater than 600 ft^2. ATT feedback informed the acceptance test throughout the process of drafting and revising the code language. More details can be found in Section 2.1.5.

Field verification and acceptance testing does not apply to the Lighting Power Density requirements in Section 140.6(c).

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Email comments and suggestions to info@title24stakeholders.com *by* ***August 14, 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 will 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 nonresidential indoor lighting. The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, lighting designers, contractors, 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 12, 2019, and March 3, 2020 (Statewide CASE Team 2019a) (Statewide CASE Team 2019b).

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

- Section 2.1 and Section 3.1 of this Draft CASE Report provide a description of the each measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 2.2 and Section 3.2 includes a review of the current market structure in addition to the Market Analysis section. Sections 2.2.2 and 3.2.2 describe 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.
- Sections 2.3 and 3.3 present the per-unit energy, demand reduction, and energy cost savings associated with each 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.
- Sections 2.4 and 3.4 includes a discussion and presents analysis 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.
- Sections 2.5 and 3.5 present the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect for each measure. 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.

- Sections 2.6 and 3.6 Proposed Revisions to Code Language conclude each measure in the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, compliance manual, and compliance documents.
- Section 4 – 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: Multi-zone Occupancy Sensing in Large Offices Outreach Survey Scripts and Results summarizes the Statewide CASE Team's outreach efforts, findings, and response to feedback. Stakeholder input includes manufacturers, designers, lighting reps, acceptance test technicians (ATTs), and more.
- Appendix H: Multi-zone Occupancy Sensing in Large Offices Energy Savings Calculations Details explains the model office layouts and occupancy schedule generation and randomization in detail.
- Appendix I: Data on luminaires used for the lighting power density updates.

- Appendix J: Description of all the inputs used for the Inverse Lumen Method Model that was used to develop the updated lighting power density values.
- Appendix K: Description of the color tuning analysis performed by the Statewide CASE Team to further refine lighting power density values.
- Appendix L: Analysis on product availability showing available luminaires and range of efficiencies.
- Appendix M: Nominal Savings Tables presents the energy cost savings in nominal dollars by building type and climate zone for both measures.
- Appendix N: Description of analysis used to update the Tailored Method general lighting LPDs.
- Appendix O: Description of analysis used to update the Tailored Method floor and wall LPDs.
- Appendix Q: Description of analysis used to update the Tailored Method ornamental and special lighting LPDs.
- Appendix R: Description of the approach to updating the Area Category LPDs, including assumptions, and description of methodology. This expands upon information already provided in Section 3.1.
- Appendix S: Description of the cost analysis performed for the LPD update.

2. Multi-Zone Occupancy Sensing in Large Offices

2.1 Measure Description

2.1.1 Measure Overview

The multi-zone occupancy sensing in large offices measure proposes a mandatory control requirement for nonresidential indoor lighting systems in “large” offices, defined as enclosed offices greater than 250ft^2. This proposed measure especially includes open office workstations, although the term “open office” itself is undefined in Title 24, Part 6. The proposed code change impacts all lighting, with an exception for under shelf or furniture-mounted supplemental task lighting. This includes general lighting and decorative lighting in all large offices. Under shelf and furniture-mounted supplemental task lighting are exempted due to the feasibility and technical challenges to include them in the same lighting circuit controlled by the occupancy sensors.

The proposed measure mandates that each occupancy sensor in a large office controls no more than 600 ft^2. The 600 ft^2 limit ensures both cost effectiveness and alignment with similar requirements in other national model codes, including the International Energy Conservation Code (IECC). This divides the space into smaller occupancy control zones than in past code cycles. Based on occupancy status, the control zones would respond accordingly:

- When a control zone becomes occupied:
    - The control zone’s lighting shall be allowed to automatically turn on.
    - For lighting controlled by both automatic daylighting controls and occupant sensing controls, lighting power shall remain at the lesser level allowed by either control.
- When a control zone becomes unoccupied:
    - The occupancy sensing controls in the control zone shall uniformly reduce lighting power by 80 percent or more from full power. This shall occur within 20 minutes after all occupants have left the control zone.
        - Note: If an office space also implements institutional tuning, the “full power” refers to the power at the maximum light output level after institutional tuning has been applied. This is for efficiency and accuracy of both the compliance and programming processes.
    - When all control zones in the office are unoccupied, the occupancy sensing controls shall automatically turn off lighting in all control zones within 20 minutes after no occupants are detected in the space. Occupied

standby HVAC control must be initiated after five minutes of all control zones in the office being unoccupied, for a total delay time of no longer than 20 minutes. HVAC Occupied standby mode turns off ventilation and resets thermostat setpoints.

The above requirements do not dedicate any particular control system architecture, nor do they mandate the control zones being able to communicate with each other. When using a simple system without communication between control zones, the requirements can be met by uniformly turning the lights off in the control zone within 20 minutes after the control zone becomes unoccupied. The requirements provide flexibility in implementation, as more complex systems can also be used to meet the code.

The proposed measure applies to new construction and additions of large office spaces in all building types. This measure is required for alterations as all other automatic shutoff controls are required during alterations.

Title 24, Part 6 already has Power Adjustment Factors (PAFs) for occupant sensing controls in large offices which vary by control zone size. If adopted, the proposed measure would modify the existing related PAFs to account for a new baseline with occupancy sensing and a maximum 600 ft^2 control zone size. The updated PAFs would encourage more granular lighting controls for increased energy efficiency. Additionally, new acceptance test procedures would need to be added for verifying the measure's mandatory control requirement in NA7.6.2.3.2.

The proposed measure might require updates to the compliance software. The PAF values would need to be updated, as described in Appendix D. The Statewide CASE Team is still researching compliance software updates and will include results in the Final CASE Report.

2.1.2 Measure History

2.1.2.1 Historical Context

Currently, occupant sensing control requirements for office spaces greater than 250 ft^2 are not mandatory. The current shut-off options include time-switch controls and an occupancy sensor without coverage area limits. PAFs from the 2013 Title 24, Part 6 code cycle enable a pathway for utilizing occupancy controls with varying control zone sizes. See Section 2.1.4 for more details.

The PAFs were adopted in the 2013 code cycle. More recently, the 2018 IECC added a similar measure.

2.1.2.2 Energy Savings

The Statewide CASE Team is proposing this measure due to its potential for significant energy savings, cost effectiveness, and market readiness. While Title 24, Part 6 currently mandates shut-off controls for large offices, a single occupancy sensor can control an area as large as 5,000 ft^2. Occupants in large offices are away from their desks frequently for meetings or other tasks, leaving significant portions of the office area unoccupied. This presents opportunities for deeper savings and using separate occupancy controls can reduce lighting energy consumption in unoccupied parts of a larger office area. The proposed measure intends to improve the code to capture energy savings in large workspaces where there is often partial vacancy.

The proposed measure includes other benefits besides energy savings. It may reduce disruption for occupants staying after hours who would previously need to walk over to a manual control switch to enable an override control. Additionally, the code change would simplify the standard by displacing the PAFs for Occupant Sensing Controls in Large Open Plan Offices (Table 140.6-A).

As shown in Section 2.3, the proposed measure is estimated to achieve 0.940 $kWh/ft^2/yr$ in per-unit energy savings. This measure would save energy through two main mechanisms:

1. Reducing the full load hours of operation on the lighting system in large offices, and
2. Enabling HVAC occupied standby mode in large office spaces, and therefore reducing energy usage from HVAC systems. Occupied standby resets thermostat setpoints and shuts off ventilation air to a zone when the entire space is unoccupied.

The first mechanism would save energy by requiring occupancy sensors to control lighting based on occupancy rather than a presumed occupant schedule, as well as by using smaller control zones to make lighting responsive to actual occupancy within a subzone of the room. With the combined impacts of reduced lighting load and application of occupied standby to large offices, this measure has significant potential for indoor lighting energy savings.

2.1.2.3 Technology

Technology to implement this measure is already readily available in the market. Most occupancy sensors control the lights digitally through either a room controller or a networked lighting control system. The occupancy sensors are configurable in terms of their associations with the luminaires and/or control zones. By using software, and occasionally hardware, different sensors can be configured to monitor and work with different control zones and control zone sizes. As such, control zones can be easily programmed, added, and rearranged at the control panel or remotely through computer, and even mobile phone applications, rather than rewiring and ladders.

Another popular control implementation is luminaire level lighting control (LLLC), where sensors are an integral part of the luminaires, so each luminaire would have its own sensor. This luminaire and sensor configuration would increase the granularity of the control area as each on-board sensor controls an individual luminaire independently. With LLLCs, the luminaires may also be networked together to coordinate with each other and act as a single, larger zone if that would be the desired lighting design.

2.1.2.4 Demand Response

The proposed measure could support demand reduction by way of increased energy efficiency through reduced lighting load and mitigated unnecessary HVAC usage. For example, during late afternoon and evening energy demand peaks, such as those between 4 and 9 PM, demand would be diminished as the large office lighting load responds to occupancy in a more granular fashion than would occur with a time-switch control and manual override. Considering 4 PM to 9 PM to be the peak period, the current model estimates 29 percent of the energy savings from the proposed code change would occur during peak periods. While it depends on the specific large office occupancy schedule, the proposed code change would likely reduce energy usage during peak periods, especially 4 to 9 PM, when compared to a large office using a time-switch control with manual override, based on the 2019 requirements.

2.1.3 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 Proposed Revisions to Code Language2.6 of this report for detailed proposed revisions to code language.

2.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 2.6.2 of this report for marked-up code language.

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

Section 130.1(c)6 – Areas where full or partial OFF occupant sensing controls are required: Adds Part D describing how all lighting in large offices shall be controlled by occupancy sensing controls. This addition specifies control zone maximum size and how occupancy sensing controls reduce lighting power based on occupancy. There is an exception for under shelf or furniture-mounted supplemental task lighting.

Section 130.1(f) – Control Interactions: Adds Part 8 to clarify how automatic daylighting controls and occupant sensing controls interact. Power shall remain at the lesser of that allowed by either control.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

Table 140.6-A – Lighting Power Adjustment Factors (PAF): Modifies the PAFs for Occupant Sensing Controls in Large Open Plan Offices.

2.1.3.2 Summary of Changes to the Reference Appendices

This proposal modifies the sections of the Reference Appendices identified below. See Section 2.6.3 of this report for the detailed proposed revisions to the text of the reference appendices.

APPENDIX NA7 – INSTALLATION AND ACCEPTANCE REQUIREMENTS FOR NONRESIDENTIAL BUILDINGS AND COVERED PROCESSES

NA7.6.2.3 – Occupancy Sensing Lighting Control Functional Testing: The proposed requirements update the acceptance test to confirm lighting is limited to at most 20 percent of full power when the control zones are unoccupied and that all lights are off when the entire room is unoccupied.

2.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal would modify the following sections of the Nonresidential ACM Reference Manual as shown below.

- **Section 5.4.4:** Update PAF instructions form “open office” to “office” to improve clarity and align with proposed code language.
- **Appendix 5.4B:** Update fractional occupancy and lighting schedules for offices.

See Section 2.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

2.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change modifies the following section of the Nonresidential Compliance Manual:

- **Section 5.4.3.4:** Add a new subsection (subsection C. Part 3) for multi-zone occupancy sensing control in large office spaces. The original Subsection C. Part 3 (partial off occupant sensing controls) would be shifted to Subsection D. Part 4.
- **Section 5.4.7:** Add a new subsection E to explain how multi-zone occupancy sensing control works.

See Section 2.6.5 of this report for the detailed proposed revisions to the text of the compliance manuals.

2.1.3.5 Summary of Changes to Compliance Documents

The proposed code change modifies the compliance documents listed below. Examples of the revised documents are presented in Section 2.6.6.

- **NRCI-LTI-05-E:** Update the PAF options in Part 2.A.2.a related to occupant sensing controls in large offices.
- **NRCC-LTI-E:** Modify Section P Power Adjustment to reflect the updated PAFs for occupant sensing in large offices.
- **NRCA-LTI-02-A:** Add additional functional testing procedures for occupancy sensing in large offices as C-2.

2.1.4 Regulatory Context

2.1.4.1 Existing Requirements in the California Energy Code

2019 Title 24, Part 6 lacks a specific mandatory automatic shut-off controls requirement for offices greater than 250 ft^2. Shut-off options include time-switch controls with two hour timed manual override (minimal compliance) and an occupancy sensor that can monitor the full space, although sensor limitations typically limit to less than 1,200 ft^2.

2019 Title 24, Part 6 includes a PAF that was adopted in the 2013 code cycle. The PAF can be found in Table 140.6-A for Occupant Sensing Controls in Large Open Plan Offices. It allows a factor of 0.40 for control zones no larger than 125 ft^2, a factor of 0.30 for control zones between 126 and 250 ft^2, and a factor of 0.20 for zones between 251 and 500 ft^2.

No other code change proposals under consideration for the 2022 code cycle overlap with the recommendations in this report. The Lighting Power Densities (LPDs) measure, described later in this report, would revise the existing 2019 Title 24, Part 6 LPD requirements and has some overlap since it also addresses requirements for interior lighting.

2.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

2.1.4.3 Relationship to Local, State, or Federal Laws

The Statewide CASE Team is not aware of any relevant local, state, or federal laws that conflicts with the recommendations in this proposal.

2.1.4.4 Relationship to Industry Standards

This proposal aligns with the 2018 IECC Section C405.2.1.3 Open Plan Office Control. The 2018 IECC is mandatory and specifies that all control zones shall be switched separately, lights shall automatically turn off all control zones within 20 minutes of all occupants leaving the space, and that each control zone must reduce lighting by at least 80 percent power, or switch off, within 20 minutes of occupants leaving a control zone. It specifies 600 ft^2 as the maximum control zone size and that daylight responsive controls in each zone are only active when a zone is occupied. The proposed code change matches all of the aforementioned details.

The 2018 IECC specifies the requirement for open office areas greater than 300 ft^2, which is a difference in nomenclature— "open office" versus "large office"—and sizing—300 ft^2 versus 250 ft^2—between the proposed code change and the 2018 IECC. The space type "open office" is neither defined in the IECC, ASHRAE 90.1, nor Title 24, Part 6. An enclosed office space greater than 250 ft^2, however, is a defined space type in Title 24, Part 6 and therefore is the most accurate, clear, and applicable way to define terminology for the proposed measure. The difference in sizing of the requirement corresponds to the already existing mandatory shut-off controls requirement for offices less than 250 ft^2.

2.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how to mitigate or remove negative impacts on market actors who are involved in the compliance process. 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.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** The lighting designer and electrical engineer identify the relevant requirements and either perform calculations by space to confirm compliance or use an energy consultant. For example, the lighting designer lays out the occupancy sensors along with the luminaires on the reflected ceiling plan taking into consideration the furniture layout. The lighting designer also provides a control narrative specifying the sequence of operation of the occupancy sensors within each large office area. In the control diagram, the electrical engineer specifies the actual or virtual connection between each occupancy sensor and the luminaires it controls.
- **Permit Application Phase:** The lighting designer, sometimes with the assistance of the energy consultant, contributes to the Certificate of Compliance (NRCC) to certify that the layout, connections, and coverage areas of occupancy sensors in the design drawings are compliant with the multizone occupancy sensing control requirement. The plan examiner reviews the NRCC documentation and confirms that the mandatory multi-zone occupancy sensing control for large offices is incorporated into the design documentation.
- **Construction Phase:** The electrical contractor installs, connects, and configures the occupancy sensors and luminaires following the design drawings and documentations. The contractor fills out the Certificate of Installation (NRCI) after the lighting control system is properly installed and commissioned. An ATT is engaged to test the controls per the acceptance testing criteria before final inspection and to fill out the Certificate of Acceptance (NRCA) forms. Increased coordination among lighting designers, electrical engineers, mechanical engineers, electricians and controls contractors, and lighting and mechanical ATTs would significantly reduce negative impacts on compliance and enforcement in the both the construction and inspection phases.
- **Inspection Phase:** The building inspector verifies that the mandatory controls have been provided per the plan set, specifications, and the NRCC documents. If the controls are missing or do not meet plan set, specification, or the NRCC documents, the building inspector would require the installation to be corrected as designed. The building inspector confirms that the NRCI and NRCA documentations have been provided on site for the building owner.

2.1.5.1 Comparison to Existing Compliance Process

The compliance process described above differs from the existing compliance process in a few ways. In the current design phase, lighting designers neither need to document compliance with occupancy sensors for large offices nor coordinate with mechanical designers or engineers on HVAC occupied standby controls integration. In the permit application phase, the plans examiner’s role does not currently require verification of mandatory occupancy sensors in large offices, so an awareness of the new requirement and the changes needed in NRCC forms and lighting design documents would be required. In the construction phase, there currently is no functional test for multi-zone occupancy sensing in large offices. The controls contractor does not currently need to coordinate between the lighting and mechanical design teams and the lighting and mechanical ATTs to ensure compliance for large offices.

The proposed compliance process would benefit from increased coordination, as both multi-zone occupancy sensing and HVAC occupied standby integration would add complexity to controls programming. The current inspection phase does not include large offices as a space type requiring occupancy sensors, so the building inspector would need to be aware of the new requirement and NRCA forms and update the training accordingly. Detailed in Section 4.1.1.4, lighting ATTs provided feedback that training for both installation market actors and ATTs would help with compliance for both installation and acceptance testing.

The compliance documents NRCI-LTI-05-E, NRCC-LTI-E, and NRCA-LTI-02-A would be changed as specified in Section 2.6.6. The main changes are the updating of the PAF table in the first two documents and the addition of a functional test in the last document. The new acceptance test requirements would need to complete inspections as detailed in Section 2.6.3. Lighting ATTs would need to complete the inspections for the new acceptance test requirements.

2.1.5.2 Mitigating Potential Compliance and Enforcement Challenges

The Statewide CASE Team mitigated potential compliance and enforcement challenges by including an exception in proposed code language for under shelf and furniture-mounted task lighting, incorporating ATT feedback into both drafting and revisions of the proposed acceptance test, clarifying the role of the lighting ATT in verifying zone size in the acceptance test, and specifying the need for increased coordination among lighting and mechanical design, contractor, and ATT actors.

The Statewide CASE Team gathered input from ATTs throughout all stages of the proposed code language development process. Before drafting the proposed changes to the Reference Appendices, the Statewide CASE Team distributed a survey to members of both the California Advanced Lighting Controls Training Program (CALCTP) and the National Lighting Contractor's Association of America (NLCAA) and received 196 total responses. Survey questions, quantified responses, and specific comments can be found in Section 4.1.1.4. Key results include:

- Most (91.8 percent) of ATT survey respondents had previously completed lighting controls acceptance tests for indoor occupancy sensors.
- 47 percent of ATT survey respondents had completed tests for occupancy sensors serving small zones in large open plan offices (PAF number 2 from Table 140.6-A),

while 52 percent had not. One percent replied “maybe.” 53 percent of ATT survey respondents anticipated doing so in the future.

- 45 percent of ATT survey respondents felt functional testing requirements would need to allow for PIR sensor detection zone overlap with adjacent zones, while 42 percent felt this was unnecessary and 9 percent were unsure.
- About one third (36.4 percent) of ATT survey respondents felt it was neither easy nor difficult to discern an occupancy sensor’s control zone boundary. 36.4 percent found it difficult or very difficult, and 23.3 percent found it easy or very easy.
- Floorplans are the most popular document to help ATTs discern occupancy zones, followed by lighting plans.

This feedback was taken into consideration when drafting the acceptance test, especially that control zone overlap should not be prohibited in order to reduce control zone coverage gaps.

Once the acceptance test was drafted, the Statewide CASE Team engaged with the Energy Commission to provide further guidance. The Energy Commission shared comments from their ATT reviewers on the drafted language. Key points of the feedback are included in Section 4.1.1.5, as well as the Statewide CASE Team’s response. In response to the comments, the Statewide CASE Team added a control zone size verification acceptance test and an explanation on zone overlap acceptability in the Reference Appendices.

2.1.5.3 Feasibility of Compliance and Enforcement

The Statewide CASE Team’s Compliance Improvement Subject Matter Experts (SMEs) shared that the proposed code change would add additional complexity due to the control integration required for lighting and mechanical systems. While HVAC occupied standby integration already exists in Title 24, Part 6, it is a requirement for which good design and compliance practices can be challenging due to the need for increased collaboration and communication among usually non-interacting actors (Sagehorn 2020). One example involves the process that should occur when both lighting and mechanical controls are used. There is a need for clarification of the protocol for acceptance testing on a control when both lighting and mechanical controls apply. Another challenge to compliance and enforcement would be raising the awareness with market actors that large offices would now be required to comply with HVAC occupied standby controls integration. Further details on impacts can be found in Appendix E.

While compliance could be slightly more complicated due to the new requirement, this would not be an insurmountable challenge. There would be no additional required compliance documents, but rather, only altered current forms. The most significant change would be the new acceptance test, which incorporated ATT feedback to best mitigate compliance and enforcement issues, as described earlier. The building inspector’s role does not change significantly in scope, but rather adds another space type to an already existing requirement. Enforcement should not add additional burden, as the forms clearly articulate the mandatory updated changes.

The Compliance Improvement SMEs described a few potential compliance and enforcement loopholes to be considered:

- ATTs could alter the sensors between lighting and mechanical acceptance testing such that the controls are non-compliant.
- If an HVAC zone serves the large office as well as other spaces with occupancy, it would be exempt from the HVAC occupied standby initiation until all spaces within the HVAC zone had been unoccupied for more than five minutes as per Section 120.2(e)3 of the 2019 Title 24, Part 6 Standards.
- The control zone size could be larger than the required 600 ft^2 maximum zone size.
- If all of the lighting was specified as under shelf or furniture-mounted task lighting with no lighting on the ceiling, the large office would be exempt from the proposed code change.

Contingent upon approval of a nonresidential data registry by the Energy Commission, all nonresidential energy compliance documents would require registration with a nonresidential data registry prior to submittal to an enforcement agency. Implementation of a nonresidential data registry would provide an opportunity to utilize certain quality assurance features, such as the Project Status Report (PSR).

When a project is uploaded, the data registry determines which compliance documents are required for the project based on the Certificate of Compliance. The data registry maintains the project status with a summary of the current status of completion of all required documents for the project. The project status report is accessible to authorized users of the Data Registry, including plans examiners and building inspectors. This feature allows building inspectors to quickly determine whether required compliance documents have been completed.

2.2 Market Analysis

2.2.1 Market Structure

The Statewide CASE Team confirmed current product availability, investigated market trends, and considered how the proposed standard may impact 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 outreach to 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 a public stakeholder meeting that the Statewide CASE Team held on September 12, 2019. Meeting notes (Statewide CASE Team 2019a) and the meeting presentation (Statewide CASE Team 2019b) are both included in the Bibliography.

The market for occupancy sensors and lighting controls is well established in the United States (U.S.). Currently, the main market actors include lighting designers, electrical engineers, electrical contractors, distributors, manufacturer sales representatives and agencies, manufacturers, and lighting controls acceptance test technicians. The following descriptions explain the core functions of each market actor:

- Lighting designers initiate the implementation by designing the layout of the luminaires and overall lighting system. This code change has potential to impact lighting designers' work in large offices.
- Electrical engineers determine the electrical wiring of the luminaires and controls. In the absence of a lighting designer, typically smaller design-build or retrofit projects, the electrical engineers also determine the layout and use of the luminaries.
- Electrical contractors procure, install, and commission the lighting system, which includes occupancy sensors.
- Distributors sell the lighting equipment which includes fixtures and controls. Distributors make product recommendations as needed to the contractors who buy their products.
- Manufacturer sales representatives are agencies focus on sale generation. They work with distributors to order and supply products from the manufacturers. They can also provide design support and other consulting services to electrical contractors and distributors as requested, especially when a project lacks a lighting designer.
- Manufacturers produce lighting equipment which includes fixtures and controls.
- Lighting controls acceptance test technicians administer the acceptance test required to make sure a project is code compliant.

The distribution channel often includes manufacturers, sales representatives, distributors, designers, and contractors. Although the process is not always linear, the prior list represents a typical method for distribution of occupancy control technologies.

2.2.2 Technical Feasibility, Market Availability, and Current Practices

2.2.2.1 Technical Feasibility

Technology to implement this code change is readily available in California. Most occupancy sensors control the lighting digitally through either a room controller or a networked lighting control system. The occupancy sensors are configurable in terms of their associations with the luminaires and/or control zones. By using software, and occasionally hardware, different sensors can be configured to monitor and work with different control zones and control zone sizes. As such, control zones can be reprogrammed, added, and rearranged at the control panel or remotely through computer, and even mobile phone applications, rather than rewiring. Research and interviews with stakeholders confirmed the availability of the necessary technology to implement the proposed measure.

Luminaire level lighting control (LLLC), where sensors are an integral part of each luminaires, also offers options for implementation. This luminaire and sensor configuration can increase the granularity of the control area if each sensor makes control decisions independently. With LLLCs, the luminaires may also be networked together to coordinate with each other and act as a single, larger zone if that would be the desired lighting design.

Multiple Design Paths

The proposed measure offers design flexibility to lighting designers, sales reps, and other market actors by enabling lights to follow a dim to 20 percent lighting power or more implementation or an auto-off implementation. Such flexibility for compliance was critical to every stakeholder interviewed and was also voiced by multiple market actors in the first utility-sponsored stakeholder meeting. The first design path would be occupancy sensor dimming to 20 percent lighting power. Interviews with stakeholders revealed a strong preference for the dim to 20 percent design path. It would enable relatively uniform general lighting, with 20 percent to 100 percent light at any given time in an occupied large office. A dry contact, BACnet, or other implementation could be used to turn all lights off and activate occupied standby for the HVAC system upon full office vacancy.

The second design path is a low cost on/off occupancy sensor implementation. This would lead to a less uniform general lighting aesthetic, as all unoccupied control zones' lighting would turn off while occupied control zone lighting would remain fully on. This design path would also enable higher energy savings, as it would further reduce lighting load by turning lights fully off rather than dimming to 20 percent power. As with the first design path, a dry contact, BACnet, or other implementation method could be used to turn all lights off and activate occupied standby for the HVAC system upon full office vacancy. Concerns were voiced for this design path around safety at night and building owners or occupants thinking lighting systems are not properly functioning. While this design path was less preferable to the majority of stakeholders interviewed, almost all expressed the need for this design path to remain an option for building owners to offer flexibility in cost effectiveness, energy savings, and aesthetic preference.

2.2.2.2 Market Availability

With the advancement of solid-state lighting technology, which enables easier integration of lighting controls and opportunities to provide non-lighting related features as part of a lighting system, manufacturers, sales representatives, contractors, and designers have been shifting the focus from stand-alone products, such as lamps and ballasts, to full-system offerings. Currently, occupancy sensors are required in California in small offices, classrooms, conference rooms, restrooms, multi-purpose rooms, aisleways, warehouses, library book stacks, stairwells, corridors, and parking garages. The occupancy sensing market is well established in California.

Compiled based on research and the Statewide CASE Authors' prior knowledge, the following non-exhaustive list of manufacturers offering lighting controls includes:

- Acuity Controls
- Cooper Lighting Solutions
- Cree, Inc.
- Digital Lumens, an Osram Business
- Douglas Lighting Controls
- Enlighted, a Siemens Company
- GE Current, a Daintree Company
- Hubbell Control Solutions
- Legrand/WattStopper
- Leviton
- Lutron
- Magnum Innovations
- OSRAM
- Signify

Many of the large companies, along with emerging smaller companies, offer occupancy controls as part of whole-building energy management solutions. Many include wireless and digital options for controls, some involving mobile applications to monitor and reduce lighting, HVAC, and other energy consumption. This integration is important when using occupancy controls to activate occupied standby when all control zones in a large office are completely unoccupied.

In a study conducted by the National Lighting Product Information Program (NLPIP), it was noted that wireless lighting controls are available from more than 40 companies in the U.S. (NLPIP 2015). NLPIP's outreach to 152 lighting specifiers not associated with a particular manufacturer concluded that the most frequently selected brands of wireless controls are Leviton, Lutron, and WattStopper. Some of the prominent manufacturers, for example both Leviton (Leviton 2019) and Lutron (Lutron 2020, 26-29), have already released documents describing how their products can be used to comply with the 2018 IECC, Section C405.2.1.3 Open Plan Office Control, to which the proposed code change closely parallels.

2.2.2.3 Current Practices

Interviews with stakeholders revealed that occupancy sensors are commonly implemented in large office spaces, sometimes in combination with time-switch controls. Currently, most of the interviewees prefer occupancy sensors in some combination with time-switch control rather than a time-switch control-only design strategy. Current occupancy controls implementation commonly treats office spaces as one zone, rather than multiple, smaller control zones. Some design and consulting firms interviewed, however, are already implementing strategies even more granular than the proposed measure due to the cost-effective energy savings benefits.

Going from the more common standard practice of time-switch controls and occupancy sensors to complying with the proposed code change would require market actors to utilize more occupancy sensors, a more granular control strategy, and potentially different equipment. A few stakeholders mentioned that when demand response is required for large buildings, digital systems are used and are already configurable to meet the proposed code change requirements. For this implementation, correctly programming controls to meet the requirement would be needed and no additional equipment is necessary. While this is an encouraging observation, the Statewide CASE Team did not use this as the basis for the cost and cost-effectiveness analysis in Sections 2.4.3.2 in favor of being diligent on the incremental costs for projects where demand responsive lighting control is not required.

To summarize the impact to the baseline approach from the current Title 24, Part 6 Standards; for large offices not needing to meet the demand response requirements, the proposed measure would entail a change from the code minimum design strategy by requiring smaller control zones for occupancy sensors. Manufacturers and lighting representatives would likely benefit due to increased sales. The design strategy would necessitate more work for electrical engineers and/or contractors to specify a code compliant control strategy. The design, installation, and compliance processes would likely benefit from increased communication between contractors, sales representatives, and designers.

While the proposed measure goes beyond current standard practice in some scenarios, multiple stakeholders mentioned support for the proposed code change as they believe it is where standard practice is heading and would help achieve additional energy efficiency in California buildings. Stakeholders also supported alignment across industry standards to reduce complexity in compliance. The 2018 IECC already mandates a parallel controls requirement.

Some stakeholders shared that they had not seen the PAFs for Occupant Sensing Controls in Large Open Plan Offices in Title 24, Part 6 frequently used prior to the 2019 Title 24, Part 6 Standards going into effect. They noted that it has been easy to stay below the allowed LPD in office spaces using light emitting diodes (LEDs) and therefore not needing an additional LPD allowance in recent years. Additionally, stakeholders and some lighting ATTs mentioned PAFs add unnecessary complexity and that they believe they can lead to higher energy use. While the Statewide CASE Team considered removing the PAFs entirely, lighting ATT feedback demonstrated its continued use, encouraging the modification of, rather than the removal of, the PAF table. The Statewide CASE Team also believe that the PAFs would continue to encourage implementing occupancy shut-off control using smaller control zones, which can result in deeper energy savings.

In a February 2020 survey, 118 ATTs responded to inquiries about their experience with the PAF from Table 140.6-A. 47 percent had completed acceptance tests on a project using the relevant PAF, and 52 percent had not, with one response as “maybe.” When asked if they anticipated completing such an acceptance test on a future project, 53 percent responded “yes,” 42 percent responded “no,” and 6 percent responded “maybe.” Detailed results from the survey can be found in Appendix G. The stakeholder and lighting ATT feedback bolsters the Statewide CASE Team’s suggestion to remove the larger control zone size in the PAF table and update the smaller control zone PAF values. While some stakeholders had suggested removing the PAF completely, the ATT feedback demonstrates both its current and predicted use. Instead of removing the PAFs, the Statewide CASE Team updated PAF values to incentivize smaller control zones and increased energy savings.

The energy savings for the proposed measure are not expected to diminish throughout the 15-year lifetime of the measure. The implementation involves a reliable control strategy that is not expected to require regular maintenance in order to achieve persistent savings.

The proposed measure would not result in a change in installation technique for those already implementing multiple occupancy sensors in a space. However, it could require more complex configurations for installation depending upon the chosen technology and design path.

The proposed measure requires a new acceptance test which is detailed in Section 2.6.3. ATT perspectives were gathered and incorporated before drafting the acceptance test and after the first draft of the test was completed, as described in Section 2.1.5. Detailed survey responses and reviewer comments can be found in Sections 4.1.1.4 and 4.1.1.5.

Market and Technological Critical Barriers

Incremental first cost for implementation has been brought up as a barrier for the proposed measure. Stakeholder feedback raised the concern that costs would increase, especially in smaller projects. The proposed measure is anticipated to raise the cost for projects involving large offices. As shown in Section 2.4.5, the proposed measure is found to be cost effective over a 15-year lifetime. The Statewide CASE Team contacted manufacturers, sales representatives, contractors, designers, and acceptance test technicians to obtain cost estimates for equipment and labor for both base case costs and proposed measure costs. There is flexibility for material costs built into the proposed code change, via multiple compliant design paths. The Statewide CASE Team modeled the more costly implementation path, with findings included in Section 2.4.3 through Section 2.4.5. Installation costs would likely see an increase due to more material installation and commissioning needs. There is potential for increased complexity of verifying a functional system for electricians currently unfamiliar with the technology.

Much of the cost of complying with the measure comes from installation and commissioning labor wages, which can vary geographically. For this reason, the Statewide CASE Team took precautions to create a conservative estimate using the highest cost implementation method for code compliance and high labor wages, scaled to the California average value from RSMeans. Through outreach, the Statewide CASE Team realized many large offices are already using occupancy sensors, rather than time-switch controls alone, which would reduce the experienced incremental first cost due to current practices. Additionally, some projects already focused on improved energy savings are proactively incorporating multi-zone occupancy sensing. At the most efficient levels, this sensing is down to the individual desk or individual fixture and has been proven to have great returns.

Another potential critical barrier is the aesthetic or amenity impact of the proposed measure. Multiple stakeholders have raised this as a concern to the Statewide CASE Team, especially designers. The proposed measure does not require unoccupied control zones to turn lights fully off, as lights can comply by dimming to 20 percent of full power. There is concern over non-uniform lighting appearance and the acceptability of lights dimming to 20 percent of full power; however, the Statewide CASE Team received comments from those already implementing the 2018 IECC in open plan offices in Texas that such concerns were not an issue. The Statewide CASE Team is currently seeking additional input on this topic, especially from building owners in regions which have already adopted the 2018 IECC.

Other Market and Technology Barriers

Concern Over Potential Dead Zones

Some stakeholders have raised concerns over occupancy sensors failing to bring the lighting to full power, creating dead zones in the large office space due to obstructions such as cubicle partitions. This issue depends on occupancy sensing technology and furniture setup, such as cubicle height and divider layout. While passive infrared (PIR) sensors may have obstructed lines of sight due to high partitions or improper lighting control plan design, the proposed measure does not prescribe a specific technology. Other occupancy sensing technologies such as ultrasonic, dual technology, and microphonic are readily available and frequently used, as was verified in stakeholder interviews. For those occupancy sensors utilizing pressure changes as an indicator of movement, the sensitivity can be adjusted to account for dead zones.

Concern Over Signal Interference

During the first utility-sponsored stakeholder meeting, a comment was raised over concern about potential for signal interference. However, zero poll responses indicated this to be an issue of concern and stakeholders responded in the public chat that signal interference is only an issue with some manufacturers. Both the signal interference and its solution are well known. For ultrasonic occupancy sensors, this issue can be overcome by using different frequencies for adjacent control zones and adjusting sensitivity. Another occupancy sensing technology, microphonics, eliminates this issue as it does not transmit sound waves into a space (Acuity Brands, Inc. 2016). Signal interference should not be a technology-based barrier to compliance with the proposed code change.

Concern for Including HVAC Occupied Standby

The point has been raised that requiring HVAC occupied standby adds complexity and does not belong in a lighting proposed measure. It is important to note that Section 120.2(e)3 of the Title 24, Part 6 2019 code already requires HVAC occupied standby capabilities for multiple spaces, including offices less than 250 ft^2. In fact, the Title 24, Part 6 requires such capabilities for all spaces where occupancy sensing is required and spaces are allowed to reduce ventilation to 0, as per Table 120.1-A and Note F for offices. Therefore, the proposed measure does not alter any HVAC related code, but rather, requires occupancy sensors in offices greater than 250 ft^2, which is a space where ventilation can be reduced to 0. This condition of mandatory occupancy sensors would subsequently require offices greater than 250 ft^2 to have HVAC occupied standby capability due to existing Title 24, Part 6 code language.

Concern Regarding Egress Lighting

The proposed measure does not apply to egress lighting. Egress lighting would remain on as designed and allowed. The building owner or operator has the flexibility to dim to 20 percent lighting power rather than off, if preferred. Current minimal code compliance with a time-switch control requires occupants be able to physically turn lights on again, regardless of occupancy status.

2.2.3 Market Impacts and Economic Assessments

2.2.3.1 *Impact on Builders*

Builders of residential and commercial structures are directly impacted by many of the proposed code changes 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 4).[1] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector, while another 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

[1] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 4: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establish ments	Employ ment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
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
Commercial	**17,273**	**343,513**	**$27.8**
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
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
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

Source: (State of California, Employment Development Department n.d.)

The proposed measure to multi-zone occupancy sensing in large offices would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The measure would not affect the residential building industry. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 5 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Commercial building construction and nonresidential electrical contractors are expected to be impacted by the proposed change due to their engagement with lighting in nonresidential projects. Nonresidential HVAC contractors and equipment contractors would be impacted by the proposed code change primarily due to the need to implement occupied standby ventilation control in large office spaces, which becomes mandatory as a result of this code change proposal. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 2.2.4.

Table 5: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Standard

Construction Subsector	Establish ments	Employ ment	Annual Payroll (billions $)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential Electrical Contractors	3,115	66,951	$5.6
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4,.7
Other Nonresidential equipment contractors	506	8,884	$0.9

Source: (State of California, Employment Development Department n.d.)

2.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 6 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The Statewide CASE Team anticipates the impacts for multi-zone occupancy sensing in large offices to affect firms that focus on nonresidential office construction.

There is not a North American Industry Classification System (NAICS)[2] code specifically assigned to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[3] It is not possible to determine

[2] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[3] Establishments in this sector include businesses primarily engaged in evaluating a building’s structure and component systems and includes energy efficiency inspection services and home inspection

which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 6 provides an upper bound indication of the size of this sector in California.

Table 6: California Building Designer and Energy Consultant Sectors, 2018

Sector	Establish ments	Employ ment	Annual Payroll (millions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

2.2.3.3 Impact on Occupational Safety and Health

The proposed measure 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.

2.2.3.4 Impact on Building Owners and Occupants

Commercial Buildings

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) (Kenney 2019). 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

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services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

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 (Kenney 2019). 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.

Estimating Impacts

Building owners and occupants would benefit from lower energy bills. As discussed in Section 2.2.4.1, money saved on energy bills tends to be spent 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 2022 code cycle to impact building owners or occupants adversely.

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

The proposed code change would likely improve the sales of occupancy sensors and lighting control technology such as room controllers or networked lighting controls (NLCs). It is possible the sales of time-switch controls for use in large office spaces would decrease, although this is not guaranteed. Manufacturers and distributors for occupancy sensors, occupancy related lighting controls, and equipment with HVAC occupied standby integration capabilities would likely have increased demand and sales. See Section 2.2.4.2 for more specific details on the creation or elimination of businesses.

2.2.3.6 Impact on Building Inspectors

Table 7 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. The scope of the building inspectors’ role conducting energy efficiency inspections would be revised to include a new space type, large offices, in which to verify the presence of occupancy sensing controls. This scope change is standard procedure in line with typical code updates and is therefore not expected to have a significant impact.

Table 7: Employment in California State and Government Agencies with Building Inspectors, 2018

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

2.2.3.7 *Impact on Statewide Employment*

As described in Sections 2.2.3.1 through 2.2.3.6, 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 2.2.4, the Statewide CASE Team estimated the proposed change in multi-zone occupancy sensing in large offices 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 that energy savings associated with the proposed change in multi-zone occupancy sensing in large offices would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

2.2.4 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.[4] While this is the first code cycle in which the Statewide CASE Team develops

[4] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

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 those in the commercial building industry, lighting designers, electrical and mechanical engineers, and energy consultants. 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.

Table 8: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (person)	Labor Income ($ million)	Total Value Added ($ million)	Output (million)
Direct Effects (Additional spending by Commercial Builders)	341.2	$22.6	$29.9	$49.5
Indirect Effect (Additional spending by firms supporting Commercial Builders)	74.2	$5.4	$8.6	$16.6
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	148.4	$8.4	$15.0	$24.4
Total Economic Impacts	563.8	$36.3	$53.5	$90.5

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 9: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (person)	Labor Income ($ million)	Total Value Added ($ million)	Output (million)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	128.5	$13.3	$13.1	$23.4
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	81.8	$5.5	$7.4	$11.8
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	100.5	$5.6	$10.0	$16.4
Total Economic Impacts	**310.8**	**$24.4**	**$30.6**	**$51.5**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

2.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new types of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 2.2.4 would lead to modest changes in employment of existing jobs.

2.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 2.2.4.1, 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 nonresidential indoor large office lighting control strategy, which would neither excessively burden nor 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.

2.2.4.3 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.[5] 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.

2.2.4.4 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).[6] As Table 10 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.

Table 10: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	$609.2	$1,740.3	35%
2016	$456.0	$1,739.8	26%
2017	$509.3	$1,813.6	28%
2018	$618.2	$1,843.7	34%
2019	$580.9	$1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

[5] 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.

[6] 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.

Estimated increase in investment in California:

Change in Total Estimated Proprietor Income ($7,755,195) * 0.31 = **$2,398,258.**

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 8 and Table 9 above by 31 percent.

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

The Statewide CASE Team does not expect the proposed code changes would have a measurable impact on the California's General Fund, any state special funds, or local government funds.

2.2.4.6 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. The proposed measure may impact state buildings – new construction, alterations, and/or additions for those buildings with large office spaces. Despite some additional incremental cost, the proposed code changes have been found to be cost effective and save significant amounts of energy.

Cost to Local Governments

All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in

Section 2.1.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

2.2.4.7 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 Statewide CASE Team does not anticipate the impact of the proposed code change on any specific group or groups of persons (i.e., persons of a specific protected class, persons eligible to participate in affordable housing programs, renters, commuters, etc.) would differ from impacts to persons generally. This conclusion was reached by understanding that the proposed code change impacts nonresidential large office spaces, which should logically have a negligible impact on residential spaces and therefore a negligible difference in impact on affordable housing programs, renters, commuters, etc., as on persons generally.

2.3 Energy Savings

2.3.1 Key Assumptions for Energy Savings Analysis

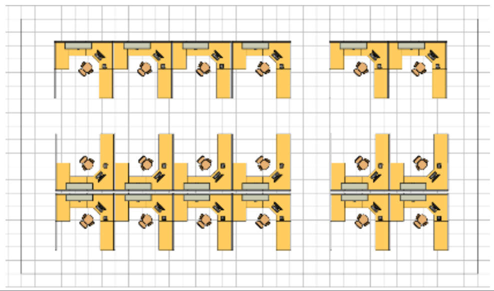
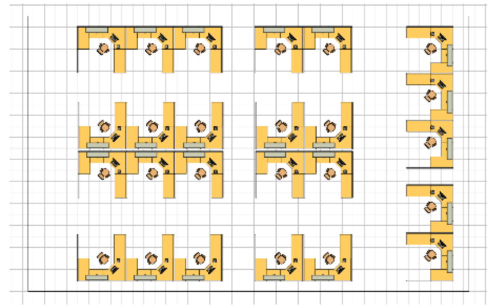
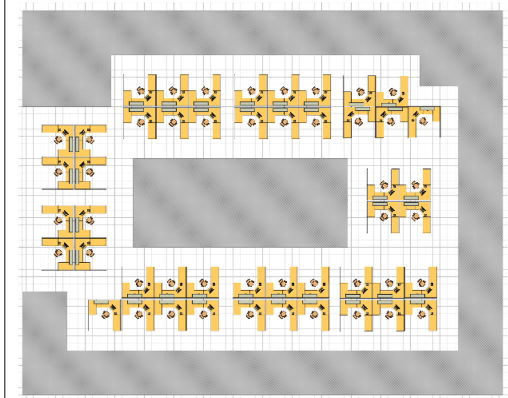
The energy and cost analysis presented in this report used the TDV factors that are consistent with the TDV factors presented during the Energy Commission's March 27, 2020 workshop on compliance metrics (California Energy Commission 2020). The electricity TDV factors include the 15 percent retail adder 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 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 from E3 in a spreadsheet titled "2022 TDV Demand Factors.xlsx". The final TDV factors that the Energy Commission released in June 2020 use 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. The 20-year GWP values increased 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 that use 20-year GWP values were used in the analysis. 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.

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 has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric that was developed for the 2022 code cycle. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

To estimate the energy savings from multi-zone occupancy sensing controls in large offices, the Statewide CASE Team used three model floor plans representative of offices greater than 250 ft^2, in small, medium, and large areas as summarized in Table 11. These models were based on the 2013 Final CASE Report for Indoor Lighting Controls (Table 11) with modifications and simplifications (Statewide CASE Team 2011). More details about the floor plan model can be found in Appendix H.

Table 11: Model Floor Plan Details for Energy Savings Calculations

Office Floor Plan Model	Model Office A	Model Office B	Model Office C
			
Square footage	2,584 ft^2	4,000 ft^2	7,540 ft^2 (a)
Number of occupants	18	25	48
Average area per workstation/cubicle (b)	140 ft^2	154 ft^2	154 ft^2
Number of luminaires	28	40	76
General lighting layout	95 ft^2/luminaire	100 ft^2/luminaire	100 ft^2/luminaire
Total lighting load(c)	1,301 W	2,000 W	3,794 W
Lighting power density(c)	0.50 W/ft^2	0.50 W/ft^2	0.50 W/ft^2

(a) This is the square footage of the large office area within the 13,520 ft^2 floor space of an office building.

(b) The average area per workstation/cubicle includes the square footages of the circulation and common area between the workstation or cubicles.

(c) The total lighting load and LPDs shown here consider all lighting in the space, including troffers for overhead general lighting as well as other vertical or decorative lighting.

2.3.1.1 Assumptions on Occupancy Schedules

The Statewide CASE Team obtained the raw data set used in the analysis for the Power Adjustment Factors (PAFs) for Occupancy Controls in the 2013 Final CASE Report (Statewide CASE Team 2011). This data set contains the presence and absence status of 82 individual workstations and cubicles in a large government office building recorded in a 2-minute interval over 34 workdays between August 2009 and January 2010. It was assumed that these occupancy patterns are sufficiently diverse to represent a wide range of typical office workers' working schedules.

2.3.1.2 Assumptions on Office and Luminaire Spatial Layouts

The three large office models, based on the 2013 Final CASE Report for Indoor Lighting Controls (Table 11) with modifications and simplifications (Statewide CASE Team 2011), were created in an effort to capture the typical floor plan of large offices in small, medium, and large square footage configurations. It was assumed that the overhead lighting in all three model office areas were provided by 2ft-by-4ft troffers with a nominal input power of 40 watts arranged in a roughly 10ft-by-10ft grid. Since this proposed code change is applicable to all lighting, additional lighting power was assumed for vertical lighting or decorative lighting. This resulted in a LPD of 0.5 W/ft^2 in all three models.

2.3.1.3 Assumption on the Number of Control Zones

The number of control zones was determined based on the square footage of the model offices and the maximum allowed control zone size (600 ft^2). For example, there would be seven control zones for the 4000 ft^2 medium-size office model. This would result in the most conservative energy reduction as savings are likely to increase with the number of control zones. The impact of additional cost per control zones was not explicitly evaluated, although it can be calculated from the data in Sections 2.4.3 and 2.4.5. The lighting load in the model offices was also assumed to be evenly divided and controlled by each control zone.

2.3.1.4 Assumptions on Workdays

It was assumed that the primary savings of this measure would result from some control zones being unoccupied during work hours on workdays. Therefore, the savings analysis was performed on an average of 250 workdays within a year. Lighting energy usage and savings for weekends and holidays were not analyzed and not included in the savings calculations, which likely results in more conservative savings.

2.3.1.5 Assumption on the Baseline Setup and Sequence of Operation

For offices greater than 250 ft^2, Title 24, Part 6 currently mandates the space to be controlled by automatic time-switch controls or occupancy sensors. Therefore, two baseline cases were considered, one implements time-switch control and the other implements occupancy sensor control.

For the occupancy sensor baseline case, the number of occupancy sensors used for the baseline calculation were determined based on the square footage of the model offices and the coverage of an occupancy sensors (typically 1,000 ft^2 for occupancy sensors that detect large motions). Regardless of the number of occupancy sensors used to cover each model office, all the lights were assumed to be full-on as long as there is an occupant in the space, and the lights are turned off only when the entire office space area is vacant. This was the most common sequence of operation for occupancy sensors in large office areas based on the stakeholder outreach results.

When using a time-switch for shut-off control, the schedules are typically programmed to leave the lights on much longer, compared to using occupancy sensors, to avoid occupant complaints. In addition, time-switches are commonly configured with a 2-hour override time delay. To account for these factors in constructing the baseline, it was conservatively assumed that the time-switch baseline would have additional 30 minutes of daily full-load operating hours over the occupancy sensor baseline.

Savings from other lighting control strategies, such as daylighting control, are not accounted for in this analysis.

The energy savings from both the time-switch control and the occupancy sensing baseline cases then needed to be combined into a representative savings value for the overall measure baseline case. The frequency of deployment of occupancy sensors versus time-switch controls as the solution for shut-off controls typically depends on the size of the space. Table 12 shows the assumptions used for the relative fraction of occupancy sensors versus time-switch control prevalence in office spaces analogous in size to the three model offices, as based on data collected by the Statewide CASE Team during outreach.

Table 12: Assumption for the Fractions of the Baseline Shut-off Technologies Used in the Model Offices

Baseline Shut-off Technology	Model Office A (2,584 ft^2)	Model Office B (4,000 ft^2)	Model Office C (7,540 ft^2)
Time-switch	40%	70%	80%
Occupancy Sensor	60%	30%	20%

2.3.1.6 Assumptions on the Proposed Measure Setup and Sequence of Operation

There are two primary control methods that can be used to comply with the proposed measure.

1. Independent occupancy sensors turn lights on and off in each control zone in response to sensed occupancy in the zone. This implementation is relatively inexpensive and saves the most energy. However, this implementation results in non-uniform lighting in the space and could result in some paths of egress having illumination levels below the required 1 footcandle (FC) minimum when the other areas along the path of egress are still occupied.
2. Networked occupancy sensors dim lights in each control zone to no more than 20 percent of rated power in response to sensed occupancy in the zone, and when all zones are unoccupied, the lights in the entire space are turned off.

While the proposed measure allows various implementations, for this analysis, the Statewide CASE Team used the implementation of the second control method. This implementation, while being the most conservative in energy savings, is not necessarily the lowest cost option, which results in a more conservative cost-effectiveness assessment. Additionally, the 20 percent dimming implementation was the preferred approach for every stakeholder interviewed in the first round of outreach, with the exception of one who did not respond to this question. Each stakeholder also felt the 0 – 20 percent range should remain an option in the code language to provide flexibility.

2.3.1.7 Assumptions on Building-Level Energy Savings

The savings generated from the proposed measure is specific to office spaces larger than 250 ft^2 within nonresidential building types. The prototypical building models and the new construction forecast provided by the Energy Commission are at the building level and do not further differentiate the composition of different spaces within each building type. The following assumptions were made to project the savings from offices larger than 250 ft^2 within each building type to building-level savings.

The Statewide CASE Team used the building models in the Database for Energy Efficiency Resources (DEER) to estimate the fraction of offices greater than 250 ft^2 within the impacted nonresidential building types. For small and large office buildings, the fraction of “open offices[7]” was used as the fraction of large offices in these building types. For other building types, DEER provided only fraction of general office[7] areas without distinguishing office types. The Statewide CASE Team made a conservative assumption on the fraction of offices that are larger than 250 ft^2 within the general office areas as summarized in Table 13.

Table 13: Assumptions for the Large Office Fractions in Impacted Building Types in Energy Commission’s Statewide New Construction Forecast

Impacted Building Types	DEER Open Office Fraction	DEER General Office Fraction	Fraction of Large Office within DEER General Office	Overall Large Office Fraction
Small Office	35.7%	N/A	N/A	35.7%
Large Office	46.0%	N/A	N/A	46.0%
Single-Story Large Retail[a]	N/A	8.4%	50%	4.2%
Multistory Large Retail[a]	N/A	8.3%	50%	4.1%
Non-refrigerated Warehouse	N/A	6.8%[b]	50%	3.4%
Refrigerated Warehouse	N/A	5.1%	50%	2.5%
Primary School[c]	N/A	8.0%	70%	5.6%
Secondary School[c]	N/A	7.4%	70%	5.2%
College	N/A	17.7%[d]	25%	4.4%
Hospital	N/A	10.9%[e]	25%	3.2%

a. These two retail building types were further combined into a single “Retail” building type when applying Energy Commission’s statewide construction forecast in further analyses. It was assumed that the retail building sector consists of 75% single-story large retail stores, 10% multistory large retail stores, and 15% other types of retails stores per Table 16, and no large office space was assumed for those other types of retail stores.

b. There is no non-refrigerated warehouse building type in DEER. The average general office fraction for “Storage – Conditioned” and “Storage – Unconditioned” in DEER was used.

c. Primary school and secondary school were further combined into “Schools” building type when applying Energy Commission’s statewide construction forecast in further analyses assuming 60% primary schools and 40% secondary schools per Table 16.

d. The average general office fraction for “Education – Community College” and “Education – University” in DEER was used. This deviates from the Energy Commission’s prototype building for college, which is a compilation of small office, medium office, medium lab office, public assembly, secondary school, and high-raise apartment prototype buildings. In the context of determining the fraction of large offices in college buildings, the Statewide CASE Team used the information from

[7] The DEER building models for small and large office building types are composed of “small office” spaces and “open office” spaces. Office spaces within other DEER building models are captured as “general office” spaces without further distinguishing the size and type of the office spaces.

DEER to avoid making multiple layers of additional assumptions on the fraction of large offices within those individual prototype buildings.

e. The average general office fraction for "Health/Medical – Hospital" and "Health/Medical – Nursing Home" in DEER was used.

2.3.2 Energy Savings Methodology

2.3.2.1 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 Statewide CASE Team did not use the prototypical building models as they would typically be used because the scope of this measure is limited to large office areas within buildings. Luminaires responding to occupancy sensors in multiple control zones involve dynamic occupancy patterns and office spatial layouts, which could not be effectively modeled within the prototypical buildings.

The three model office spaces in Table 11 were used in energy savings calculations in place of the prototypical buildings, and the savings were assessed specifically and exclusively for offices larger than 250 ft^2 at the space level, rather than at the building level. The savings calculation does not distinguish between new construction, additions or alterations; the savings estimate should be equally applicable to all scenarios.

2.3.2.2 Per-Unit Savings Calculations Methodology

A spreadsheet-based model was developed for assessing the per-unit savings calculations using the model offices in Table 11 and the 82 individual occupancy patterns. The template takes two sets of inputs. The first set of inputs are setups related to the model office including the following parameters and are filled out based on the assumptions made in Section 2.3.1 and Table 11:

- Square footage of the model office;
- Luminaire layout, e.g. 100ft^2/luminaire;
- Nominal input power of the luminaires for general lighting;
- Additional LPD to account for non-general lighting, including vertical lighting and decorative lighting;
- Average workstation or cubicle size, including the circulation and common areas;
- Number of occupants, which is the same as the number of workstations/cubicles.

The second set of input is a time series of an occupancy pattern representing the average occupancy (in percentage) for the entire office space. With these two sets of inputs, the per-unit energy savings for the specific occupancy pattern are automatically populated.

2.3.2.3 Stochastic Occupancy Patterns

The occupancy patterns were derived from the 82 individual occupancy patterns described above using a stochastic approach. For each of the three model office layouts and the corresponding number of occupants, occupancy patterns were randomly sampled from the 82 individual occupancy patterns. A generated occupancy pattern was entered into the spreadsheet template to produce the per-unit energy savings. For example, for the Model Office B floor plan with 25 occupants, 25 occupancy patterns were randomly sampled from the 82 individual occupancy patterns to form the overall average occupancy pattern of the office space. This exercise was repeated 15 times for each model office space; 15 per-unit energy savings analyses were performed using the spreadsheet template. Figure 1 shows the daily average occupancy patterns for the 25-occupant Model Office B from the 15 sample runs, each represents the aggregated occupancy pattern of different 25 occupants.

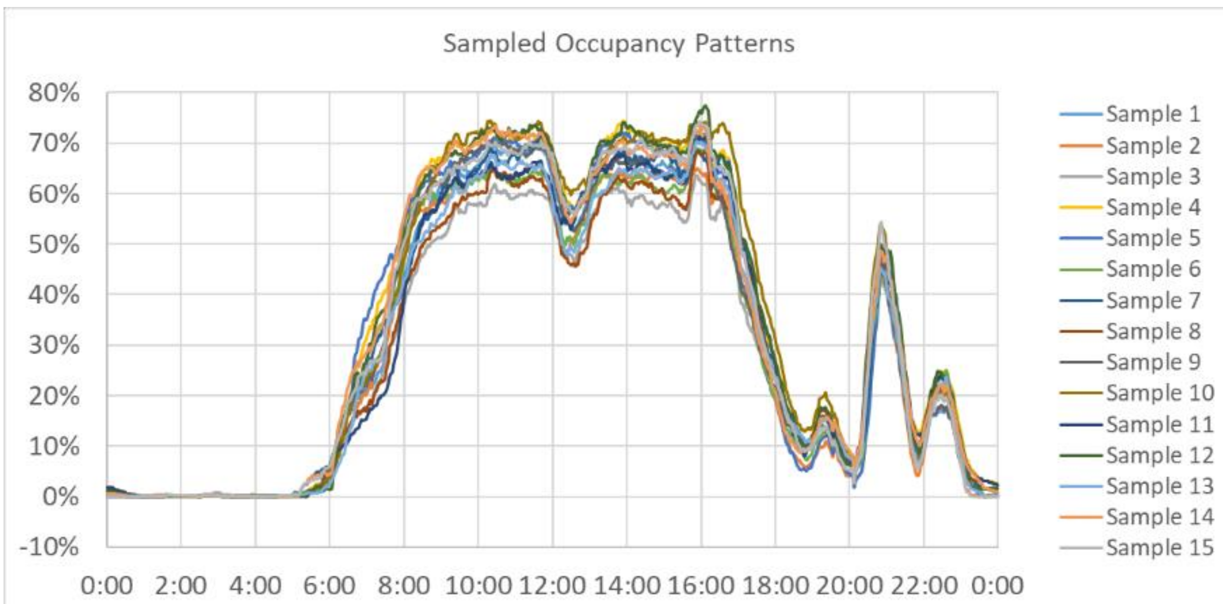


Figure 1: Average daily occupancy pattern from 15 random sample runs.

2.3.2.4 Base-case and Worst-case Savings

The per-unit energy savings is dependent not only on the occupancy pattern but also on the spatial distribution of the present occupants. For example, in a 25-occupant large office[8] with seven occupancy control zones, if the office is only 40 percent occupied, i.e. 10 occupants are present, the highest savings occurs if all 10 occupants happen to cluster in three of the seven control zones. In this case, the lights are full-on only in those three occupied control zones and off or dimmed to less than or equal to 20 percent of full rated power in the other four control zones. This would be the best-case savings scenario. In the worst-case scenario, the 10 occupants may occupy all seven control zones, and consequently, the lights in the entire open office space remain at full power, resulting the lowest savings potential. The actual energy savings may have a strong correlation to occupant spatial distribution. To account for this, the spreadsheet model calculates savings for both the best- and worst-case savings scenarios.

2.3.2.5 Occupied Standby Savings

This proposed code change makes occupancy sensors mandatory for shut-off control in offices larger than 250 ft^2, thereby automatically triggering the HVAC occupied standby requirement in the current Title 24, Part 6 code. Implementing HVAC occupied standby in large offices would result in additional energy savings, which have not yet been accounted for in previous code cycles or in other 2022 code change proposals. Therefore, the additional energy savings from HVAC occupied standby are included in the energy impact analysis in this Draft CASE Report.

The prototypical model for small office buildings provided by the Energy Commission was used to obtain the electricity and gas savings from HVAC occupied standby control. The average daily occupancy pattern described in Section 2.3.2.3 was supplied as both the occupancy schedule and the HVAC availability schedule for modeling and simulating energy usage of the small office prototype building. The resulting HVAC energy savings, including cooling and fan electricity savings as well as heating gas savings, were divided by the net conditioned space square footage of the small office prototype building. The result of the division provided the per-unit electricity and gas savings from occupied standby control. These savings were added to the per-unit lighting electricity savings described in Section 2.3.2.6 and incorporated into the first-year statewide energy impact analysis described in Section 2.5.

2.3.2.6 Per-unit Energy Savings Calculations

The per-unit energy savings are calculated using the following steps. First, the sampled occupancy pattern informed the percent of occupied office space for an average

[8] This can be an enclosed office with a total area greater than 250 ft^2 or an open-plan office not completely enclosed by full-height walls.

workday. The percent of occupied office for each time interval was used to determine the number of occupied control zones for that time period, in both the best-case and worst-case scenarios. In this case, the time interval was two minutes as the occupancy data was recorded at a two-minute interval as described in Section 2.3.1, but the spreadsheet can accommodate occupancy pattern with a different time interval.

For each sampled occupancy pattern, the baseline was constructed for large-zone occupancy sensing control. The lights are controlled by occupancy sensors, and as long an occupant is present in the office area, regardless of the control zones, all the lights stayed on until everyone left the office.

For each time period during the average workday, the number of occupied control zones is multiplied by the average controlled wattage per sensor per control zone to provide the average power of the occupied control zone (W). The average controlled wattage per sensor per control zone equals the total wattage of the office divided by the number of control zones.

The above step is also repeated for the unoccupied zones. The baseline case would still provide the unoccupied zones with full power; however, the proposed measure case requires unoccupied zones to dim to 0 – 20 percent of full power. The unoccupied zone average power (W) is the outcome of multiplying the number of unoccupied zones by the controlled wattage per sensor per zone by the percent of unoccupied control zone background lighting level, which is assumed to be 20 percent for the calculations.

Once both the occupied and unoccupied average zone powers have been calculated for both the baseline and proposed measure case, they are summed to result in the entire space average power (W) for each time period for both the baseline and proposed measure case. The entire space average power represents the average power used during a time period for the whole office area, incorporating all control zones.

Next, the entire space average power is multiplied by the time interval (2 minutes) to determine the entire space energy used during each time period. The energy usages within the same hour were then added up to become an hourly energy usage time series for each sample run and each model office. The hourly energy usages across the 15 sample runs were averaged for each model office and for both the large-zone occupancy sensing base case and the proposed measure case. The time-switch base case was then constructed based on the large-zone occupancy sensing base by adding additional energy usage equivalent to 30 minutes of full-load operating hours. The hourly savings time series was calculated as the hourly energy usage difference between each of the two base cases and the proposed measure case in both the best-case and worst-case scenarios. The Statewide CASE Team took a more conservative approach and assumed an average savings for each model office to fall at the 25 percentile between the worst- and best-case savings scenarios, closer to the worst-case savings scenario.

The hourly energy savings were then populated to every hour of the year on workdays to obtain the savings in kilowatt-hours per year (kWh/yr). To be conservative, no savings were assigned to hours on weekends and federal or state holidays. 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). The TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars were also calculated. The energy impacts of the proposed code change do not vary by climate zone, and the Statewide CASE Team used the statewide average TDV factors when calculating energy and energy cost impacts.

The per-unit energy impacts as well as nominal and 2023 present value TDV energy cost savings over 15 years for the three large office models are summarized in Table 14 and Table 15, respectively. These values were extrapolated to the first-year savings for the impacted buildings in the later sections based on the per-unit impacts in Table 14.

Table 14: Office Models First-Year Energy Impacts Per Square Foot

Model Office Floor Plan	Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings (therms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
Model Office A (2,584 ft^2)	All	0.824	0.136	0.00021	25.993
Model Office B (4,000 ft^2)	All	0.925	0.147	0.00021	28.788
Model Office C (7,540 ft^2)	All	1.071	0.159	0.00021	32.915
Average	All	0.940	0.147	0.00021	29.232

Table 15: Office Models 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction, Alterations, and Additions

Model Office Floor Plan	Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV $)	Total 15-Year TDV Energy Cost Savings (2023 PV$)[9]
Model Office A (2,584 ft^2)	All	$2.31	$0.00	$2.31
Model Office B (4,000 ft^2)	All	$2.56	$0.00	$2.56
Model Office C (7,540 ft^2)	All	$2.92	$0.00	$2.93
Average	All	$2.60	$0.00	$2.60

2.3.2.7 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 Commisison 2020). The Statewide Construction Forecasts estimate new construction that will occur 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, so the Energy Commission provided guidance on which prototypical buildings to use for each Building Type ID when calculating statewide energy impacts. Table 16 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.

[9] The Total 15-Year TDV Energy Cost Savings is a summation of the 15-Year TDV Electricity Cost Savings and the 15-Year TDV Natural Gas Cost Savings. The slight $0.01 inconsistence in some rows is due to rounding. The numbers in the table were rounded to the second digit below the decimal point; however, the actual calculations preserved all the insignificant digits. The small amount of natural gas cost savings rounded to zero dollar; however, when summed with the electricity cost savings, the insignificant digits rounded up to $0.01 in those rows.

Table 16: Nonresidential Building Types and Associated Prototype Weighting

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis
Small Office	OfficeSmall	100%
Large Office	OfficeMedium	50%
	OfficeLarge	50%
Restaurant	RestaurantFastFood	100%
Retail	RetailStandAlone	10%
	RetailLarge	75%
	RetailStripMall	5%
	RetailMixedUse	10%
Grocery Store	Grocery	100%
Non-Refrigerated Warehouse	Warehouse	100%
Refrigerated Warehouse	RefrigWarehouse	N/A
Schools	SchoolPrimary	60%
	SchoolSecondary	40%
Colleges	OfficeSmall	5%
	OfficeMedium	15%
	OfficeMediumLab	20%
	PublicAssembly	5%
	SchoolSecondary	30%
	ApartmentHighRise	25%
Hospitals	Hospital	100%
Hotel/Motels	HotelSmall	100%

2.3.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 17. The presented savings are for both new construction and alterations. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to be the highest for large office buildings at 0.242 kWh/yr, followed by 0.187 kWh/yr for small office buildings. Demand reductions are expected to be 0.041 W and 0.032 W for large and small office buildings, respectively. The savings are less significant for other building types primarily due to the fraction of large office areas within those building types.

Table 17: First-Year Energy Impacts Per Square Foot

Impacted Building Types	Climate Zone	Electricity Savings (kWh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings (therms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
Small Office	All	0.335	0.053	0.00007	10.425
Large Office	All	0.433	0.068	0.00009	13.453
Retail	All	0.033	0.005	0.00001	1.038
Non-Refrigerated Warehouse	All	0.033	0.005	0.00001	1.015
Refrigerated Warehouse	All	0.024	0.004	0.00001	0.744
Schools	All	0.051	0.008	0.00001	1.593
Colleges	All	0.042	0.007	0.00001	1.295
Hospitals	All	0.026	0.004	0.00001	0.799

a. Includes energy impacts result from HVAC occupied standby.

2.3.4 Calculating Updated PAF Values

The PAFs for Occupant Sensing Controls in Large Open Plan Offices (Table 140.6-A) would be updated to eliminate the largest PAF for control zones of 251-500 ft^2—to reduce complexity—and update the PAF values for control zones of 126-250 ft^2 and 125 ft^2 and below. The PAFs for implementing smaller control zones were retained to continue to provide an incentive for taking steps to use smaller controls such as luminaire level controls. Depending upon the prevalence of use and the long term savings from luminaire level controls, these might be a mandatory requirement in a future code, at which time this PAF would be entirely eliminated. Proposed code language revisions can be found in Section 2.6.2. The updated PAF values were calculated based on the same three model office layouts, detailed in Table 11, as used in the energy savings analysis. For simplicity, only general lighting was considered in the models. The calculations used the exact same approach as the energy analysis in Sections 2.3.2.1 through Sections 2.3.2.5, however the control zones were reduced to 125 ft^2 and 250 ft^2.

As with the proposed code change energy analysis, both best- and worst- case scenarios were considered. The best-case scenario represented all present occupants clustering in the same control zones so the least number of occupancy sensors would be triggered and the most energy would be saved. The worst-case scenario represented all present occupants spreading across the entire office such that the greatest number of occupancy sensors would be triggered, and the least energy would be saved.

The hourly energy consumption from the 125 ft^2 and 250 ft^2 scenarios were then compared to the hourly energy consumptions from the proposed code measure scenario to calculate the savings for each of the three large office models and for both the best-case and worst-case scenarios. The formula used for hourly percentage reductions in lighting load matches that of the original development of the PAFs in the 2013 Final CASE Report for Indoor Lighting Controls (Statewide CASE Team 2011, 37-38).

$$\text{Power Adjustment Factor (PAF)} = \frac{\sum_{i=0}^{23} B_i * PR_i}{\sum_{i=0}^{23} B_i}$$

Where:

B_i = Baseline lighting energy use for hour i, averaged across the three office models

PR_i = Percentage reduction in lighting load at hour i, due to occupancy sensor control

The PAF values were estimated conservatively as controls have less certainty of savings than lowering LPDs. The PAF values for the two reduced control zones were calculated by assuming the actual savings as the 30th percentile between the best- and worst-case scenarios, weighted towards the worst-case scenario. These values can be found in the row "Weighted Average" in Table 18. Table 18 summarizes the calculated values for updating the PAFs.

Table 18: Calculated Values to Update PAFs for Occupant Sensing Controls in Large Offices

	125 ft^2 Control Zone		250 ft^2 Control Zone	
Power Adjustment Factor Scenario	**Least-efficient Case**	**Most-efficient Case**	**Least-efficient Case**	**Most-efficient Case**
Model Office A (2,584 ft^2)	0.14	0.43	0.10	0.17
Model Office B (4,000 ft^2)	0.11	0.44	0.08	0.17
Model Office C (7,540 ft^2)	0.06	0.43	0.05	0.16
Average	0.10	0.44	0.07	0.17
Weighted Average		0.20		0.10
Recommended PAF		**0.20**		**0.10**
Note: The "Least-efficient case" and "most-efficient case" here reflects the impact of the best-case and worst-case distribution of the present occupants on the savings as described in Section 2.3.2.4.				

2.4 Cost and Cost Effectiveness

2.4.1 Energy Cost Savings Methodology

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 2.3. 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.

The proposed code change applies to additions and alterations. For both additions and alterations, and the incremental cost would be the same as new construction. Therefore, the energy cost savings for additions and alterations are the same as that of new construction.

2.4.2 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 nominal dollars and 2023 dollars in Appendix L.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Utilities often have commercial peak periods between 4 PM and 9 PM, depending on the utility (PG&E Time of Use Rates 2020). Some demand response programs are shifting later, but generally have operating hours between 2 PM and 9 PM. Considering 4 PM to 9 PM to be the peak period, 23 percent of the energy savings from the proposed code change would occur during peak periods.

Table 19: 2023 PV TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction and Alterations

Impacted Prototypical Building Types	Climate Zone	15-Year TDV Electricity Cost Savings (2023 PV$)	15-Year TDV Natural Gas Cost Savings (2023 PV $)	Total 15-Year TDV Energy Cost Savings (2023 PV$)
Small Office	All	$0.93	$0.00	$0.93
Large Office	All	$1.20	$0.00	$1.20
Retail	All	$0.09	$0.00	$0.09
Non-Refrigerated Warehouse	All	$0.09	$0.00	$0.09

Refrigerated Warehouse	All	$0.07	$0.00	$0.07
Schools	All	$0.14	$0.00	$0.14
Colleges	All	$0.12	$0.00	$0.12
Hospitals	All	$0.07	$0.00	$0.07

a. Includes 2023 TDV energy cost savings from HVAC occupied standby.

2.4.3 Incremental First Cost

As described in the energy analysis, two base cases were considered:

1. Minimal compliance with a time-switch control implementation and no occupancy sensors, and
2. Above minimal compliance implementation with occupancy sensors that function as one control zone per office.

The proposed measure case would be using occupancy sensors compliant with the proposed code change. Costs were collected for the three office layouts shared in Section 2.3.

Both base cases were compared with the proposed code change to estimate two incremental first costs. This is because Section 130.1(c) in Title 24, Part 6 allows for either occupancy sensing controls or automatic time-switch controls to comply with the code. Thus, each implementation's incremental first cost was computed. The Statewide CASE Team then used the same weighted averages as those from Table 16 to calculate incremental first costs to determine the overall measure incremental first cost.

2.4.3.1 Incremental First Cost Data Collection Process

At the first utility-sponsored stakeholder meeting, for which presentation materials can be found in the Bibliography, the proposed cost estimate was generated using RSMeans data. Stakeholders responded to a poll question with 44 percent agreeing that the estimated labor cost at $96/hr adjusted to the California maximum scaling factor was too high (11 percent said the labor cost was too low). 55 percent of the poll respondents found the material cost of the occupancy sensor ($138) to be too high and 0 percent found it to be too low. Additionally, 44 percent of poll respondents said dual technology sensors were unnecessary.

To get more accurate cost estimates, the Statewide CASE Team conducted three rounds of outreach with stakeholders, including poll respondents, distributors, manufacturers, and sales representatives. In the first round of outreach, fourteen interviews were conducted with designers, manufacturers, sales representatives, and contractors as described in Appendix F and Appendix G. During each interview, the Statewide CASE Team asked the interviewee to share their best estimate for each cost component listed in Table 20 for each of the three office layouts, and for both the base cases and proposed measure case. The Statewide CASE Team conducted a second round of outreach with occupancy sensor and lighting controls distributors to gain further insight into accurate cost data.

In response to the poll engagement from the first utility-sponsored stakeholder meeting, the Statewide CASE Team moved forward with an installation labor rate of $74.11/hr scaled to Sacramento, California (120.8 percent compared to the 2020 national average electrician labor rate of $61.35/hr). This was determined to be a high estimate for an electrician's apprentice or an electrician's crew blended rate in RSMeans and replaced the $96.00/hr average California adjusted rate presented at the meeting. The Statewide CASE Team also used the price of a PIR sensor for analysis rather than a dual technology sensor based on the meeting feedback.

The Statewide CASE Team conferred with the Energy Commission in April and received guidance to use a rate closer to the $96.00/hr estimate to develop a conservative incremental first cost. The Statewide CASE Team referred to the 2020 Quarter 1 RSMeans City Cost Index for California, which ranges from 107.3 to 193.5 times the national average for electrician installation scaling factors. The Statewide CASE Team included overhead and profit in the cost estimate moving forward and used a California average scaling factor of 129.6 percent for commissioning and installation labor as explained in the assumptions of Section 2.4.3.2. The Statewide CASE Team moved forward with the labor rates at $118.41/hr and $129.53/hr for commissioning and installation labor, respectively. The final estimate utilized the higher rates to present a more conservative B/C ratio.

Results in this Draft CASE Report are a combination of stakeholder feedback and RSMeans. The Statewide CASE Team is concurrently conducting a third round of outreach with lighting representatives, controls sales representatives, and an electrical engineer to verify reasonable assumptions were made in design methodology and actual cost estimates. The Statewide CASE Team will update the Final CASE Report based on this ongoing outreach.

2.4.3.2 Incremental First Cost Components

The incremental first cost for multi-zone occupancy sensing in large offices involves the components listed in Table 20, where the minimum, maximum, and average values for each component of incremental costs can be found.

Table 20: Incremental Measure First Cost Components Minimum, Maximum, and Average

Cost Component	Minimum	Maximum	Average	Value Used in Estimate	Source
Cable Connector ($/item)	N/A	N/A	N/A	$5.34	Manufacturers
Commissioning Labor ($/hour)	$91.35	$176.76	$118.41	$118.41	RSMeans
HVAC Occupied Standby Integration	N/A	N/A	N/A	$0.13	2019 Final CASE Report Proposals Based on ASHRAE 90.1
Installation Labor ($/hour)	$79.18	$153.21	$102.63	$102.63	RSMeans
Junction Box	$2.24	$4.45	$3.35	$3.35	Manufacturers
Occupancy Sensors ($/item)	$55.63	$190.21	$113.76	$55.63	Multiple Stakeholders
Power Cable ($/1')	N/A	N/A	N/A	$0.73	RSMeans
Room Controllers ($/item)	$69.82	$250.00	$144.97	$104.50	Multiple Stakeholders
Time-switch ($/item)	$243.24	$1,360.00	$595.17	$244.54	Multiple Stakeholders
2-Wire 0-10V Cable ($/25')	N/A	N/A	N/A	$25.31	RSMeans

Other relevant assumptions are listed below:

- The power cable is a metal (steel) clad cable with 3 wires and 600 volt capacity. The cost estimate is from an RSMeans year 2020, line item 260519209020. The amount of cable calculated to bring line voltage to each control component is 30 feet per time-switch control and per room controller, as estimated based on the model office layouts and the experience of engineers on the Statewide CASE Team.
- The two-wire 0-10 Volt (V) cable is from RSMeans 2020 first quarter and carries dimming signal from the room controllers to the light fixtures based on occupancy signal. The estimate assumes six 25 foot cable segments per 2,584 ft^2 space based on the model offices, including extra cable for contingency. There is no incremental cost for this component as there is no change in material needed between proposed and base cases.
- The cost for HVAC occupied standby integration originates from the 2019 Final

CASE Report Proposals Based on ASHRAE 90.1 (Statewide CASE Team 2017). This includes the cost of an additional occupancy sensor and added controls for the building monitoring system, as informed by actual contractor quotes. While the \$0.13/ft^2 may be redundant in including an additional occupancy sensor, it makes the cost estimate more conservative.

- All labor rates include overhead and profit. The commissioning labor rate is based on RSMeans Labor Rate National Average for 2020 electricians, which is \$91.35/hr. The commissioning labor rate is scaled to \$118.41/hr, the average California rate, at 129.6 percent of the national rate for all installation and commissioning as based on the Uniformat II Cost City Indexes Year 2020 Quarter 1. The installation labor rate is based on the Crew R-1B blended rate of \$79.18. It is scaled to \$102.63/hr, the average California rate, at 129.6 percent of the national rate for all installation and commissioning as based on the Uniformat II Cost City Indexes Year 2020 Quarter 1.
- In regard to labor hour assumptions:
    - The installation and commissioning hours are determined from values for similar products within the RSMeans tool. Occupancy sensors take about the same time to install as they do to commission, and room controllers take significantly more time to install than to commission. The commissioning estimates include acceptance test technician time and were determined by engineers on the Statewide CASE Team. The installation estimate for the 2-wire 0-10 V cables was estimated by engineers on the Statewide CASE Team.
    - If "a" equals the number of room controllers, "b" equals the number of occupancy sensors, and "c" equals the number of time-switch controls, and "d" equals the number of 2-wire 0-10 V 25 foot cables, then the following equations were used to calculate installation and commissioning time:
        - Installation hours (time-switch) = c*5.109 + d*1.28
        - Installation hours (occupancy sensor) = a*3.374 + b*0.399 + d*1.28
        - Commissioning hours (time-switch) = c*4.506
        - Commissioning hours (occupancy sensor) = a*0.57 + b*0.399

    The formula for the installation and commission hours for occupancy sensors are applicable to both the occupancy sensor base case and the proposed case.
- The occupancy sensor cost was obtained from a vendor, and the model selected is a wireless PIR sensor.

- The junction box average cost was determined from two four by four inch steel junction boxes readily accessible for online purchase from popular vendors in early 2020.
- The room controller cost was obtained from a California vendor using a wireless load controller with a 0 – 10 Volt control from a popular manufacturer.
- The cable connector was estimated to be two units per junction box.
- The time-switch control model selected for use is a common model with accuracy to the minute, temporary override, and permanent manual override.

The following tables summarize the base case costs, the proposed measure case costs, and the incremental measure cost.

Table 21: Base Case First Cost for Time-Switch Implementation (Minimal Compliance) – Model Office A

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.54
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	12.789	$1,312.56
Junction Box	$3.35	N/A	N/A
Occupancy Sensors ($/item)	$55.63	N/A	N/A
Power Cable ($/1’)	$0.73	30	$21.90
Room Controllers ($/item)	$104.50	N/A	N/A
Time-Switch ($/item)	$244.54	1	$244.54
2-Wire 0-10V Cable ($/25’)	$25.31	6	$151.86
Total Project Cost	N/A	N/A	**$2,264.41**

Table 22: Base Case First Cost for Time-Switch Implementation (Minimal Compliance) – Model Office B

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.54
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	17.909	$1,838.04
Junction Box	$3.35	N/A	N/A
Occupancy Sensors ($/item)	$55.63	N/A	N/A
Power Cable ($/1’)	$0.73	30	$21.90
Room Controllers ($/item)	$104.50	N/A	N/A
Time-Switch ($/item)	$244.54	1	$244.54
2-Wire 0-10V Cable ($/25’)	$25.31	10	$253.10
Total Project Cost	N/A	N/A	**$2,891.12**

Table 23: Base Case First Cost for Time-Switch Implementation (Minimal Compliance) – Model Office C

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	9.012	$1,067.08
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	33.258	$3,413.34
Junction Box	$3.35	N/A	N/A
Occupancy Sensors ($/item)	$55.63	N/A	N/A
Power Cable ($/1’)	$0.73	60	$43.80
Room Controllers ($/item)	$104.50	N/A	N/A
Time-Switch ($/item)	$244.54	2	$489.08
2-Wire 0-10V Cable ($/25’)	$25.31	18	$455.58
Total Project Cost	N/A	N/A	**$5,468.89**

Table 24: Base Case First Cost for Occupancy Sensor Implementation (Above Minimal Compliance) – Model Office A

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	2	$10.68
Commissioning Labor ($/hour)	$118.41	3.363	$398.20
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	13.847	$1,421.15
Junction Box	$3.35	1	$3.35
Occupancy Sensors ($/item)	$55.63	7	$389.41
Power Cable ($/1’)	$0.73	30	$21.90
Room Controllers ($/item)	$104.50	1	$104.50
Time-Switch ($/item)	$244.54	N/A	N/A
2-Wire 0-10V Cable ($/25’)	$25.31	6	$151.86
Total Project Cost	N/A	N/A	**$2,501.05**

Table 25: Base Case First Cost for Occupancy Sensor Implementation (Above Minimal Compliance) – Model Office B

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	4	$21.36
Commissioning Labor ($/hour)	$118.41	5.13	$607.43
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	23.538	$2,415.76
Junction Box	$3.35	2	$6.70
Occupancy Sensors ($/item)	$55.63	10	$556.30
Power Cable ($/1’)	$0.73	60	$43.80
Room Controllers ($/item)	$104.50	2	$209.00
Time-Switch ($/item)	$244.54	N/A	N/A
2-Wire 0-10V Cable ($/25’)	$25.31	10	$253.10
Total Project Cost	N/A	N/A	**$4,113.45**

Table 26: Base Case First Cost for Occupancy Sensor Implementation (Above Minimal Compliance) – Model Office C

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	8	$42.72
Commissioning Labor ($/hour)	$118.41	11.457	$1,356.59
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	45.713	$4,691.63
Junction Box	$3.35	4	$13.40
Occupancy Sensors ($/item)	$55.63	23	$1,279.49
Power Cable ($/1’)	$0.73	120	$87.60
Room Controllers ($/item)	$104.50	4	$418.00
Time-Switch ($/item)	$244.54	N/A	N/A
2-Wire 0-10V Cable ($/25’)	$25.31	18	$455.58
Total Project Cost	N/A	N/A	**$8,345.01**

Table 27: Proposed Measure First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office A

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	14	$74.76
Commissioning Labor ($/hour)	$118.41	6.783	$803.15
HVAC Occupied Standby Integration ($/ft^2)	$0.13	2,584	$335.92
Installation Labor ($/hour)	$102.63	34.091	$3,498.84
Junction Box	$3.35	7	$23.45
Occupancy Sensors ($/item)	$55.63	7	$389.41
Power Cable ($/1’)	$0.73	210	$153.30
Room Controllers ($/item)	$104.50	7	$731.50
Time-Switch ($/item)	$244.54	N/A	N/A
2-Wire 0-10V Cable ($/25’)	$25.31	6	$151.86
Total Project Cost	N/A	N/A	**$6,162.19**

Table 28: Proposed Measure First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office B

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	20	$106.80
Commissioning Labor ($/hour)	$118.41	9.69	$1,147.36
HVAC Occupied Standby Integration ($/ft^2)	$0.13	4,000	$520.00
Installation Labor ($/hour)	$102.63	50.53	$5,186.01
Junction Box	$3.35	10	$33.50
Occupancy Sensors ($/item)	$55.63	10	$446.30
Power Cable ($/1’)	$0.73	300	$219.00
Room Controllers ($/item)	$104.50	10	$1,045.00
Time-Switch ($/item)	$244.54	N/A	N/A
2-Wire 0-10V Cable ($/25’)	$25.31	10	$253.10
Total Project Cost	N/A	N/A	**$9,067.07**

Table 29: Proposed Measure First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office C

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Cable Connector ($/item)	$5.34	40	$213.60
Commissioning Labor ($/hour)	$118.41	20.577	$2,436.46
HVAC Occupied Standby Integration ($/ft^2)	$0.13	7,540	$980.20
Installation Labor ($/hour)	$102.63	99.697	$10,232.13
Junction Box	$3.35	20	$67.00
Occupancy Sensors ($/item)	$55.63	23	$1,279.49
Power Cable ($/1’)	$0.73	600	$438.00
Room Controllers ($/item)	$104.50	20	$2,090.00
Time-Switch ($/item)	$244.54	N/A	N/A
2-Wire 0-10V Cable ($/25’)	$25.31	18	$455.58
Total Project Cost	N/A	N/A	**$18,192.46**

For each office layout, the incremental measure cost was then calculated by subtracting the proposed measure cost from the base case, both for the time-switch control and occupancy sensor implementation.

Table 30: Incremental Measure First Cost by Office Layout

Model Office Floor Plan	Incremental Measure Cost with Time-Switch; Minimal Compliance ($/ft^2)	Incremental Measure Cost with Occupancy Sensor; Above Minimal Compliance ($/ft^2)	Weighted-Average Incremental Measure Cost by Implementation ($/ft^2)
Model Office A 2,584 ft^2)	$1.51/ft^2	$1.42/ft^2	**$1.45**
Model Office B (4,000 ft^2)	$1.54/ft^2	$1.24/ft^2	**$1.45**
Model Office C (7,540 ft^2)	$1.69/ft^2	$1.31/ft^2	**$1.61**
Average	$1.58/ft^2	$1.32/ft^2	**$1.51**

The incremental first costs for additions and alterations would be the same as that of new construction.

The two base case incremental first costs were averaged to determine the overall measure incremental first cost, $1.51/ft^2.

2.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the nth year is calculated as follows:

$$\text{Present Value of Maintenance Cost} = \text{Maintenance Cost} \times \left\lfloor \frac{1}{1+\mathrm{d}} \right\rfloor^{\mathrm{n}}$$

The Energy Commission cost-effectiveness methodology requires all nonresidential measures, excluding building envelope, to be assessed assuming a 15-year measure life. The energy savings related to the proposed measure are expected to persist throughout the 15-year measure life. Occupancy sensors and controls typically last 15 years or more and do not require maintenance, expect for replacing batteries when wireless components, such as sensors, are used.

The Statewide CASE Team included battery replacement in the maintenance cost as wireless occupancy sensors. The batteries in the wireless occupancy sensors would need to be replaced after 10 years, as based on manufacturer product specifications. It is possible to implement the proposed code change with occupancy sensors that do not require batteries, so for some implementations the incremental maintenance and replacement cost would be zero dollars. This assumption would be similar to the work done in the 2013 Indoor Lighting Controls Final CASE Report (Statewide CASE Team 2011).

The Statewide CASE Team's cost estimate used wireless sensors, so the following methodology was used to determine the incremental maintenance costs:

- Estimate battery and labor costs;
- Determine incremental occupancy sensors per-unit (ft^2);
- Calculate incremental battery replacement costs per-unit (ft^2);
- Calculate the present value cost as per the equation above.

The Statewide CASE Team determined the cost per battery, when bought in bulk to be about $1.50 per battery. The maximum price located was $2.45 per item and the minimum price was $0.90 per item. The Statewide CASE Team assumed the installation time to be about 5 minutes per battery for labor. The Statewide CASE Team assumed an electrician's apprentice rate for labor, as the task at hand is not very technically challenging. The RSMeans 2020 Quarter 1 electrician apprentice rate was $73.10/hr (including overhead and profit) for the national average. Scaled up 129.6 percent to the California average scaling factor, as done in Section 2.4.3, brings the labor rate to $94.75 per hour. Because the battery life is 10 years per the manufacturer, the Statewide CASE Team assumed only one battery replacement would be necessary for the 15 year lifetime of the proposed measure.

The Statewide CASE Team calculated the average incremental number of occupancy sensors per square foot in order to determine per-unit maintenance costs over the lifetime of the proposed code change. First, the Statewide CASE Team determined the average incremental occupancy sensor per office layout by averaging the incremental occupancy sensors for model offices A, B, and C. Next, the Statewide CASE Team divided the average incremental occupancy sensors per office layout, or 6.67, by the average square footage per office to determine 1.377×10^{-3} incremental occupancy sensors per square foot. The hours of labor would be 5 minutes, or 1/12 hours per occupancy sensor. This would result in 1.15×10^{-4} hours of labor per square foot of large office. The calculations are summarized in Table 31.

Table 31: Per-Unit Incremental Maintenance and Replacement Costs

Cost Component	Cost Per Unit	Unit	Number of Units per Square Foot of Office	Cost Component Total ($/ft^2)
Installation Labor	$94.75	Hour	1.15×10^{-4}	$0.01087
Battery	$1.50	Item	1.38×10^{-3}	$0.00207
Incremental Maintenance Cost	N/A	N/A	N/A	**$0.01293**

The Statewide CASE Team calculated the per-unit present value of the incremental maintenance cost using the following equation:

$$\text{Present Value of Maintenance Cost} = \$0.01054 \times \left\lfloor \frac{1}{1+0.03} \right\rfloor^{10}$$

Present Value of Maintenance Cost = $0.00962/ft^2

2.4.5 Cost Effectiveness

This measure proposes a mandatory requirement. 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 from electricity 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 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.

Results of the per-unit cost-effectiveness analyses are presented in Table 32 for new construction, additions, and alterations, as the incremental first cost is the same for each. Climate zone has no impact on cost effectiveness for this measure.

The proposed measure is cost effective and saves money over the 15-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone. The B/C ratio is valid for both additions and alterations, as it is identical to that of new construction. Thus, the measure is also cost effective for alterations.

The B/C ratio for the proposed measure ranges from 1.58 to 1.80 and has an average value of 1.71. It is important to note that the B/C ratio is a rather conservative estimate due to multiple assumptions. The Statewide CASE Team assumed conservative estimates for the following:

- Energy savings estimate including only savings on workdays and omitting savings on weekends or holidays.

- Energy savings estimate that uses LPDs lower than the 2019 LPD allowance.
- Energy savings estimate assumed a time-switch base case that had only 30 minutes of additional full-load operating hours over the occupancy sensor base case.
- Energy savings and cost estimate based on electing a “dim to 20 percent power” implementation rather than an “auto off” implementation, and;
- Cost estimate based on an installation and commissioning labor rate at 129.6 percent of the national.
- Cost estimate based on HVAC occupied standby integration that includes an additional occupancy sensor.
- Cost estimate more conservative than the 2018 IECC analysis, which estimated $0.90/ft^2 - $1.00/ft^2, whereas this report estimates $1.46/ft^2 - $1.62/ft^2 (R. Athalye 2015).

Table 32: 15-Year Cost Effectiveness Summary Per Square Foot – New Construction, Additions, and Alterations

Model Office Layout	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
Model Office A (2,584 ft^2)	$2.31	$1.46	1.58
Model Office B (4,000 ft^2)	$2.56	$1.46	1.75
Model Office C (7,540 ft^2)	$2.92	$1.62	1.80
		Average B/C Ratio	**1.71**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. PV maintenance cost savings are included if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate. Costs include incremental first cost if proposed first cost is greater than current first cost. Costs include PV of maintenance incremental cost if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no Total Incremental PV Costs, the Benefit-to-Cost ratio is infinite.

2.4.5.1 Cost Effectiveness Verification

As described in Section 2.4.3.1, the Statewide CASE Team is conducting a third round of outreach with lighting representatives, controls sales representatives, and an electrical engineer to verify reasonable assumptions were made in design methodology and actual cost estimates. The preliminary results are summarized here and will be further updated in the Final CASE Report.

2.4.5.1.1 Lighting Representative Incremental First Cost Estimate

A lighting representative in California provided an estimate for the incremental first cost averaged across multiple vendors and implementation methods. The calculation includes four different 2019 Title 24, Part 6 compliant wired and wireless time-switch control implementations for the baseline scenario. There are eight different proposed 2022 Title 24, Part 6 compliant wired and wireless multi-zone occupancy sensing control solutions for the proposed case. The estimate includes product and labor costs for both install and start-up, and is representative of both fixture level and zone-based solutions. The labor estimate does not include additional design hours. Detailed data can be found in Section 4.1.1.1. The average incremental cost per square foot was $0.69/ft^2. Table 33 demonstrates the projected B/C ratio using this lighting representative's cost estimate. Note, the maintenance and replacement costs were assumed to be the same as calculated in Section 2.4.4.

Table 33: Estimated 15-Year Cost-Effectiveness Summary Per Square Foot

Model Office Layout	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
Model Office A (2,584 ft^2)	$2.31	$0.66	3.52
Model Office B (4,000 ft^2)	$2.56	$0.64	4.02
Model Office C (7,540 ft^2)	$2.92	$0.83	3.51
		Average B/C Ratio	**3.68**

This cost estimate verifies the Statewide CASE Team's incremental first cost estimate as plausible, if not conservative, as the average B/C Ratio is 2.1 times that as the estimate in Table 32. This cost estimate is perhaps more accurate, as it mixes multiple implementations—both wireless and wired, and both fixture level controlled and zone-based solutions. The estimate does not provide granular enough data for the Statewide CASE Team to use the exact B/C Ratio as the official analysis.

2.4.5.1.2 Lighting Representative Wired and Wireless Estimate

A lighting representative in California provided an estimate breaking down the incremental first measure costs between wired and wireless solutions, which have a 50/50 market distribution, according to this stakeholder. The lighting representative estimated three wired solutions from multiple vendors and five wireless solutions (with batteries) from multiple vendors. These solutions represented both fixture level and zone-based solutions. The costs were modeled for large offices of 2,584, 4,000, 7,540, and 10,000 ft^2, and the estimate includes both product and labor costs. The comparison demonstrated an average of 16.8 percent savings for installed wireless systems (batteries) compared to wired systems. While wireless systems had a product cost that was on average 6.9 percent higher, the average total labor cost across the four modeled offices was 33.1 percent lower, thus making the wireless implementation more cost effective. Detailed results can be found in Section 4.1.1.2.

2.4.5.1.3 Lighting Representative Equipment and Programming Incremental First Cost

A lighting representative in California provided an estimate using fixture embedded controls for Model Office A and external wireless battery powered controls for Model Offices B and C. This lighting representative determined that this was the most cost-effective implementation to meet the proposed code change. The estimate did not include labor rates, however it did provide a scaling factor that labor rate savings from wired to wireless controls for all solutions would be reduced by 25 percent. Detailed data from the estimate can be found in Section 4.1.1.3.

Table 34 summarizes the incremental equipment and programming cost per model office layout. The weighted-average incremental measure cost uses percentages found in Table 16. Table 35 estimates the B/C ratio using the labor rates provided by the estimate in Section 2.4.5.1.1, assuming that they are comparable as both estimates offer a mix of fixture embedded and wireless implementations. While the labor rate may not be a perfect match, it is a closer comparison than that of the estimate used by the Statewide CASE Team in Section 2.4.3.

Table 34: Incremental Equipment and Programming Cost Per Model Office

Model Office Floor Plan	Incremental Measure Cost with Time-Switch; Minimal Compliance ($/ft^2)	Incremental Measure Cost with Occupancy Sensor; Above Minimal Compliance ($/ft^2)	Weighted-Average Incremental Measure Cost by Implementation ($/ft^2)
Model Office A (2,584 ft^2)	$0.14	$0.00	$0.06

Model Office B (4,000 ft^2)	$0.39	$0.21	$0.34
Model Office C (7,540 ft^2)	$0.45	$0.21	$0.41
Average	**$0.33**	**$0.14**	**$0.27**

Table 35: Estimated 15-Year Cost-Effectiveness Summary Per Square Foot

Model Office Layout	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
Model Office A (2,584 ft^2)	$2.31	$0.31	7.38
Model Office B (4,000 ft^2)	$2.56	$0.56	4.59
Model Office C (7,540 ft^2)	$2.92	$0.70	4.18
		Average B/C Ratio	**5.39**

This cost estimate verifies the Statewide CASE Team's incremental first cost estimate as plausible, if not conservative, as the average B/C ratio is 3.1 times that as the estimate in Table 32. This cost estimate is perhaps more accurate, as it mixes multiple implementations—both wireless and wired, and both fixture level controlled and zone-based solutions. The Statewide CASE Team may use this data to update the measure incremental first cost and final B/C ratio.

2.5 First-Year Statewide Impacts

2.5.1 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 2.3.3, 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 determined the statewide savings from new construction to be 13.5 GWh, and the statewide savings from additions and alterations be 77.0 GWh. The first-year peak electric demand reduction is 2.1 MW for new construction and 11.9 MW for additions and alterations.

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.

Table 36 presents first-year statewide savings from new construction, additions, and alterations.

Table 36: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions

Construction Type	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	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)
New Construction	23.82	22.448	3.51	0.01	$62.29
Additions and Alterations	73.98	72.32	10.83	0.04	$199.79
TOTAL	**97.80**	**94.75**	**14.34**	**0.05**	**$262.08**

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

b. Includes energy and energy cost impacts result from HVAC occupied-standby.

2.5.2 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. 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. In short, this analysis assumes an average electricity emission factors of 240.4 metric tons CO2e per GWh and an average natural gas emission factor of 5,454.4 metric tons CO2 per therm based on the average emission factors for the CACX EGRID subregion

Table 37 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 17,279 metric tons of carbon dioxide equivalents (metric CO2e) would be avoided.

Table 37: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a, b] (Metric Tons CO2e)
Multi-zone Occupancy Sensing in Large Offices[c]	94.75	22,775	0.05	257	23,032

a. First-year savings from all buildings completed statewide in 2023.
b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.
c. Includes savings and GHG emission reductions result from HVAC occupied-standby.

2.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

2.5.4 Statewide Material Impacts

The proposed code change does not switch existing equipment or products for new ones, as all of the required equipment already exists and is in use in the industry. However, the proposed mandatory code change would likely increase the usage of occupancy sensors, control technology, and potentially cables and low voltage wires, depending upon implementation. The proposed code change could result in a decrease in usage of time-switch controls.

The Statewide CASE Team estimated material impacts using the following methodology:

- Estimate the material composition of each cost component listed in Table 20.
- Estimate the net change (from base case to proposed case) in units of cost component per square foot of large office spaces. This analysis uses a weighted average estimate across model office layouts A, B, and C.
- Estimate the change in each material for the proposed code change per-unit of office (per ft^2).
- Apply the per-unit savings to new construction and alterations to develop statewide savings.

The Statewide CASE Team estimated material composition of cable connectors by looking at the manufacturer specifications of a product used in the cost estimate. The specifications listed the component’s weight at 0.320 pounds (lbs) and material as zinc. Because the weight provided was component weight rather than shipping weight, the Statewide CASE Team estimated each cable connector to account for 0.32 lbs of zinc.

The Statewide CASE Team estimated the material composition of junction boxes by looking at the manufacturer specifications of a standard junction box closely aligned with the model used in the cost estimate. The specifications list the component’s weight as 0.850 lbs and material as steel. Because the weight provided was component weight rather than shipping weight, the Statewide CASE Team estimated each junction box to account for 0.85 lbs of steel.

The Statewide CASE Team estimated the material composition of the occupancy sensor by first looking at the manufacturer specifications for the model used in the cost estimate as well as the environmental information of similar products. The specifications provided a shipping weight of 0.25 pounds, which includes mounting hardware and a lithium battery. The dimensions of the sensor are about 11.5 in^3. The Statewide CASE Team estimated about 0.10 lbs of plastic,0.08 lbs of other materials, and traceable amount of lead, copper, steel and zinc to account for the occupancy sensor.

The Statewide CASE Team estimated the material composition of the power cable by looking at a manufacturer product specification similar to the one used in the cost estimate. The specifications included the total weight at 215 lb/1000 ft, or 0.215 lb/ft. The materials included a copper conductor, an outer jacket of aluminum armor, thermoplastic high-heat resistant nylon (THHN) insulation, and an assembly covering of polypropylene tape. The aluminum armor had a minimum of 0.6 inches in outer diameter. The following assumptions were made to determine the material impact of the cable:

- Conductor (copper) diameter of 0.0808 inches.
- Outer jacket armor (aluminum) diameter of 0.6 inches and thickness of 0.2 inches.
- Insulation (THHN) outer diameter of 0.118 inches.
- Assembly covering (polypropylene) diameter of 0.55 inches and thickness of 0.0004 inches. The diameter was based on a larger diameter with four wires. The thickness was based on an approximation of gauge 40.

For the room controller, the Statewide CASE Team identified a description on an online retailer website of the model used in the cost estimate as well as the environmental information of similar products from other manufacturers. The item weight was 6.7

ounces, with product dimensions of 4 x 2.25 x 4.5 inches. The room controller can vary by manufacturer, so the material use was an approximation based on multiple sources.

The Statewide CASE Team estimated the material composition of the time-switches by looking at a manufacturer product specification for the model used in the cost estimate, and assumes similar material compositions to room controllers. The shipping weight per item is 2.9 lbs.

The Statewide CASE Team did not estimate the material composition of the 2-wire 0-10 V dimming cables, as the same amount of each component was used in the base case and proposed case so there is no expected material impact for this component.

Table 38 summarizes the material impact by weight per component of the proposed code change based on the assumptions previously described.

Table 38: Material Impact by Weight per Component

Component	Mercury (lbs)	Lead (lbs)	Copper (lbs)	Steel (lbs)	Plastic (lbs)	Zinc (lbs)	Other (lbs)
Cable Connector	N/A	N/A	N/A	N/A	N/A	0.32	N/A
Junction Box	N/A	N/A	N/A	0.85	N/A	N/A	N/A
Occupancy Sensor	N/A	0.00	0.00	0.00	0.10	0.00	0.08
Power Cable	N/A	N/A	4.73	N/A	1.04	N/A	2.62
Room Controller	N/A	0.00	0.03	0.01	0.13	0.00	0.15
Time-Switch	N/A	0.02	0.23	0.05	0.97	0.01	1.07

The Statewide CASE Team analyzed the average number of units of each of the previously described components per ft^2 for both the proposed case and the base case. The base case scenario was created by assuming an even proportion of time-switch control implementation and occupancy sensor implementation as described for the cost-effectiveness analysis in Section 2.4.3. The analysis was averaged across model offices A, B, and C. The Statewide CASE Team subtracted the average component use per ft^2 of the base case from the proposed case in order to generate an incremental, or net, material usage per square foot of large office spaces. Table 39 describes the estimated net change in unit per square foot of large office space.

The Statewide CASE Team estimated the first-year statewide impacts on material use shown in Table 39 by multiplying each component's material impact by its corresponding incremental unit per ft^2 for large offices and summing material impacts for the proposed code change. The result was the per-unit impact on material use in pounds/year. The Statewide CASE Team then determined first-year statewide impacts by multiplying each material per-unit impact by 97.80 million ft^2, which is the estimated ft^2 —for new construction, additions, and alterations—of large offices to be completed statewide in 2023.

Table 39: First-Year Statewide Impacts on Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Mercury	NC	N/A	N/A
Lead	I	3.31×10^{-6}	3.23×10^{2}
Copper	I	5.42×10^{-3}	5.30×10^{5}
Steel	I	2.10×10^{-3}	2.06×10^{5}
Plastic	I	1.52×10^{-3}	1.49×10^{5}
Zinc	I	1.57×10^{-3}	1.54×10^{5}
Others	I	3.30×10^{-3}	3.23×10^{5}

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

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

2.5.5 Other Non-Energy Impacts

There are a few non-energy benefits related to the proposed measure. It may improve productivity of building occupants by reducing disruption for those who stay after hours and would otherwise need to walk over to enable the override control on a time-switch. The proposed measure also simplifies the standard by displacing the PAFs for Occupant Sensing Controls in Large Open Plan Offices. The data from more densely deployed occupancy sensors could be used for advanced space utilization analytics, which help optimize space utilization, thereby increasing operational efficiency and reducing operational cost at the organization level.

There are potential negative non-energy impacts such as leaving the occupant in a private office feeling surrounding by darkness after the lights have been turned off in a neighboring large office due to vacancy. Additionally, stakeholders have raised concern over a non-uniform aesthetic look to the space.

2.6 Proposed Revisions to Code Language

2.6.1 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 ~~strikethroughs~~ (deletions).

2.6.2 Standards

Modify Section 130.1(c)6 as follows:

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

(c) Shut-OFF Controls. All installed indoor lighting shall be equipped with controls able to automatically reduce lighting power when the space is typically unoccupied.

…

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

A. In aisle ways and open areas in warehouses…

B. In library book stack aisles 10 feet or longer…

C. Lighting installed in corridors and stairwells…

D. Lighting in office spaces greater than 250 ft^2 shall be controlled by occupancy sensing controls that comply with all of the following:

a. The occupancy sensing controls shall be configured so that lighting shall be controlled separately in control zones not greater than 600 ft^2.

b. Within 20 minutes of the control zone being unoccupied, the occupancy sensing controls shall uniformly reduce lighting power in the control zone to no more than 20 percent of full power.

c. Within 20 minutes of the entire office space being unoccupied, the occupancy sensing controls shall automatically turn off all lighting in all control zones in the space.

d. Lighting in each control zone shall be allowed to automatically turn on to full power upon occupancy within the control zone. When occupancy is detected in any control zone in the space, the lighting in other control zones that are unoccupied shall operate at no more than 20 percent of full power.

Exception: Under shelf or furniture-mounted supplemental task lighting controlled by a local switch and either a time-switch or an occupancy sensor.

Modify Section 130.1(f) as follows:

(f) Control Interactions. Each lighting control installed to comply with Section 130.1 shall permit or incorporate the functions of the other lighting controls required by this Section

…

8. For lighting controlled by automatic daylighting controls and by occupant sensing controls, the controls shall be configured so that power does not exceed the lesser of the allowed power by either control.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

Table 140.6-A Lighting Power Adjustment Factors (PAF)

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		0.1
2. Occupant Sensing Controls in ~~Large Open Plan~~ Office Spaces Greater than 250 Square Feet	One sensor controlling an area that is:	No larger than 125 square feet	~~0.40~~ 0.20
		From 126 to 250 square feet	~~0.30~~ 0.10
		~~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.		0.05

	Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.	
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

2.6.3 Reference Appendices

NA7.6.2.3 Occupancy Sensing Lighting Control Functional testing

For buildings with up to seven (7) occupancy sensors, all occupancy sensors shall be tested. For buildings with more than seven (7) occupancy sensors, sampling may be done on spaces with similar sensors and space geometries; sampling shall include a minimum of one (1) occupancy sensor for each group of up to seven (7) additional occupancy sensors. If the first occupancy sensor in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass. If the first occupancy sensor in the sample group fails the acceptance test the rest of the occupancy sensors in that group must be tested. If any tested occupancy sensor fails it shall be repaired, replaced or adjusted until it passes the test.

NA 7.6.2.3.1 Full or Partial-OFF Occupant Sensing Controls

This requirement is for areas where full or partial-OFF occupant sensing controls are required to comply with Section 130.1(c)6 A. – C.

For each sensor to be tested do the following:

(a) For a representative sample of building spaces, simulate an unoccupied condition. Verify and document the following:

1. Lights controlled by occupancy sensors turn off within a maximum of 20 minutes from the start of an unoccupied condition.

2. The occupant sensor does not trigger a false "on" from movement in an area adjacent to the space containing the controlled luminaires or from HVAC operation.

3. Signal sensitivity is adequate to achieve desired control.

(b) For a representative sample of building spaces, simulate an occupied condition. Verify and document the following:

1. Status indicator or annunciator operates correctly.

2. Lights controlled by occupancy sensors turn on immediately upon an occupied condition, OR sensor indicates space is "occupied" and lights are turned on manually (automatic OFF and manual ON control strategy).

NA 7.6.2.3.2 Multi-Zone Full or Partial-OFF Occupant Sensing Controls

This requirement is for multi-zone occupancy sensing in compliance with Section 130.1(c)6D.

Note: Under shelf or furniture-mounted supplemental task lighting controlled by a local switch and either a time-switch control or an occupancy sensor is exempted from these control requirements, all other lighting in large offices shall be subject to this test.

Note: When a control zone becomes unoccupied, the reduction metric is specified in lighting power in the code language. To reduce complexity and the technical challenge of sub-dividing the circuit to contain only a control zone of interest for measuring power, the acceptance test procedure is designed and implemented by using illuminance reduction as a proxy of lighting power reduction.

Note: If the office space implements institutional tuning, this test shall be performed after institutional tuning has been applied.

Select the occupancy sensors that are not close to the corner of the office and their field of views are not severely obstructed by walls or tall dividers. For each occupancy sensor to be tested, do the following:

(a) Simulate an occupied condition in the control zone controlled by the occupancy sensor. Verify and document the following:

1. Lights controlled by the occupancy sensor turn on immediately upon occupancy of the control zone.
2. Measure the illuminance at a location in the control zone where the light output is due to the controlled lighting.
3. Signal sensitivity is adequate to achieve desired control.

4. Status indicator or annunciator operates properly.

(b) Simulate an unoccupied condition in the control zone controlled by the occupancy sensor. Confirm that at least one control zone within the office greater than 250 ft^2 is occupied. Verify and document the following:

1. Lights controlled by the occupancy sensor uniformly reduce light output within 20 minutes from the start of the unoccupied condition in the control zone.
2. Measure the illuminance at the same location as in Step (a)1. Verify that the light reduction during unoccupancy is no more than 20% of the full light output measured in Step (a)1.
3. The sensor does not trigger a false "on" from movement outside of the control zone.
    a. **Note**: The field of view of occupancy sensors in the adjacent control zones in offices greater than 250 ft^2 may overlap, but the field of view must not include an adjacent enclosed spaces that is not part of the large office, like conference rooms, private offices, etc.
4. Signal sensitivity is adequate to achieve desired control.

(c) Simulate an unoccupied condition in the control zone controlled by the occupancy sensor while standing in an adjacent control zone. Determine the "edge" of the control zone controlled by the occupancy sensor by moving toward the occupancy sensor until the lights controlled by the occupancy sensor turn on as in Step (a)1, therefore simulating an occupied condition. Complete the following:

1. Measure the distance (in feet) from the "edge" of the control zone to the spot that is directly below the occupancy sensor. This is the radius of the control zone.
2. Determine the area of the control zone by using the formula: Area = $\pi(3.145)*radius^2$.
    a. **Note:** The formula assumes the field of view of the occupancy sensor is a circle, which is the most common coverage pattern of occupancy sensors. If the coverage pattern for an occupancy sensor under test is non-circular and is supported by available documentation, the test technician shall adjust the formula accordingly.
3. The area of the control zone must be less than or equal to 600 ft^2.

(d) Simulate an unoccupied condition in the control zone controlled by the occupancy sensor and in all other control zones within the enclosed space (room). Verify and document the following:

1. All lighting in the controlled zone turns off within 20 minutes from the start of the unoccupied condition.

2.6.4 NR ACM Reference Manual

The following marked-up language would occur in Section 5.4.4 Interior Lighting of the Nonresidential ACM Reference Manual.

Lighting Power Adjustment Factors (PAF)

Applicability **All projects**

Definition Automatic controls that are not already required by the Energy Standards and which reduce lighting power more or less uniformly over the day can be modeled as power adjustment factors. Power adjustment factors represent the percent reduction in lighting power that will approximate the effect of the control. Models account for such controls by multiplying the controlled watts by (1–PAF).

Eligible California power adjustment factors are defined in Table 140.6- A. Reduction in lighting power using the PAF method can be used only for nonresidential controlled general lights. Only one PAF can be used for a qualifying lighting system unless multiple adjustment factors are allowed in Table 140.6.A of the standards. Controls for which PAFs are eligible are listed in Table 140.6-A of the standards and include:

a) Occupancy Sensing Controls for ~~qualifying enclosed spaces and open~~ office~~s~~ spaces greater than 250 square feet.
b) Demand Response Controls – Demand responsive lighting control that reduces lighting power consumption in response to a demand response signal for qualifying building types.
c) Institutional tuning – lighting tuned to not use more than 85 percent of rated power, per Section 140.6 of the standards.
d) Daylight dimming plus off controls – daylight dimming controls that automatically shut off luminaires when natural lighting provides an illuminance level of at least 150 percent of the space requirement.
e) Horizontal slats – interior or exterior horizontal slats on fenestration adjacent to daylit areas
f) Light shelves – interior or exterior light shelves adjacent to daylit areas

Clerestories are modeled as Power Adjustment Factors and are not modeled directly by compliance software. Compliance software shall have a means of disregarding daylight through clerestory windows when using the PAF. If handled with a PAF, daylight controls in zones with clerestory windows should be disabled.

The Statewide CASE Team considered suggesting an update to the fractional occupancy schedule and light schedule for Offices in Appendix 5.4B. However, the proposed code change would be mandatory and therefore there would be no difference between the baseline and proposed cases in the compliance software, making a change to Appendix 5.4B unnecessary.

2.6.5 Title 24 Nonresidential User Compliance Manuals

Chapter 5 of the Nonresidential Compliance Manual would need to be revised. In Section 5.4.3.4, a Subsection C. Part 3 for multi-zone occupancy sensing control in large office spaces would need to be added. The original Subsection C. Part 3 (partial off occupant sensing controls) would need to be shifted to Subsection D. Part 4. In Section 5.4.7, a Subsection E would need to be added to explain how multi-zone occupancy sensing control works, including the dimming interaction with institutional tuning. If a project utilizes a dim to 20 percent implementation and also has institutional tuning, the institutional tuning should set the new baseline from which to dim to 20 percent or less from full power. This is for increased efficiency and accuracy of the compliance process—as acceptance testing occurs after commissioning, improved energy savings, and easier integration with programming software for relevant controls.

Additionally, Chapter 13 of the Nonresidential Compliance Manual would need to be revised. Section 13.4.3 (Lighting Controls) would need to reflect the changes to acceptance tests listed in this report in Section 2.6.3. The updates should include the fact that “open plan offices” are a type of “large office” spaces, which are defined as offices greater than 250 ft^2.

2.6.6 Compliance Documents (Forms)

Compliance documents NRCI-LTI-05-E, NRCC-LTI-E, and NRCA-LTI-02-A would need to be revised.

The compliance document NRCI-LTI-05-E would need the PAF options in Part 2.A.2.a related to occupant sensing controls in large offices to be modified to reflect the proposed code change and the updated PAFs.

The compliance document NRCC-LTI-E would need Section P Power Adjustment to be modified to reflect the updated PAF options for occupant sensing in large offices.

The compliance document NRCA-LTI-02-A would need to add a part C-2 to describe the additional functional testing procedures for occupancy sensing in large offices. This would provide market actors with clear documentation for the additional functional testing procedures.

No new compliance documents would be added.

3. Lighting Power Densities

3.1 Measure Description

3.1.1 Measure Overview

This measure proposes to update the allowable LPD values (watts of lighting per square foot of room floor area) based on a re-analysis of LPDs with improved tools and changes to the products available in the market. This proposal for updating the LPDs would be comparing all LED designs from the 2019 Title 24, Part 6 Standards against all LED designs proposed for the 2022 Title 24, Part 6 Standards. The proposed updates are derived from the following:

- Reexamining efficacy increases for low and high color rendering index (CRI), color tuning, dim-to-warm, and other luminaire performance factors:
  - Efficacy increases over the past three years has been greater for high CRI than for standard CRI systems.
  - Efficacy loss for color tuning and dim-to-warm features has been reduced as compared to three years ago when they were examined for the 2019 LPDs.
- Revisiting IES recommended practice and IES Standards, which includes:
  - Evaluating current illumination (FC) targets for general as well as task illumination from the recommended practices (RPs) as well as from the IES Handbook. The Statewide CASE Team has taken special effort to document the sources of the recommended illumination targets.
  - Including an explicit definition of the fraction of the prototypical spaces that are illuminated to general circulation levels and task levels, as well as the fraction of wall area that is illuminated by wall washing luminaires.
  - Explicit calculation of luminaire depreciation making use of the guidance from IES RP 36-15 “Recommended Practice for Lighting Maintenance.”
- Enhancing the Inverse Lumen Method Modeling, including:
  - Unlike prior models, the new model makes direct use of the luminaires’ zonal lumen values in 10° vertical angular increments to calculate the coefficient of utilization of the luminaires for any combination of ceiling, wall, and floor reflectances, any space geometry, and any combination of work plane height and luminaire mounting height. In the past, coefficients of utilization were typically limited to a couple of reflectance combinations.

- During the development of the 2019 LPDs, the Statewide CASE Team added an explicit calculation for the wall washing LPD that varied by luminaire type, and also calculated how much general lighting could be offset by reflected light from the wall washing system. These calculations were developed by a normalization of Radiosity (AGi32) simulations. In the past, this calculation was conducted only for walls with a reflectance of 50 percent. For this code cycle, the models have been expanded to a wider range of wall reflectances.
- The inverse lumen method models have been updated to explicitly calculate light loss factors that are dependent upon the luminaire photometric distribution, whether or not it is enclosed, the hours of operation, how frequently the luminaires are cleaned, and their L70, L80 or L90 lamp lumen depreciation tested values.

The above outlined analysis and modeling updates would, in some cases, result in changes to the general lighting LPDs and the additional lighting wattages. Some applications would have an allowed lighting wattage increase while some would result in a decrease, but many would stay the same.

The primary changes in this proposal are to update the allowed indoor LPDs based on cost-effective lighting designs based on readily available lighting products. This proposal is based on LED sources that have color temperature and color rendering index (CRI) comparable to legacy light sources, so that lighting color and fidelity are maintained or improved.

The Statewide CASE Team is committed to recommending code changes that would not compromise light quality or increase glare and would not exclude color-tuning systems. In addition to the general lighting LPDs, the additional power allowances,[10] lighting power adjustments,[11] and the PAFs all contribute to providing sufficient lighting power that would ensure proper light levels are achievable. The additional allowances assure there is sufficient light for task work, display, and ornamental lighting. There are also additional wattage allowances for several special needs and capabilities. For example, additional lighting wattage is allowed for providing extra light to areas occupied by elderly or visually impaired. Indoor lighting systems comply with the building energy efficiency standards when their adjusted indoor lighting power is less

[10] The additional allowance is also colloquially known as a use-it-or-lose-it adder. It refers to additional LPDs that can be used for certain applications and for certain spaces. Section 140.6(c)2G in Title 24, Part 6 provides additional information on additional allowances, also referred to as additional lighting power allowances. Examples of additional allowances can be found in Table 140.6-C in Title 24, Part 6.

[11] More information can be found on light power adjustments in Section 140.6(a)4 in Title 24, Part 6.

than or equal to the allowed indoor lighting power. The adjusted indoor lighting power is the installed wattage of the indoor lighting system after being adjusted for:

- Interlocked lighting systems,
- Advanced controls receiving Power Adjustment factors,
- Excluded lighting power,
- Small aperture color tuning luminaires, and
- Tailored Method display luminaires that are mounted higher than 11 feet.

Lighting design contains a multitude of considerations. These considerations were evaluated for each of the primary function area applications. As a result, there is no single across-the-board change for the proposed 2022 LPDs. For some applications, the LPDs increased, for others the LPDs decreased, and many of the LPDs stayed the same. However, there is a modest decrease in LPDs which result in energy savings and emissions savings for the people of California and reduced life cycle costs of new and altered lighting systems. Though these savings are modest in comparison to the lighting energy savings in the 2019 Title 24, Part 6 Standards, the proposal, if adopted, would save a significant amount of energy. Since this proposal is necessarily based on technologies that are available and cost effective today, the proposal is conservative as it does not assume future increases in efficacy or cost effectiveness.

The Statewide CASE Team is also aware of stakeholders' requests and concerns over simplifying code requirements. Specifically, the Statewide CASE Team has identified the need to revise the standards to allow the use of screw-base LED lamps without a wattage penalty. Some lighting alterations projects depend on the allowance of screw-base LED lamps; this section was updated in the 2019 Title 24, Part 6 code cycle, but only allows a way to claim the actual wattage of screw-base LED replacement lamps if it is JA8 compliant. Limiting to JA8 compliant can be problematic for certain nonresidential applications which require higher color temperatures than would be appropriate for new homes. This proposal would allow the labelled maximum wattage of the luminaire to be used as the basis for the defined wattage of these luminaires.

3.1.1.1 Importance of Lighting Power Density Updates

A majority of nonresidential lighting systems in new construction and alterations utilize LED technology. Given that high efficiency light sources are widespread and standard practice, continued LPD updates in Title 24, Part 6 may seem unnecessary, however, this is not the case. Updating LPDs based on current IES recommended practice and appropriate illumination levels provides benefits, including continued energy savings and supports the energy effectiveness of the California lighting market. These updates are needed because several things have changed:

- IES standards have been updated and improved (more of IES standards are making use of the more rigorous ANSI adoption process).

- Models have revisited the mapping of primary function areas to the task in the updated IES standards.
- The underlying Inverse Lumen Method model has been improved.
- Models have been updated with more recent luminaire data representing updated design practice, and in some cases, increased efficacy.

An explanation of the mechanism for actual energy savings resulting from the proposed LPDs and additional benefits can be summarized as follows:

- LPDs are the basis of the standards case in the Nonresidential ACM Reference Manual. If equipment efficacy increases and LPDs do not similarly decrease, designs that match good practice would have installed wattages below the allowed wattage. The reduction in the design lighting power versus an LPD baseline that did not capture recent changes in design standards or efficacy could be applied to other building components (i.e. HVAC and envelope) and allow a less efficient design of other building components than would be the case if the LPDs were updated. If the LPDs were not updated, the rest of the building systems would be backsliding relative to the last version of the building efficiency standard. This is the most obvious direct impact on the stringency of Title 24, Part 6.
- Less obvious is the impact of the prescriptive LPDs on maintaining the application efficiency of lighting systems. Light source efficacy is only one of several tools used for energy effective design. Other tools include optically efficient luminaires, placing light where it is needed, and matching the light levels to the need. Relying only on source efficacy for future lighting energy savings and not updating the LPDs would assume that that installed lighting power would proportionately decrease in response to efficacy increases. However, without updates to the LPD allowances, energy consumption would not proportionately decrease through the following mechanisms:
    - **Designs to match LPD**: Title 24, Part 6 is known to have very efficient lighting standards, as a result, the LPD limits are used as a point of comparison and these power limits drive the configuration of lighting systems.
    - **Inappropriate light levels:** One of the advantages of setting LPD limits, is that it declares a "cease fire" in illumination (brightness) wars where different competing retailers are increasing light levels to be relatively brighter. Competing retailers do not improve visibility with these practices, but the spaces are relatively brighter.
    - **Uniform lighting:** While more light is needed on tasks than for circulation,

a simple design process, which doesn't take into account task/ambient illumination, is to design the entire space to the highest task illuminance value.

- **Optically inefficient luminaires:** Specifying luminaires that put the light where it is needed and does not illuminate areas where it is not needed, takes some skill not only for the designer but also for the luminaire manufacturer. The updated LPDs, based on optically efficient luminaires with high efficacy light sources, provide feedback to the designer and the lighting industry on higher performance expectations.
- **Low efficacy luminaires:** Not all LEDs are created equal. Besides the inherent efficacy of the LED itself, the overall luminaire efficiency is highly dependent on its thermal performance. As shown in Appendix L, the variability of efficacy within a given luminaire type is significant. The cost premium for this efficacy increase is small and sometimes is zero.

3.1.2 Measure History

Over the past 30 years, lighting efficacy has continued to improve. As a result, the LPD values in Title 24, Part 6 have been updated every cycle. Prior to the 2019 Title 24, Part 6 updates, the allowable LPDs in Section 140.6 were based on a mixture of fluorescent, metal halide, and infrared reflecting halogen light sources. During the 2019 update of the LPDs, the basis of standards shifted from the legacy lighting technologies to LEDs. Besides the higher efficacy of LEDs as compared to most sources, LEDs are typically dimmable, and the distribution of light is more controllable, allowing for higher optical efficiencies. The resulting LPDs in the 2019 Title 24, Part 6 revision, were significantly reduced. The statewide energy savings that would result from adoption of this proposal are approximately a quarter of the statewide energy savings that resulted from the 2019 updates to the allowed LPDs. The modest savings from this proposal reflect that this proposal is fine tuning that efficiency gains captured in 2019.

Similar to the 2019 code cycle, members of the Statewide CASE Team participated in the development of LPDs for ASHRAE 90.1-2019 and 189.1-2020. The analysis conducted for these updates has been leveraged for the Title 24, Part 6 LPD update. The insights provided by the ASHRAE Committees and their commenters have been invaluable.

3.1.3 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 3.6 of this report for detailed proposed revisions to code language.

3.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 3.6.2 of this report for marked-up code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Improve the definition of Ornamental Lighting, Decorative. This is proposed so that it is clear that qualifying luminaires include architectural lighting that emphasizes building surfaces. Edits to this definition that would remove references to light source types and emphasizes their distribution and how they are used.

Names of function areas reordered. This is proposed to simplify finding the function area of interest in the LPD tables. By placing the primary application at the beginning of the function area name and ordered the function names alphabetically, new users would be able to find the category of interest more quickly. Thus, General Commercial and Industrial Work Area have been renamed Manufacturing, and Commercial and Industrial Work Area. The term “general” was not descriptive and it would be easier to find manufacturing from the list of function types than starting with general. Similar approaches were taken to defining laboratories, lobbies, and storage.

Combining Parking Zone and Ramps in Parking Garage Function Areas. The Statewide CASE Team’s analysis found that the required LPD for these two areas were close enough that these zones could be merged. This would simplify code enforcement as there is no longer a need to separately define and calculate dedicated ramp area from parking area.

Barber and Spa Treatment added to Beauty Salon function area. These other functions have similar requirements and likely used Beauty Salon as the closest applicable function in the past. This edit to the name would result in greater clarity for compliance.

SECTION 130.0 – LIGHTING SYSTEMS AND EQUIPMENT, AND ELECTRICAL POWER DISTRIBUTION SYSTEMS —GENERAL

Section 130.0(c)2 – Luminaire classification and power. Removes the 50 watt per socket and JA8 requirement and sets to the installed lamp wattage instead.

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

Section 140.6(a)3. Lighting wattage excluded

Medical lighting exemption. The listing of building types to where this exemption applies have been removed. This was an artifact from prior versions of Title 24, part 6 when hospitals were not covered by the standard. This is no longer the case and thus the building types were this exemption applies no longer is needed.

Controlled Environment Horticulture. Items G, H, O, P would now reference the proposed plant lighting requirements in section 120.6(h). More details can be found in the 2022 Controlled Environment Horticulture (CEH) CASE Report.

TABLE 140.6-B – COMPLETE BUILDING METHOD LIGHTING POWER DENSITY VALUES: Approximately half of the building types were updated to reflect the changes in the Area Category LPDs. The Complete Building Method LPDs are an area weighted average of the general lighting power allowances of area categories allocated to each building type.

TABLE 140.6-C – AREA CATEGORY METHOD – LIGHTING POWER DENSITIES (WATTS/FT^2): About half of the primary function application area LPDs and Additional Allowances have updates; some LPDs increase and others decrease depending upon application. Additionally, for ease of use of the standard, rearrange specific areas to be more alphabetical and grouped by function. Examples include: kitchen applications located near dining applications, Manufacturing listed under “M” instead of listed under “G” for General Commercial/Industrial Work Area, and the larger groupings of application for Healthcare, Aging Eye/Low Vision and Sports Arena located at end of the Area category table.

TABLE 140.6-C – TAILORED METHOD LIGHTING POWER ALLOWANCES: Update LPDs for general illumination, wall display, floor display and ornamental based on higher efficacies for LED light sources with high (90+) CRI. High CRI light sources were the basis of the allowances for the tailored lighting approach for both 2019 standard and as proposed here for the 2022 standards. This provides conservatively high (but appropriate) allowances for this method as high CRI LED products in general have lower efficacies than standard CRI (around 80 CRI) luminaires.

3.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

3.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal modifies the following sections of the Nonresidential ACM Reference Manual as shown below. See Section 3.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

- **Appendix 5.4A Space Use Data:** Appendix 5.4A would need to be updated with new LPDs for those spaces that have been updated.

3.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

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

- Section 5.1.1: Update to summarize changes to the code.
- Section 5.3: Update description of recessed line-voltage luminaire wattage requirements.
- Section 5.4.2: Update the language and Table 5-1 to reflect the removal of legacy light sources.
- Section 5.6: This section would be updated to reflect the new LPD values as well as the reduction of specific Additional Allowances.

See Section 3.6.5 of this report for the detailed proposed revisions to the text of the compliance manual.

3.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would not modify the compliance documents.

3.1.4 Regulatory Context

3.1.4.1 Existing Requirements in the California Energy Code

Section 140.6 of Title 24, Part 6 includes existing requirements in for indoor LPDs. Indoor lighting in nonresidential buildings is limited by LPDs; the LPDs specify how much wattage for lighting is allowed in the different building and space types.

The proposed code change would revise the existing 2019 Title 24, Part 6 LPD requirements. There is some overlap with the multi-zone occupancy sensing in large offices proposal since it also addresses requirements for interior lighting.

3.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

The proposed code changes do not affect other parts of Title 24, Part 6.

3.1.4.3 Relationship to Local, State, or Federal Laws

There are federal standards and Title 20 Standards for certain lamps and luminaires. This measure does not set efficiency levels for lamps or luminaires. Rather, the California Energy Code set specific maximum allowed adjusted wattages for indoor spaces. As such, this measure would not affect or duplicate any federal or Title 20 Standards. This measure would consider the Title 20 Standards for LED lamps (phase 2, Section 1605.3) and small diameter directional lamps (effective 2019 and 2018, respectively), and U.S. DOE lamp standards, when modeling for cost effectiveness and establishing new LPD values. Since this measure does not require performance levels or test procedures for federally covered products, there are no pre-emption concerns.

3.1.4.4 Relationship to Industry Standards

There are similar requirements in national model codes such as ANSI/ASHRAE/IES 90.1, ASHRAE 189.1, and the IECC. The Statewide CASE Team has communicated with members of the Lighting Subcommittee that supports the ASHRAE 90.1 standard. The LSC chair and members are stakeholders and the Statewide CASE Team welcomes their comments and suggestions.

3.1.5 Compliance and Enforcement

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. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** The new, lower LPDs may result in designers having less wattage to trade off with HVAC and envelope measures. This may result in designers (and others) needing to ensure their HVAC and envelope designs are more efficient as lighting power limitations would be more stringent. Revised LPDs to account for increases in LED efficacy, help retain the structure of Title 24, that designers need to judiciously select and locate luminaires to meet task illuminance levels.
- **Permit Application Phase:** No changes are expected.
- **Construction Phase:** No changes are expected.
- **Inspection Phase:** No changes are expected.

The Statewide CASE Team does not expect significant changes to the compliance process as a result of this proposal. The primary changes proposed here are changes to the light power allowances within the current structure of the standard.

3.2 Market Analysis

3.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends considering how the proposed changes may impact the market in general, as well as individuals. Information was gathered about the incremental cost of complying. 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 a public stakeholder meeting that the Statewide CASE Team held on September 12, 2019.

The current market structure for indoor lighting sources has not experienced much change over the past five years. Lighting designers still develop lighting systems and specify fixture types, lumen output, and wattages. Contractors and electricians are responsible for obtaining products and installing lighting systems. While the market actors and technologies have not experienced much change, the efficacies and costs of products have. The Statewide CASE Team conducted research, spoke with manufacturers, and other stakeholders to gather data on increased efficacies and dropping costs.

3.2.2 Technical Feasibility, Market Availability, and Current Practices

LEDs became the baseline lighting technology in the 2019 code cycle and are still the baseline for this code cycle. Since the 2019 update, several segments of the LEDs market continued to increase in efficacy, making – allowing for lower LPDs possible. For selected applications and space types. Specifically, the Statewide CASE Team has seen a reduction in efficacy differences for the following applications:

- The differential in efficacy between 90+ CRI products evaluated for the 2022 standards is 15 percent to 20 percent higher than the 90+ CRI products when developing a similar proposal for the 2019 standards. As a result, this proposal contains a recommended reduction for the LPDs for spaces where the 2019 code cycle models were based on 90+ CRI. See Appendix O through Appendix Q for more details.
- Large aperture color tuning luminaires have also continued to increase in efficacy. The Statewide CASE Team surveyed over 100 products from five different manufacturers and found that the efficacy penalty between 80 CRI large aperture color tuning luminaires and similar luminaires that do not include color tunability has dropped to five percent. In the 2019 code cycle, the Statewide CASE Team found the efficacy differential to be nine percent. Based on this small differential, the Statewide CASE Team still found no need to provide additional allowances for large aperture, color tuning fixtures. Finding that the differential has reduced even further, the Statewide CASE Team again recommends not to add any additional allowances for large aperture color tuning luminaires. See Appendix K for more details.
- Small aperture luminaires (2-inch and 4-inch and narrower slots less than 4-inches) are now more efficacious than they were when the 2019 LPDs were

developed. The Statewide CASE Team examined over 160 products from six manufacturers and found that the efficacy differential between 90 CRI small aperture, color tuning and static fixtures to be less than 20 percent versus 34 percent when examined during the 2019 code cycle. Likewise, the Statewide CASE Team surveyed nearly 150 products from five manufacturers for 90 CRI small aperture, dim-to-warm fixtures and found the efficacy differential as compared to static fixtures has since dropped to 14 percent versus 21 percent in the 2019 code cycle. As a result of this analysis, the Statewide CASE Team has proposed to reduce the additional allowances for these fixtures. See Appendix K for more details.

These changes form the underpinning for the proposed updated LPDs, as they have allowed lower LPDs to be achieved in a cost-effective manner. To test whether standard lighting design practices were possible with the new proposed LPDs, the Statewide CASE Team mapped pertinent IES standards to the indoor spaces to ensure more transparency in the LPD update process, as well as ensure the appropriate light levels are assigned to the correct spaces. This exercise resulted in several spaces increasing or reducing light levels which also contributed to the updated LPDs. Please see Appendix I for more details.

Additionally, the Statewide CASE Team analyzed over 27,000 products from 1,848 manufacturers from the Design Lights Consortium (DLC) qualified product list to better understand the current efficacy of products on the market. Table 40 provides details on the product type and corresponding quantities of model numbers and manufacturers. The Statewide CASE Team was interested in understanding the total number of products and manufacturers for specific CRI and efficacy levels. The product list was narrowed based on the following parameters:

- Lumen output
- CRI
- CCT
- Dimmability

Table 40: Quantity of Products and Manufacturers Analyzed

Product Type	Number of Manufacturers	Number of Products
2x2 Troffers CRI 80-84	608	7,327
2x2 Troffers CRI >= 90	10	211
2x4 Troffers 78-84	420	4,222
2x4 Troffers >= 90	10	224
Direct Linear Ambient CRI 80-86	212	2,653
Direct Linear Ambient CRI >=90	5	85
High Bay	511	10,997
Linear Indirect Ambient CRI 78-86	40	1,685
Linear Indirect Ambient CRI>90	2	3
Low Bay	28	142
Sports Flood	2	2
Total	**1,848**	**27,551**

Figure 2 and Figure 3 are examples of analyzed products. The figures show the number of manufacturers, number of products, and efficacy levels of the products. This information was essential in the process of determining whether or not lower LPDs could reasonably be achieved based on product availability. More details are presented in Appendix L.

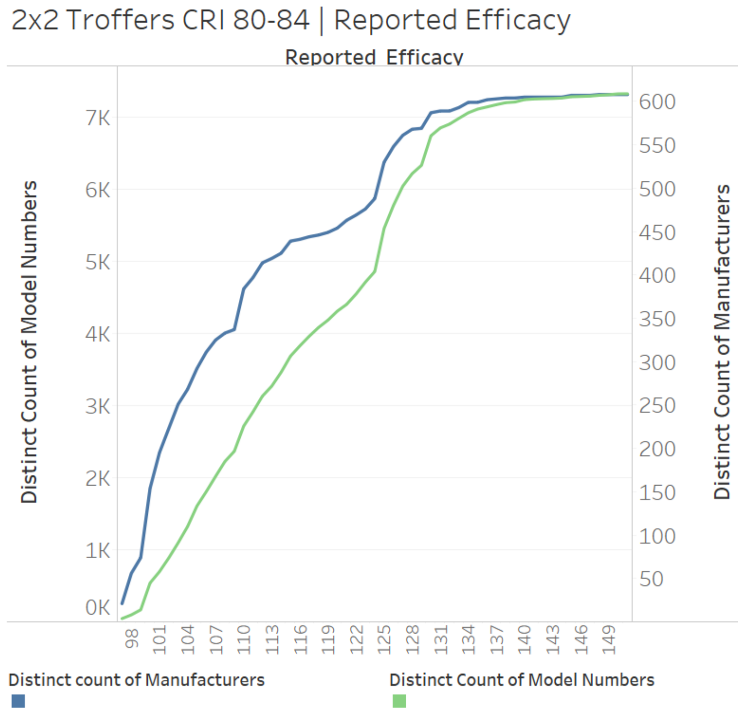


Figure 2: Distinct number of 80-84 CRI 2x2 Troffers and number of manufacturers with their reported efficacy.

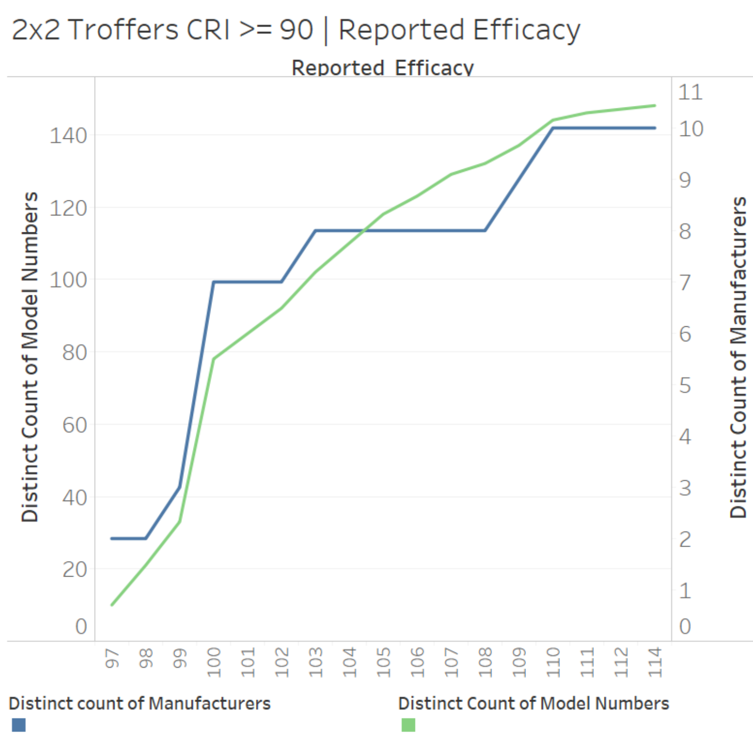


Figure 3: Distinct number of greater than 90 CRI 2x2 Troffers and number of manufacturers with their reported efficacy.

3.2.3 Market Impacts and Economic Assessments

3.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the proposed code changes 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 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 41).[12] In 2018, total payroll was $80 billion. Over 17,000 establishments and nearly 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 41: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establish ments	Employ ment	Annual Payroll (billions $)
Commercial	**17,273**	**343,513**	**$27.8**
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

Source: (State of California, Employment Development Department n.d.)

The proposed change to LPDs would likely affect commercial builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The proposed changes would not affect the residential building industry. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 42 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Commercial building construction and nonresidential electrical

[12] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

contractors are expected to be impacted by the proposed change due to their engagement with lighting in nonresidential projects. Nonresidential equipment contractors would be impacted by the proposed code change primarily due to changes in allowed LPDs which may result in higher efficacy lighting equipment being favored. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.2.4 Economic Impacts.

Table 42: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential Electrical Contractors	3,115	66,951	$5.6
Other Nonresidential equipment contractors	506	8,884	$0.9

Source: (State of California, Employment Development Department n.d.)

3.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 43 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The Statewide CASE Team anticipates the impacts for updating the LPDs to affect all nonresidential construction firms.

There is not a North American Industry Classification System (NAICS)[13] code specifically assigned to energy consultants. Instead, businesses that focus on

[13] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[14] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 43 provides an upper bound indication of the size of this sector in California.

Table 43: California Building Designer and Energy Consultant Sectors, 2018

Sector	Establish ments	Employ ment	Annual Payroll (millions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

3.2.3.3 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.

[14] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

3.2.3.4 Impact on Building Owners and Occupants

Commercial Buildings

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) (Kenney 2019). 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 (Kenney 2019). 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.

Estimating Impacts

Building owners and occupants would benefit from lower energy bills. As discussed in Section 3.2.4.1, money saved on energy bills tends to be spent 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 2022 code cycle to impact building owners or occupants adversely

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

The proposed code change would increase the specification of high performance luminaires with higher source efficacy, lower lamp lumen depreciation, and improved optical control to meet the LPD limits. Additionally, more stringent LPD requirements would nudge the market towards using lighting controls which gain lighting PAFs, such as that for institutional tuning. Discussions with compliance analysts indicate that there has not yet been a pressing demand to make use of these PAFs. See Section 3.2.4.2 for more specific details on the creation or elimination of businesses.

3.2.3.6 Impact on Building Inspectors

Table 44 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 44: Employment in California State and Government Agencies with Building Inspectors, 2018

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.2.3.7 Impact on Statewide Employment

As described in Sections 3.2.3.1 through 3.2.3.7, 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 3.2.4, the Statewide CASE Team estimated the proposed change in LPDs 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 that energy savings associated with the proposed change in LPDs would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.2.4 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.[15] While this is the first code cycle in which the Statewide CASE Team

[15] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic

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 those in the commercial building industry, lighting designers, electrical engineers, and energy consultants. 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. The Statewide CASE Team found that incremental costs were negative in many cases for the proposed LPD updates which results in negative impacts on the California Commercial Construction Sector as outlined in Table 45 below. However, this does not take into account the potential economic gains that could result from the savings that businesses would experience from this proposed measure as this analysis is outside of the scope of this report. See Section 3.2.4.1 for additional details.

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impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

Table 45: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (person)	Labor Income ($ million)	Total Value Added ($ million)	Output (million)
Direct Effects (Additional spending by Commercial Builders)	(2,953)	($195,264,655)	($258,737,565)	($427,971,697)
Indirect Effect (Additional spending by firms supporting Commercial Builders)	(642)	($46,720,814)	($74,430,698)	($143,602,051)
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	(1,284)	($72,331,069)	($129,418,641)	($211,294,763)
Total Economic Impacts	**(4,879)**	**($314,316,538)**	**($462,586,904)**	**($782,868,511)**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 46: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (person)	Labor Income ($ million)	Total Value Added ($ million)	Output (million)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	48	$4,960,537	$4,901,123	$8,718,160
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	31	$2,043,188	$2,760,448	$4,388,198
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	38	$2,092,681	$3,744,354	$6,113,156
Total Economic Impacts	**119.0**	**$9,096,406**	**$11,405,925**	**$19,219,514**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

3.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.2.4 would lead to modest changes in employment of existing jobs.

While Table 45 shows that this proposed code change may lead to job loss, the modeling software only shows this result since the incremental cost for the code change is negative in many cases. There would, therefore, be a reduction in economic activity associated with installation of the measure according to the software. However, Table 45 does not take into account the potential economic gains that could result from the savings that businesses would experience from this proposed measure. Such analysis is outside of the scope of this report.

3.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.2.4.1, 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 nonresidential indoor lighting strategy, which would neither excessively burden nor 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.

3.2.4.3 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.[16] 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.

3.2.4.4 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

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[16] 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.

domestic investment, or NPDI).[17] As Table 47 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.

Table 47: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	$609.2	$1,740.3	35%
2016	$456.0	$1,739.8	26%
2017	$509.3	$1,813.6	28%
2018	$618.2	$1,843.7	34%
2019	$580.9	$1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

Estimated increase in investment in California:

Change in Total Estimated Proprietor Income ($11,510,461) * 0.31 = **$3,559,556.**

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 45 and Table 46 above by 31 percent.

[17] 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.

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

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. The proposed measure would impact any state buildings (new construction, alterations, and/or additions) that have any spaces where there are proposed updates to the LPDs. In many cases, incremental cost are negative. However, even in spaces with some incremental costs, the proposed code changes have been found to be cost effective and save significant amounts of energy.

Cost to Local Governments

All proposed code changes to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU Codes and Standards program (such as Energy Code Ace). As noted in Section 3.1.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.2.4.6 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 Statewide CASE Team does not anticipate the impact of the proposed code change on any specific group or groups of persons (i.e., persons of a specific protected class, persons eligible to participate in affordable housing programs, renters, commuters, etc.) would differ from impacts to persons generally. This conclusion was reached by understanding that the proposed code change impacts many nonresidential indoor spaces, which should not have an impact on any specific group or group of persons.

3.3 Energy Savings

3.3.1 Key Assumptions for Lighting Power Density Energy Savings Analysis

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 2020). 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 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 from E3 in a spreadsheet titled "2022 TDV Demand Factors.xlsx". The final TDV factors that the Energy Commission released in June 2020 use 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. The 20-year GWP values increased 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 that use 20-year GWP values were used in the analysis. 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.

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 has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric that was developed for the 2022 code cycle. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

The Statewide CASE Team calculated per-unit impacts and statewide impacts associated with both new construction and alterations by comparing energy use of lighting that is minimally compliant with the 2019 Title 24, Part 6 Standards to lighting that is minimally compliant with the proposed requirements for the 2022 Standards. That is, savings are based on a comparison between 2019 LPDs and the proposed LPDs for each building and area/space type that has been updated. The proposed LPDs were developed with the same assumption as the 2019 code cycle, that all lighting would use LED technology or another technology with equivalent performance.

The Statewide CASE Team used an improved version of the Lumen Method calculation model used in the development of most of the LPDs for the 2019 version of Title 24, Part 6. The following assumptions and methodologies were used in the analysis:

- Proposed LPDs for all space/area types were assumed to be met using LEDs:
- Similar to models developed for the 2019 standards, the models developed for the 2022 standards for retail, hospitality, museums, theatrical, and liturgical include high color rendering index (90+CRI) LED luminaires.
- Hours of operation were based upon operating schedules in the 2019 Nonresidential ACM Reference Manual.
- FC targets were based on the applicable IES Recommended Practices (RP) and when these were not available, the IES Handbook. When appropriate, target illuminances were modified to align with the building and space/area types in the current Title 24, Part 6 Standards.
- Typical space dimensions from project experiences were used to develop prototype spaces. The prototype spaces were intended to be typical with the placed emphasis on taller and smaller (less floor area) configurations with conservatively higher so that room cavity ratios. are conservatively high and These higher room cavity ratios in these space types result in slightly higher LPDs, than if large floor areas or lower ceiling heights were used.
- Room surface reflectances were used that are typical for the modeled applications. The improved lumen method model calculated coefficients of utilization inside the spreadsheet, so there were no limits on the combination of ceiling, wall, and floor reflectances. Calculating the coefficient of utilization within the spreadsheet allows for more accurate representation of the impact of space geometry on lighting performance.
- Useful life was based on the 15-year period of analysis used to evaluate proposed changes to Title 24, Part 6. This impacts the calculation of lamp lumen depreciation factors. Therefore, this analysis does not use L70 (30 percent reduction in light output) but rather considers the amount of light loss expected after 15 years, that is specific to the luminaire being modeled.
- Luminaire dirt depreciation is based on the methodology provide in RP-36-15 (lighting maintenance) which is a function of the cleanliness of the space, the

time period between cleaning, the CIE distribution classification of the luminaire, and whether the luminaire is open or enclosed.

- HVAC interaction effects are small compared to the primary effect of saving lighting energy and cost and ae not included in this analysis.

The data inputs for each space type can be found in Appendix J.

3.3.2 Energy Savings Methodology

3.3.2.1 Overview of Energy Savings Methodology

The objective the LPD update is to define the maximum allowed LPD for each primary function area and compare this to the maximum allowed LPD in the existing standard. This yields a change in watts per square foot for the each of the primary function areas. Energy savings per square foot of each function area is calculated by multiplying by the expected full load hours of lighting system operation. The full load hours are calculated by taking the weekday, Saturday and Sunday lighting schedules as contained in the Nonresidential Alternative Calculation Method Approach (ACM) Manual Appendix 5.4A.[18] These schedules are used in the performance approach calculation software CBECC-Com. The savings calculated using a spreadsheet approach are equivalent to those as calculated by CBECC-Com. This calculation approach does not account for interactive effects with heating and cooling interactions. This second order effect is small as compared from the direct effect of the lighting energy savings. The additional heating loads associated with less internal gains from electric lighting is mostly offset by the decreased cooling loads.

The annual energy savings are calculated per ft^2 of each application of the area category approach. These applications are mapped to each of the building types in the complete building method with a weighted to indicate what fraction of the building area contains the various space applications. The complete building method LPDs are a weighted average of the application LPDs associated with each building type. Since interaction effects are not calculated, savings are calculated statewide and not by climate zone as other measures are.

Prescriptive lighting power code compliance is typically calculated using the area category method. Additionally, the Alternative Compliance Method (whole building performance approach simulation) makes use of the area category LPDs for the base

[18] The 2019 ACM appendix 5.4 files can be downloaded here: https://ww2.energy.ca.gov/title24/2019standards/post_adoption/documents/2019-02-13-14_workshop/2019_NRACM_Appendices.zip

case building. Thus, the statewide energy savings are calculated based on the LPD reduction by space (primary function) type and multiplying this by the square footage of new building spaces that are constructed each year. The area of new spaces is accomplished by mapping the percentage of space types for each major building classification type and multiplying by each year's new construction of each major building type. A similar approach is used for estimating energy savings associated with alterations. Assuming that, on average, lighting systems are replaced once every 15 years, the total floor area of building retrofitted each year is the total building stock divided by 15. Calculating the total retrofit energy saved due to lower LPDs makes use of the same mapping of function types to building types and multiplies this by the total floor area of buildings retrofitted each year.

Inputs to LPD Calculations:

- Typical prototypical spaces are for developed for primary function areas including geometries, ceiling wall and floor reflectances, hours of operation, dirtiness, and period between cleaning of luminaires.
- Mapping of IES application/tasks and their associated design illuminances to tasks in each primary function area. These tasks include circulation, primary task, secondary tasks, and in some cases vertical illuminance where wall washing is needed.
- Allocating fraction of floor area to circulation and tasks to associated IES design illuminances.
- Developing a prototypical design of each space by assigning luminaire types to each circulation, task and wall washing application. Luminaires have the following attributes assigned to them:
  - Zonal lumens for each 10° vertical angle increment. This is used to calculate the Coefficient of Utilization and is used to assign the CIE Classification (Direct to Indirect) used for calculating the luminaire dirt depreciation.
  - Along with the CIE Classification, whether the luminaire is open or enclosed, the dirtiness of the space and the typical period between luminaire cleaning, this used to calculate luminaire dirt depreciation in accordance with IES/NALMCO RP36-15.
  - Luminaire lumens and luminaire wattage is used to calculate luminaire efficacy.

3.3.2.2 Inverse Lumen Method – Basis of LPD Calculation

Most of the LPDs in prior ASHRAE standards and prior Title 24, Part 6 iterations have been based on a variant of the Inverse Lumen Method calculation. The Inverse Lumen Method has been used for a long time and is detailed in the IES Handbook[19] as well as other publications. This method has been used for numerous code cycles for both ASHRAE-90.1 and Title 24, Part 6. An advantage of the Inverse Lumen Method is its simplicity and transparency; all the inputs can be entered into a spreadsheet so these can be easily examined. The Inverse Lumen Method approach is based a simplified model that considers radiation exchange between a luminaire plane and work plane. This works well based on far field photometric measurements of luminaires and rooms that are essentially open rectangular boxes without too much intervening furniture, partitions or stacks. As spaces deviate from these assumptions, it is better to base the calculations on more advanced tools as has been done for large offices with systems furniture, library stacks, and warehouse areas with racks.

The updates to LPDs proposed for the 2022 Title 24, Part 6 Standards are mostly based on this same method as well. The results of these calculations were reviewed and adjusted based on the Statewide CASE Team's professional experience, and a subset of the areas were evaluated with more detailed simulations using radiosity-based lighting design software (AGi32).

Derivation of Inverse Lumen Method

The average maintained illuminance (luminous flux density), $\dot{E}_{maintained}$, (in units of FC or lux in SI units) in a space is calculated by the following Lumen Method equation:[20]

$$\dot{E}_{maintained} = \frac{(no.\, luminaires)\left(\frac{lamps}{luminaire}\right)(lamp\ lumens)(CU)(LLF)}{workplane\ area}$$

Where,

CU = coefficient of utilization, or fraction of lumens from light sources that reaches the work plane directly or via interreflections. This is a function of luminance distribution of the luminaire, the geometry of the space (as described by the RCR), and the reflectance of the ceiling, walls, and floor of the space. CUs are commonly provided by luminaire manufacturers in a table format with respect to the RCR, for standard room surface reflectances. Historically the Statewide

[19] See Section 10.9 "Standardized Calculation Procedures," in the IES Handbook, 10th edition.

[20] Illumination Engineering Society (IES).2011. The Lighting Handbook 10th edition. Equation 10.30.

CASE Team has used look up tables but is now using an Excel User Defined Function to directly calculate this from the space geometry, surface reflectances, and the zonal lumen distribution of the luminaires. The Statewide CASE Team collected IES photometric files for all luminaires of interest and extracted the zonal lumens for each file using the Lighting Analysts Photometric Toolbox software.

LLF = the product of recoverable and non-recoverable light loss factors. Recoverable light loss factors are the product of lamp lumen depreciation, or reduced light source output due to aging; luminaire dirt depreciation, or reduced optical efficiency due to dirt buildup on the luminaire and its elements; and room surface dirt depreciation, or the decrease of reflected light in the space due to dirt reducing the reflectances of surfaces. Non-recoverable light loss factors are ballast factor, thermal factor, and equipment operating factor (such as lamp operating position).

For integral LED luminaires, this equation is slightly different. The light output of the LED is significantly impacted by its temperature which, in turn, is a function of the thermal performance of the luminaire in rejecting heat. As a result, the IES LM-79 test method for measuring the light output of solid-state lighting products measures the light output of the entire luminaire. The equation for integral LED luminaires can more accurately be described as follows:

$$\dot{E}_{maintained,LED} = \frac{(no.luminaires)(luminaire\ lumens)(CU)(LLF)}{workplane\ area} \text{[FC or Lumens/ft2]}$$

Where luminaire lumens represent the lumens leaving the luminaire and accounts for both the thermal effects of a luminaire and its optical efficiency. As a result, the same luminaire tested with an integral LED would have a higher CU than one with fluorescent lamps. This is because the CU for LEDs represents the fraction of light leaving the luminaire (after luminaire optical losses) that then reaches the work plane, whereas the CU for the same fixture fitted with fluorescent lamps represents the light leaving the lamps that reaches the work plane.

The total maintained lumens (luminous flux) delivered to the space, $\Phi_{main,\ delivered}$, is found by multiplying the maintained illuminance, $\dot{E}_{maintained}$, by the areas of the work plane.

$$\Phi_{maint,delivered} = \dot{E}_{maintained} \times\ workplane\ area \text{[Lumens]}$$

$$\Phi_{maint,delivered\ LED} =\ (no.\ luminaires)(luminaire\ lumens)(CU)(LLF)\ \text{[Lumens]}$$

The maintained delivered luminous efficacy, $K_{maint,delivered}$, of a given lighting system in a given space having a particular geometry (RCR) and surface reflectances is as follows:

$$K_{Maint,delivered} = \frac{\Phi_{maint,delivered}}{Total\ Input\ Watt} \text{ [Lumens/Watt]}$$

For the 2022 Title 24, Part 6 update, the Statewide CASE Team developed a database of 68 luminaires which averaged the results of 488 source luminaires, including:

- Luminaire description;
- Luminaire lumens;
- Input watts (and with lumens, luminous efficacy can be calculated);
- Zonal lumens for each degree incremental of vertical angle and normalized to 1,000 lumens total per luminaire (this is a necessary step before averaging the distributions of luminaires with different total lumen output);
- From the zonal lumen distribution, the CIE Classification (Direct to Indirect) is calculated.

Since lamp lumen depreciation is recorded differently per luminaire from L70, L80, L90 and other times a variable depreciation for 100,000 hours, a way to normalize this result was needed. The data was normalized in terms of number of hours per 10 percent loss in output. Assuming light loss is relatively linear (see Royer, 2014), the result of the analysis is conservative and uses the end of 15-year period of analysis for evaluating lamp lumen depreciation rather than the mean depreciation over the 15 year period.

From these components, maintained, delivered luminous efficacies, and $K_{maint,delivered}$ are calculated. This proposal added higher performance luminaires to this database and modified the light loss factors to best represent the performance of the equipment over their expected life and expected maintenance schedule.

For a space having a design illuminance, E_{design}, with a given RCR, and being illuminated by a lighting system with a maintained delivered luminous efficacy, $K_{maint,delivered}$, the LPD for the space is:

$$LPD_{design}[W/ft^2] = \frac{E_{Design}\ [lm/ft^2]}{K_{Maint,delivered}[lm/W]} \times Space\ Fraction\ [no\ units]$$

Where the space fraction indicates what fraction of the space area is being illuminated to a given design illuminance (FC) value.

A given space can have an area-weighted LPD where part of the space is illuminated by one lighting system type and other parts are illuminated by other system types with different efficacies.

New to the 2022 Inverse Lumen calculations is how coefficients of utilization are calculated. In the past, CU's were providing for each luminaire type for various room cavity ratios in increments of factors of 2 from 2 to 10. Typically, this was for one set of reflectances 70 percent ceiling, 50 percent wall, and 20 percent floor for most fixtures but for industrial fixtures these were typically for 50 percent ceiling, 30 percent wall, and 20 percent floor reflectances.

The new method uses the IES photometric files for the representative luminaires and uses the software Photometric Toolbox to extract the zonal lumen summary for each luminaire in eighteen, 10 degree vertical angle increments and stores this date for use. Using equations that are in the IES handbook, the Statewide CASE Team wrote a macro to calculate CU for any room geometry for any combination of reflectances. The calculated reflectances were compared with the CU tables calculated by Photometric Toolbox and found that it matched the results to two significant digits (within 1 percent).

This allows a more accurate estimation of the amount of luminaire lumens needed to illuminate the space to a given design illuminance regardless of room geometry or surface reflectances. As a result, the Statewide CASE Team has a higher level of confidence in the results than earlier models which could not be configured to the conditions of spaces being simulated.

For all spaces except retail, open plan office, warehouse, and library stack areas, the Inverse Lumen Method was used to develop the space-by-space method LPDs in this proposal. These models have been validated by the professional experience of members of the Statewide CASE Team. The remaining few spaces (Retail, Open Plan Office and Warehouse Stacks) where the Lumen Method breaks down were simulated using detailed Radiosity models. These models were simulated during the 2019 Title 24, Part 6 Standards and were not rerun, but the results were adjusted based on changes to efficacy for high CRI products. The remainder of these models are the same.

3.3.2.3 Title 24 Wall Washing Method Updated for the 2022 Analysis

Simulating the power required for wall washing to achieve a given average illuminance on walls is not directly amenable for calculation using the Lumen Method. Starting in the 2019 Indoor Lighting Power Densities report, the Statewide CASE Team developed an approach for calculating wall washing power densities per ft^2 of floor area. This approach requires detailed radiosity simulation of prototypical spaces and normalizing the results for application for this special application of the Inverse Lumen Method. There are two primary outputs from this method:

1. The amount of power required to illuminate the wall areas of the space to a given average vertical illuminance and normalized to a LPD per square foot of floor area.

2. The amount of general lighting power that is displaced from reflected or “spill” light from the illuminated walls and normalized to negative LPD per square foot of floor area.

The calculations below make use of more complex radiosity calculations (in this case the Statewide CASE Team used the AGI-32 software) to quantify these specific lighting and power characteristics of each wall washing luminaire modeled:

$P_{WallWash}$ = Wall wash lighting power, in watts

$Area_{wall}$ = Area of vertical wall being illuminated, ft^2

$E_{v,wall}$ = Average illuminance of vertical wall, foot candles

WHF = Fraction of wall height inward from wall for horizontal floor illuminance measurements, dimensionless

$E_{H,floor}$ = Average horizontal illuminance of floor plane within the fraction of wall height inward from the wall illuminated by wall wash luminaires, foot candles

The sample spaces are modeled with only the wall illuminated by an even spacing of wall wash luminaires. The models for these luminaires have the light loss factors applied so that the resulting calculated foot candles are maintained illuminance values. Rooms with wall 12 feet and less in height have WHF of 50 percent whereas spaces with taller walls, the WHF is either 25 percent or 33 percent. The horizontal illuminances are calculated at floor levels because these illuminances are displacing circulation lighting which is typically has its design illuminance defined at the floor level. Wall reflectances are varied so that one can accurately model the amount of reflected light that is displacing some of the need for separate general lighting.

For each room type modeled in the Title 24, Part 6 Lumen Method spreadsheet, a geometry is specified. For the purposes of the wall washing calculation the RCR of the space is defined as the full height RCR where the mounting height is at the ceiling levels and the horizontal work plan is at floor level.

$$RCR = \frac{5 \times height \times (Width + Length)}{Width \times Length} = \frac{2.5 \times Perimeter\ Wall\ Area}{Floor\ Area}$$

$$\frac{Area_{Wall}}{Area_{Floor}} = \frac{RCR}{2.5} = 0.4 \times RCR$$

Where,

AreaWall = area of all the walls of the room (ft^2)

AreaFloor = floor area of the room (ft^2)

The RCR is directly proportional to the ratio of wall area to floor area. This makes it relatively easy to convert the wall washing W/ft^2 of wall area to W/ft^2 of floor area. It should be noted that the heights used for RCR in the wall washing calculation are the heights of the room from the floor to luminaires (these were all mounted at ceiling level) and not the heights of the cavity between the mounting height of the luminaires and the work plane. As a result, there is a separate RCR calculated for use in the wall washing calculation.

LPDs (W/ft^2 of floor area) can be calculated using the RCR of a given space to convert the W/ft^2 of wall areas needed to wall wash all the perimeter walls in a room to given illuminance level. An $LPD_{Wall\ Wash}$ adder accounts for wall washing all the walls in a given room.

$$LPD_{Wall\ Wash}[W/sf\ floor\ area] = \frac{P_{WallWash}}{Area_{Floor}} = \frac{P_{WallWash}}{Area_{Wall}} \times \frac{Area_{Wall}}{Area_{Floor}}$$

$$LPD_{Wall\ Wash}[W/sf\ floor\ area] = \frac{P_{WallWash}}{Area_{Wall}} \times 0.4 \times RCR$$

where,

$P_{WallWash}$ = Power for wall washing, Watts

This approach assumes that the wall washing watts needed would be linearly proportional to wall illuminance levels and wall area. However, this some adjustment that is needed for tall wall heights as typically those wall washing luminaires are high output and may have a different efficacy and the ratio of average illuminance on the wall to total lumens may be different. Thus, specific luminaires that are specified for tall wall heights.

The required power for wall washing, $P_{WallWash}$, and the area of the wall, A_{Wall}, are inputs for a given detailed (radiosity) simulation. Additionally, a light loss factor is applied to the radiosity simulation so that the luminous flux output of the simulated luminaires is reduced to represent their maintained light output at the end of the 15 year period of analysis. The results from AGI simulations of the average vertical illuminance on the wall, $E_{v,wall}$, are multiplied by the area of the wall to yield the total maintained lumens (luminous flux) delivered to the wall, $\Phi_{main,v,wall}$. Dividing the maintained lumens delivered to the wall by the power for wall washing yields the maintained delivered luminous efficacy of the wall washing luminaires, $K_{maint,wall}$. This luminous efficacy value is significantly less than the luminous efficacy of the luminaire itself because some of the light from the luminaire does not end up on the wall.

The maintained delivered luminous efficacy, $K_{maint,wall}$, of a given lighting system located in a space with a particular geometry (RCR) and surface reflectances is represented by the following:

$$K_{Maint,Wall} = \frac{\Phi_{maint,v,Wall}}{P_{WallWash}} = \frac{E_{v,wall} \times A_{Wall}}{P_{WallWash}} \text{[Lumens/Watt]}$$

LPD per square foot of wall area required to light the wall to target average illuminance can be calculated by rearranging the formula:

$$\frac{P_{WallWash}}{A_{Wall}} = \frac{E_{v,wall}}{K_{Maint,Wall}}$$

As described earlier, the LPD to wall wash all perimeter wall areas in units of Watts per square foot of wall area, can be converted to a LPD units of Watts per square foot of floor area, by multiplying the wall wash LPD by 0.4 times RCR. Combining the equation for calculating the wall LPD from design vertical illuminance and delivered, maintained efficacy and the equation to convert from a wall power density to a floor power density is given below.

$$LPD_{Wall\ Wash} = \frac{E_{v,wall}}{K_{Maint,Wall}} \times 0.4 \times RCR \text{ [W/ft}^2 \text{ of floor area]}$$

Often wall washing is conducted on a portion of the walls, the following equation proportionately reduces the LPD for wall washing in units of watts per square foot of floor area.

$$LPD_{Wall\ Wash} = WallFraction \times \frac{E_{v,wall}}{K_{Maint,Wall}} \times 0.4 \times RCR \text{ [W/ft}^2 \text{ of floor area]}$$

Where,

WallFraction = fraction of the wall that is illuminated with wall washing luminaires.

This is a variable selected by the user of the model similar to the SpaceFraction variable, which is the fraction of the floor area illuminated by the other lighting systems (see prior section on Inverse Lumen Method).

In addition to wall washing increasing the LPD for illuminating walls, the presence of wall washing luminaires provides spill light that displaces some of the luminaires needed for providing general lighting. This is commonly seen in many designs, where the last row of luminaires for general lighting are replaced with wall washing luminaires that provide both wall washing and general lighting.

As previously mentioned, the average horizontal FC on the work plane at the finish floor level was extracted for the room area that is within a defined distance from the wall illuminated by the simulated wall washer. This defined distance is the wall height multiplied by the wall height fraction, WHF. The ratio of average horizontal illuminance on the work plane to the average vertical illuminance on the wall, $R_{HtoV,L}$, was calculated for each detailed prototype space simulation and averaged for each luminaire type evaluated. This becomes a characteristic of the luminaire type, which varies more between luminaires than within the simulation of the same luminaire type for different space geometries.

The average horizontal illuminance within the defined fraction of the wall-height distance from the wall, E_H, can be calculated for a wall washing system that has a target design average vertical illuminance on the wall, $E_{Wall,Design}$, as follows:

$$E_H = E_{Wall,Design} \times R_{HtoV,L}$$

The fraction of general lighting illuminance (and wattage) that is displaced the wall height fraction in from walls, F1, is given by the following equation:

$$F1 = \min\left[1, \frac{\left(E_{Wall,Design} \times R_{HtoV,L}\right)}{E_{Floor,Design}}\right]$$

Where,

$E_{Wall,Design}$ = Design (target) illuminance for wall washing (FC)

$E_{Floor,Design}$ = Design (target) general lighting floor illuminance (FC)

Note that the equation is capped at 1 so no more light or no more power than is used for providing general lighting for the floor is displaced.

As was described earlier, the ratio of total perimeter wall area to floor area is given by the following:

$$\frac{Area_{Wall}}{Area_{Floor}} = \frac{RCR}{2.5} = 0.4 \times RCR$$

However, the floor area simulated for receiving horizontal spill light from the wall washers is the wall height fraction times the wall height inwards from the base of the walls. When all walls are illuminated by wall washing, the fraction of floor area where horizontal general lighting is displaced, F2, is given by the following:

F2 = WHF x 0.4 x RCR

WHF is the fraction of wall height inward from wall for horizontal floor illuminance measurements and is 50 percent of the wall height for most walls, but for walls taller than 12 feet WHF is 25 percent and for evaluating corridor wall washers, which can illuminate a corridor without additional lighting the WHF was 80 percent for a forward throw wall washer illuminating the entire 8 foot width of a corridor with a 10 foot ceiling height.

However, in most cases, not all the walls in the space are being illuminated by wall washing luminaires. The more general equation that accounts the portion of floor area adjacent to the fraction of walls being illuminated is given below.

F2 = WallFraction x WHF x 0.4 x RCR

Combining this with the ratio of wall area to floor area yields the General Lighting Reduction Fraction, GLRF:

GLRF = F1 x F2

The General Lighting Power Density Reduction, $LPD_{Gen,Red}$, is given by the following:

$$LPD_{Gen,Red} = LPD_{Gen} \times GLRF \text{ , or}$$

$$LPD_{Gen,Red} = LPD_{Gen} \times \min\left[1, \frac{\left(E_{Wall,Design} \times R_{HtoV,L}\right)}{E_{Floor,Design}}\right] \times Wall\ Fraction\ \times WHF\ \times 0.4\ \times RCR$$

In the 2019 Title 24, Part 6 wall wash model the wall height factor was fixed and now wall height factors are a variable that is attached to the different precalculated radiosity modes that are normalized using this approach. Also new to the 2022 wall wash model is having different precalculated models that vary the reflectance of the wall. This does not impact the vertical FCs impinging on the wall, but it does impact the amount of horizontal illuminance received by horizontal workplane near the wall. Thus, reflectance of the wall impacts the General Lighting Power Density Reduction, $LPD_{Gen,Red}$. Thus, for different reflectance walls the amount of displaced general lighting power can be more accurately calculated and less LPD “safety factor” has to be worked into the LPD targets.

Wall washing luminaires have a variety of distributions for different purposes. The updated method allows users to simulate six different types of wall washing luminaires. However, more luminaire types can be added over time. The six types currently modeled are:

- Forward Wall Washer – Linear: These luminaires light the wall surface but also throw a significant amount of light to the area in front of the wall.
- Wall Grazer – Aperture: Wall grazers light the wall, highlighting wall texture or architectural features such as brick, stone, and similar wall design elements. Aperture grazers focus their lumen output, which is ideal for higher ceiling applications or when intense grazing is desired.
- Wall Grazer – Linear: Linear wall grazers also highlight wall textures, architectural features, and similar design elements. Linear grazers hug the wall

(slot of soffit immediately against a wall) which is preferred for some grazer applications. Their lumen output is ideal for applications where uniform grazing is preferred.

- Wall Washer – Aperture: Aperture wall washer luminaires effectively light the vertical wall service as well as provide significant light at the area in front of the wall. They also exhibit subtle scalloping on the wall surface (depending on spacing) which is desirable for some applications.
- Wall Washer – Linear: These luminaires light the wall surface, providing highly uniform vertical illumination. They are used when a continuous line of light or close to the wall luminaire placement is desired.
- High Ceiling Wall Washer – Aperture: High output wall washer aperture luminaires provide sufficient lumen output and the optics needed for effective wall washing for high ceiling applications.

In addition, there are high CRI versions of these luminaires, where the efficacy is derated by 20 based on luminaire photometric data and/or luminaire manufacturers' posted adjustment factors. When/where this information was not available 18 percent (average of 1,600 products from over a dozen manufacturers documented efficacy loss for 90+ CRI product) was used as the derating factor.

Key characteristics of the wall washing luminaires are tabulated in Section 3.3.2.3.

3.3.3 Per-Unit Energy Impacts Results for Lighting Power Densities

Energy savings and peak demand reductions per unit are presented in the following table. The second and third columns are the calculated watts per square foot without consideration of wall washing and with wall washing respectively. The value without wall washing provides an indication of the amount wattage needed by a well-designed system to meet the horizontal illumination requirements of the application. The second number with wall washing indicates how much total wattage would be needed to provide not only the horizontal illuminance needed for the space but also with he added wattage to provide some additional brightness on the wall in line with IES recommendation and good design practice.

The fourth and fifth columns tabulate the existing LPD requirements in the Lighting Area Category Method allowances of the 2019 Title 24, Part 6 Standards. The fourth column is the allowed LPD for general lighting and the fifth column is the total of additional allowances. These values are identical to the values in 2019 Title 24 *Table 140.6-C Area Category Method - Lighting Power Density Values (Watts/Ft²)*.

The sixth and seventh columns of the table below contain the proposed allowance for the 2022 Title 24 standards. The sixth column contains the proposed allowed LPD for general lighting and the seventh column is the proposed total of additional allowances.

The final three columns to the right contain the annual full load hours, the energy savings in Watt hours per year per square foot of each primary function area and the annual demand savings in units of Watts per year per square foot of primary function area. The annual full load hours are derived from the lighting schedules in the ACM for each primary function area. The energy savings are based on a comparison of a base case design that fully utilized both the general wattage allowance and the additional lighting power as compared to a proposed design that fully makes use of its general lighting and additional lighting power allowance.

Of the 78 primary function areas, 8 increase their LPDs, 34 decrease their LPDs and 36 of the combined general lighting and additional lighting allowances stay the same. Overall, the total savings are approximately a quarter that of the savings associated with LPD changes in the 2019 Title 24, Part 6 Standards. The small reduction in savings from this proposal relative to the savings associated with the 2019 LPD proposal indicates that the changes proposed are relatively modest and are “fine tuning” of the changes that were proposed for the 2019 Title 24, Part 6 Standards. If one compares the LPDs calculated by the models in rows 2 and 3 with the proposed lighting power allowances for the 2022 energy code in rows 6 and 7, the modeled LPD is always lower than the proposed LPD. How much additional “leeway” between the model and the proposed LPD is impacted by several factors. If the change is significant from the prior standard the changed proposed standard would be conservatively high. An example is the concourse and atria area. The recommended illuminances for concourses are relatively low and are primarily for circulation; when there are selling areas on concourses, these selling areas can use the higher retail sales allowance. The general lighting allowance dropped from 0.90 W/ft^2 to 0.60 W/ft^2. This proposed general lighting value was greater than the combined LPD of area lighting and wall washing. As another point of comparison this value closely matched the general lighting LPD of ASHRAE/IES 90.1-2019. Given the drop was relatively large, the Statewide CASE Team erred on the side of conservativism.

The counter-example where the proposed LPD can closely match the model is classrooms. For this primary function area, the lumen model works well (the space is essentially an open box shape), an average of 40 fc was provided for the entire space in alignment with RP-3-13 (educational facilities). General lighting was dropped from 0.7 to 0.6 W/ft^2. The main area of uncertainty was how much light would be needed to light white boards and the like and the additional lighting allowance was increased from 4 W/linear feet to 7 W/lin ft. Lighting a 15 foot wide white board in a 1,000 ft^2 classroom would result in an additional lighting power allowance of 105 Watts or approximately

0.10 W/ft^2 to the classroom space. The Statewide CASE Team had also communicated with the authors of a PNNL study[21] on color changing lighting in classrooms. The total LPD for these classrooms were between 0.54 and 0.63 W/ft^2.

In several of the primary function areas below, the only change is that additional lighting power for ornamental lighting is dropped from 0.30 W/ ft^2 to 0.25 W/ ft^2. When the ornamental lighting allowances were developed for the 2019 Title 24, Part 6 Standards, these were based on 90+ CRI (color rendering index) LED ornamental lighting sources. In the time period between the development of the 2019 Title 24, Part 6 proposed LPDs and this proposal for the 2022 LPDs, overall LED efficacies have not increased appreciably, but the efficacies for high CRI sources used in modeling ornamental lighting have increased by, on average, 12 percent. Thus a 0.883 factor was applied to the 0.30 W/ ft^2 allowance and rounded to the closest 0.05 W/ ft^2 which is 0.25. A detailed description of how this factor was calculated is contained in Appendix Q.

It should be noted that changes have also been made to the Complete Building Method and Tailored Lighting Method LPDs. The Complete Building Method LPDs are based on a floor areas weighted average of the general LPD for specific applications that are allocated to each complete building model. This allocation is described in Appendix R. For Tailored Lighting Method, the basis of the LPD changes are detailed in Appendix O through Appendix Q.

Energy savings are based on the Area Category Method values because most compliance submissions use the Area Category Method, and the performance approach only uses the Area Category Method.

[21] Pacific Northwest National Laboratory for USDOE. *Tuning the Light in Classrooms: Evaluating Trial LED Lighting Systems in Three Classrooms at the Carrollton-Farmers Branch Independent School District in Carrollton, TX.* September 2017. https://www.energy.gov/sites/prod/files/2017/10/f37/2017_gateway_tuning-classroom_0.pdf

Table 48: Area Category Method: 2022 Model LPDs, 2019 Base and 2022 Proposed LPDs, First-Year Energy and Demand Impacts Per Square Foot

Primary Function Area	2022 Model LPD w/o wall Washing (W/ ft^2)	Model LPD w/ Wall Washing (W/ ft^2)	2019 Allowed General LPD (W/ ft^2)	2019 Additional Lighting Power (W/ ft^2)	2022 Allowed General LPD (W/ ft^2)	2022 Additional Lighting Power (W/ ft^2)	Full Load Hours /Year	Annual Energy Savings (Wh/yr-ft^2)	Annual Demand Savings (W/ ft^2-yr)
Audience Seating Area	0.29	0.46	0.60	0.30	0.50	0.25	3,367	505	0.051
Auditorium Area	0.60	1.11	0.70	0.50	0.70	0.45	3,367	168	0.017
Auto Repair / Maintenance Area	0.41	0.41	0.55	0.20	0.50	0.20	2,831	142	0.006
Barber, Beauty Salon and Spa Area	0.90	1.02	0.80	0.50	0.65	0.45	3,515	703	0.034
Civic Meeting Place Area	0.45	0.69	1.00	0.30	0.90	0.25	3,367	505	0.051
Classroom, Lecture, Training, Vocational Area	0.58	0.68	0.70	4.5 lf	0.60	7 W/lf	2,108	132	0.009
Commercial/Industrial Storage: Warehouse	0.33	0.33	0.45		0.40		1,735	87	0.003
Commercial/Industrial Storage: Shipping & Handling	0.50	0.50	0.60		0.60		1,735	0	0.000
Concourse and Atria Area	0.25	0.50	0.90	0.30	0.60	0.25	3,515	1,230	0.060
Convention, Conference, Multipurpose and Meeting Area	0.45	0.63	0.85	0.30	0.75	0.25	3,367	505	0.051
Copy Room	0.34	0.34	0.50		0.50		2,322	0	0.000
Corridor Area	0.21	0.26	0.60		0.40	0.25	2,322	(116)	(0.006)
Dining Area: Bar/Lounge and Fine Dining	0.12	0.22	0.55	0.30	0.35	0.35	4,787	718	0.075
Dining Area: Cafeteria/Fast Food	0.31	0.40	0.40	0.30	0.45	0.25	4,787	0	0.000

Primary Function Area	2022 Model LPD w/o wall Washing (W/ ft²)	Model LPD w/ Wall Washing (W/ ft²)	2019 Allowed General LPD (W/ ft²)	2019 Additional Lighting Power (W/ ft²)	2022 Allowed General LPD (W/ ft²)	2022 Additional Lighting Power (W/ ft²)	Full Load Hours /Year	Annual Energy Savings (Wh/yr-ft²)	Annual Demand Savings (W/ ft²-yr)
Dining Area: Family and Leisure	0.20	0.23	0.50	0.30	0.40	0.25	4,787	718	0.075
Kitchen/Food Preparation Area	0.97	0.97	0.95	N/A	0.95	N/A	4,787	0	0.000
Electrical, Mechanical, Telephone Rooms	0.36	0.36	0.40	N/A	0.40	N/A	1,735	0	0.000
Exercise/Fitness Center and Gymnasium Area	0.36	0.36	0.50	N/A	0.50	N/A	3,515	0	0.000
Financial Transaction Area	0.40	0.60	0.80	0.30	0.70	0.25	2,322	348	0.019
General/Commercial & Industrial Work Area: Low Bay	0.52	0.52	0.60	0.20	0.60	0.20	2,831	0	0.000
General/Commercial & Industrial Work Area: High Bay	0.51	0.51	0.65	0.20	0.65	0.20	2,831	0	0.000
General/Commercial & Industrial Work Area: Precision	1.28	1.28	0.85	0.70	0.85	0.70	2,831	0	0.000
Hotel Function Area	0.49	0.71	0.85	0.30	0.85	0.25	3,367	168	0.017
Scientific Laboratory Area	0.75	0.75	1.00	0.35	0.90	0.35	3,793	379	0.025
Laundry Area	0.35	0.35	0.45	N/A	0.45	N/A	2,831	0	0.000
Library : Reading Area	0.67	0.67	0.80	0.30	0.80	0.25	2,322	116	0.006
Library : Stacks Area	0.72	0.72	1.10	N/A	1.00	N/A	2,322	232	0.013
Main Entry Lobby	0.34	0.59	0.85	0.30	0.70	0.25	3,367	673	0.068
Locker Room	0.36	0.36	0.45	N/A	0.45	N/A	3,367	0	0.000
Lounge, Breakroom, or	0.20	0.46	0.65	0.30	0.55	0.25	3,367	505	0.051

Primary Function Area	2022 Model LPD w/o wall Washing (W/ ft^2)	Model LPD w/ Wall Washing (W/ ft^2)	2019 Allowed General LPD (W/ ft^2)	2019 Additional Lighting Power (W/ ft^2)	2022 Allowed General LPD (W/ ft^2)	2022 Additional Lighting Power (W/ ft^2)	Full Load Hours /Year	Annual Energy Savings (Wh/yr-ft^2)	Annual Demand Savings (W/ ft^2-yr)
Waiting Area									
Museum Area: Exhibition/Display	0.13	0.13	0.60	0.50	0.60	0.50	3,367	0	0.000
Museum Area: Restoration Room	0.76	0.76	0.75	0.20	0.70	0.35	3,367	(337)	(0.034)
Office Area: ≤ 250 square feet	0.44	0.44	0.70	0.20	0.65	0.20	2,322	116	0.006
Office Area: > 250 square feet and ≤ xxx sf	0.29	0.39	0.65	0.20	0.60	0.20	2,322	116	0.006
Office Area: Open plan office > xxx sf	0.40	0.45	0.60	0.20	0.60	0.20	2,322	0	0.000
Parking Garage Area: Parking Zone	0.09	0.09	0.10	N/A	0.10	N/A	6,754	0	0.000
Parking Garage Area: Dedicated Ramps	0.10	0.10	0.25	N/A	0.10	N/A	6,754	1,013	0.111
Parking Garage Area: Daylight Adaptation Zones	0.96	0.96	0.50	N/A	1.00	N/A	6,754	(3,377)	(0.371)
Pharmacy Area	1.01	1.01	1.10	0.35	1.00	0.35	3,515	352	0.017
Retail Sales Area: Grocery Sales	0.98	1.03	1.05	0.35	1.00	0.35	3,515	176	0.009
Retail Sales Area: Retail Merchandise Sales	0.80	0.98	1.00	0.35	0.95	0.35	3,515	176	0.009
Retail Sales Area: Fitting Room	0.85	1.52	0.60	40/120 W mirror	0.60	40/120 W mirror	3,515	0	0.000
Religious Worship Area	0.87	0.97	0.95	0.30	0.95	0.25	3,367	168	0.017
Restrooms	0.26	0.33	0.65	0.35	0.65	0.35	2,322	0	0.000

Primary Function Area	2022 Model LPD w/o wall Washing (W/ ft²)	Model LPD w/ Wall Washing (W/ ft²)	2019 Allowed General LPD (W/ ft²)	2019 Additional Lighting Power (W/ ft²)	2022 Allowed General LPD (W/ ft²)	2022 Additional Lighting Power (W/ ft²)	Full Load Hours /Year	Annual Energy Savings (Wh/yr-ft²)	Annual Demand Savings (W/ ft²-yr)
Stairwell	0.21	0.23	0.50	0.35	0.45	0.35	2,322	116	0.006
Theater Area: Motion picture	0.37	0.54	0.60	0.30	0.40	0.25	3,367	842	0.085
Theater Area: Performance	0.31	0.62	1.00	0.30	0.80	0.25	3,367	842	0.085
Transportation Function : Baggage Area	0.21	0.25	0.40	N/A	0.40	N/A	3,367	0	0.000
Transportation Function : Ticketing Area	0.27	0.36	0.45	0.20	0.45	0.20	3,367	0	0.000
Videoconferencing Studio	0.68	2.04	0.90	1.00	0.90	1.00	2,322	0	0.000
Aging Eye/Low-vision: Main Entry Lobby	1.37	1.83	0.85	1.25	0.85	1.25	3,367	0	0.000
Aging Eye/Low-vision: Stairwell	0.50	0.50	0.80	N/A	0.70	0.20	2,322	(232)	(0.013)
Aging Eye/Low-vision: Corridor Area	0.44	0.69	0.80	0.15	0.70	0.30	2,322	(116)	(0.006)
Aging Eye/Low-vision: Lounge/Waiting Area	0.63	1.02	0.75	0.30	0.80	0.30	3,285	(164)	(0.027)
Aging Eye/Low-vision: Multipurpose Room	0.61	0.78	0.95	0.30	0.85	0.30	3,285	329	0.055
Aging Eye/Low-vision: Religious Worship Area	0.50	1.31	1.00	0.30	1.00	0.30	3,367	0	0.000
Aging Eye/Low-vision: Dining	0.69	1.03	0.80	0.30	0.80	0.30	4,787	0	0.000
Aging Eye/Low-vision: Restroom	0.89	1.16	0.80	0.20	1.00	0.20	2,322	(464)	(0.026)
Healthcare Facility and	1.11	1.11	1.15	N/A	1.15	N/A	2,888	0	0.000

Primary Function Area	2022 Model LPD w/o wall Washing (W/ ft²)	Model LPD w/ Wall Washing (W/ ft²)	2019 Allowed General LPD (W/ ft²)	2019 Additional Lighting Power (W/ ft²)	2022 Allowed General LPD (W/ ft²)	2022 Additional Lighting Power (W/ ft²)	Full Load Hours /Year	Annual Energy Savings (Wh/yr-ft²)	Annual Demand Savings (W/ ft²-yr)
Hospitals: Exam/Treatment Room									
Healthcare Facility and Hospitals: Imaging Room	0.44	0.44	1.00	N/A	0.60	0.30	2,888	289	0.019
Healthcare Facility and Hospitals: Medical Supply Room	0.47	0.47	0.55	N/A	0.55	N/A	2,888	0	0.000
Healthcare Facility and Hospitals: Nursery	0.47	0.47	0.95	0.10	0.80	0.10	2,888	433	0.028
Healthcare Facility and Hospitals: Nurse's Station	0.73	1.09	0.75	0.10	0.85	0.30	2,888	(866)	(0.056)
Healthcare Facility and Hospitals: Operating Room	3.61	3.61	1.90	N/A	1.90	N/A	2,888	0	0.000
Healthcare Facility and Hospitals: Patient Room	0.80	0.80	0.55	0.25	0.70	0.25	2,888	(433)	(0.028)
Healthcare Facility and Hospitals: Physical Therapy Room	0.37	0.64	0.85	0.10	0.75	0.10	2,888	289	0.019
Healthcare Facility and Hospitals: Recovery Room	0.99	1.12	0.90	0.10	0.90	0.10	2,888	0	0.000
Sports Arena – Playing Area: Class I Facility	3.08	3.08	2.25	N/A	2.25	N/A	3,515	0	0.000
Sports Arena – Playing Area: Class II Facility	1.82	1.82	1.45	N/A	1.45	N/A	3,515	0	0.000
Sports Arena – Playing Area: Class III Facility	1.14	1.14	1.10	N/A	1.10	N/A	3,515	0	0.000

Primary Function Area	2022 Model LPD w/o wall Washing (W/ ft^2)	Model LPD w/ Wall Washing (W/ ft^2)	2019 Allowed General LPD (W/ ft^2)	2019 Additional Lighting Power (W/ ft^2)	2022 Allowed General LPD (W/ ft^2)	2022 Additional Lighting Power (W/ ft^2)	Full Load Hours /Year	Annual Energy Savings (Wh/yr-ft^2)	Annual Demand Savings (W/ ft^2-yr)
Sports Arena – Playing Area: Class IV Facility	0.76	0.76	0.75	N/A	0.75	N/A	3,515	0	0.000

3.4 Cost and Cost Effectiveness

3.4.1 Energy Cost Savings Methodology

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 3.3.2. 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 in 2023 present value dollars and represent the energy cost savings realized over 15 years.

The hourly energy savings estimates for the first year of building operation were multiplied by the 2022 TDV cost values to arrive at the present valued cost savings' over the period of analysis. This measure is not climate sensitive, so energy savings estimates are the same for every California climate zone. An earlier evaluation found that given the same lighting profiles, the energy cost savings per kWh are relatively constant across climate zones. When evaluated across all building schedules, cost per kWh in the lowest cost climate zone was 95 percent of that for the average climate zone. Thus, this analysis used the average TDV cost savings to calculate cost savings. This provides the statewide average cost savings and, as long as the benefit-to-cost ratio is greater than 1.05, the measure would be cost effective in the climate zone with lowest TDV electricity costs.

3.4.2 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 TDV kBtu and 2023 present valued dollars per square foot and per prototypical space.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 49: 2023 TDV Energy Savings and Present Valued Energy Cost Savings Over 15-Year Period of Analysis (per square foot and per prototypical space)

Primary Function Area	TDV Savings kBtu/ft²	Energy Cost Savings (PV$/ ft²)	Proto-type Area (ft²)	Prototype Annual Energy Savings (kWh/yr)	Prototype Demand Savings (kW)	Prototype TDV Savings kBtu	Prototype Energy Cost Savings (PV$)
Audience Seating Area	14	$1.27	3,200	1,616	0.163	45,766	$4,073
Auditorium Area	5	$0.42	4,500	758	0.076	21,453	$1,909
Auto Repair / Maintenance Area	3	$0.31	4,800	679	0.031	16,643	$1,481
Barber, Beauty Salon and Spa Area	18	$1.61	1,440	1,012	0.049	26,079	$2,321
Civic Meeting Place Area	14	$1.27	540	273	0.028	7,723	$687
Classroom, Lecture, Training, Vocational Area	3	$0.31	1,064	140	0.009	3,666	$326
Commercial/Industrial Storage: Warehouse	2	$0.18	800	69	0.003	1,613	$144
Commercial/Industrial Storage: Shipping & Handling	0	$0.00	1,800	0	0.000	0	$0
Concourse and Atria Area	32	$2.82	12,000	14,765	0.715	380,323	$33,849
Convention, Conference, Multipurpose and Meeting Area	14	$1.27	900	455	0.046	12,872	$1,146
Copy Room	0	$0.00	200	0	0.000	0	$0
Corridor Area	(3)	($0.26)	640	(74)	(0.004)	(1,866)	($166)
Dining Area: Bar/Lounge and Fine Dining	20	$1.81	1,800	1,293	0.134	36,706	$3,267
Dining Area: Cafeteria/Fast Food	0	$0.00	1,200	0	0.000	0	$0
Dining Area: Family and Leisure	20	$1.81	2,400	1,723	0.179	48,941	$4,356
Kitchen/Food Preparation Area	0	$0.00	450	0	0.000	0	$0
Electrical, Mechanical, Telephone Rooms	0	$0.00	1,200	0	0.000	0	$0
Exercise/Fitness Center and Gymnasium Area	0	$0.00	2,400	0	0.000	0	$0
Financial Transaction Area	9	$0.78	720	251	0.014	6,297	$560
General/Commercial & Industrial Work Area: Low Bay	0	$0.00	4,800	0	0.000	0	$0
General/Commercial & Industrial Work Area:	0	$0.00	12,000	0	0.000	0	$0

Primary Function Area	TDV Savings kBtu/ft²	Energy Cost Savings (PV$/ ft²)	Proto-type Area (ft²)	Prototype Annual Energy Savings (kWh/yr)	Prototype Demand Savings (kW)	Prototype TDV Savings kBtu	Prototype Energy Cost Savings (PV$)
High Bay							
General/Commercial & Industrial Work Area: Precision	0	$0.00	4,800	0	0.000	0	$0
Hotel Function Area	5	$0.42	540	91	0.009	2,574	$229
Scientific Laboratory Area	10	$0.88	672	255	0.017	6,617	$589
Laundry Area	0	$0.00	1,200	0	0.000	0	$0
Library : Reading Area	3	$0.26	720	84	0.005	2,099	$187
Library : Stacks Area	6	$0.52	360	84	0.005	2,099	$187
Main Entry Lobby	19	$1.70	1,800	1,212	0.122	34,324	$3,055
Locker Room	0	$0.00	200	0	0.000	0	$0
Lounge, Breakroom, or Waiting Area	14	$1.27	480	242	0.024	6,865	$611
Museum Area: Exhibition/Display	0	$0.00	2,184	0	0.000	0	$0
Museum Area: Restoration Room	(10)	($0.85)	2,400	(808)	(0.082)	(22,883)	($2,037)
Office Area: ≤ 250 square feet	3	$0.26	140	16	0.001	408	$36
Office Area: > 250 square feet and ≤ xxx sf	3	$0.26	600	70	0.004	1,749	$156
Office Area: Open plan office > xxx sf	0	$0.00	2,400	0	0.000	0	$0
Parking Garage Area: Parking Zone	0	$0.00	7,200	0	0.000	0	$0
Parking Garage Area: Dedicated Ramps	28	$2.53	1,920	1,945	0.214	54,533	$4,853
Parking Garage Area: Daylight Adaptation Zones	(95)	($8.43)	1,980	(6,686)	(0.735)	(187,456)	($16,684)
Pharmacy Area	9	$0.81	480	169	0.008	4,347	$387
Retail Sales Area: Grocery Sales	5	$0.40	4,800	844	0.041	21,733	$1,934
Retail Sales Area: Retail Merchandise Sales	5	$0.40	4,800	844	0.041	21,733	$1,934
Retail Sales Area: Fitting Room	0	$0.00	60	0	0.000	0	$0
Religious Worship Area	5	$0.42	8,000	1,347	0.136	38,138	$3,394
Restrooms	0	$0.00	200	0	0.000	0	$0
Stairwell	3	$0.26	360	42	0.002	1,049	$93

Primary Function Area	TDV Savings kBtu/ft²	Energy Cost Savings (PV$/ ft²)	Proto-type Area (ft²)	Prototype Annual Energy Savings (kWh/yr)	Prototype Demand Savings (kW)	Prototype TDV Savings kBtu	Prototype Energy Cost Savings (PV$)
Theater Area: Motion picture	24	$2.12	1,560	1,313	0.132	37,185	$3,309
Theater Area: Performance	24	$2.12	16,000	13,467	1.359	381,381	$33,943
Transportation Function : Baggage Area	0	$0.00	5,400	0	0.000	0	$0
Transportation Function : Ticketing Area	0	$0.00	2,000	0	0.000	0	$0
Videoconferencing Studio	0	$0.00	828	0	0.000	0	$0
Aging Eye/Low-vision: Main Entry Lobby	0	$0.00	600	0	0.000	0	$0
Aging Eye/Low-vision: Stairwell	(6)	($0.52)	640	(149)	(0.008)	(3,731)	($332)
Aging Eye/Low-vision: Corridor Area	(3)	($0.26)	640	(74)	(0.004)	(1,866)	($166)
Aging Eye/Low-vision: Lounge/Waiting Area	(5)	($0.46)	900	(148)	(0.025)	(4,611)	($410)
Aging Eye/Low-vision: Multipurpose Room	10	$0.91	900	296	0.049	9,222	$821
Aging Eye/Low-vision: Religious Worship Area	0	$0.00	504	0	0.000	0	$0
Aging Eye/Low-vision: Dining	0	$0.00	1,600	0	0.000	0	$0
Aging Eye/Low-vision: Restroom	(12)	($1.04)	216	(100)	(0.006)	(2,519)	($224)
Healthcare Facility and Hospitals: Exam/Treatment Room	0	$0.00	120	0	0.000	0	$0
Healthcare Facility and Hospitals: Imaging Room	7	$0.64	224	65	0.004	1,615	$144
Healthcare Facility and Hospitals: Medical Supply Room	0	$0.00	1,200	0	0.000	0	$0
Healthcare Facility and Hospitals: Nursery	11	$0.96	800	347	0.022	8,651	$770
Healthcare Facility and Hospitals: Nurse's Station	(22)	($1.92)	200	(173)	(0.011)	(4,325)	($385)
Healthcare Facility and Hospitals: Operating Room	0	$0.00	900	0	0.000	0	$0
Healthcare Facility and Hospitals: Patient Room	(11)	($0.96)	192	(83)	(0.005)	(2,076)	($185)
Healthcare Facility and Hospitals: Physical	7	$0.64	1,200	347	0.022	8,651	$770

Primary Function Area	**TDV Savings kBtu/ft²**	**Energy Cost Savings (PV$/ ft²)**	**Proto-type Area (ft²)**	**Prototype Annual Energy Savings (kWh/yr)**	**Prototype Demand Savings (kW)**	**Prototype TDV Savings kBtu**	**Prototype Energy Cost Savings (PV$)**
Therapy Room							
Healthcare Facility and Hospitals: Recovery Room	0	$0.00	192	0	0.000	0	$0
Sports Arena – Playing Area: Class I Facility	0	$0.00	5,000	0	0.000	0	$0
Sports Arena – Playing Area: Class II Facility	0	$0.00	5,000	0	0.000	0	$0
Sports Arena – Playing Area: Class III Facility	0	$0.00	5,000	0	0.000	0	$0
Sports Arena – Playing Area: Class IV Facility	0	$0.00	5,000	0	0.000	0	$0

3.4.3 Incremental First Cost

Luminaire costs were collected for 3 to 8 different manufacturers' products from multiple distributors for each luminaire type. When possible specification grade and contractor grade costs were collected. Some luminaire types, such as wall washers, only come in specification grade. So that the first costs of the base case (2019 Title 24, Part 6 LPD base system) is comparable to the proposed design (2022 Title 24, Part 6 prototype) both bases case and proposed case would use same grade (spec vs contractor) of luminaire. So, costs are comparable, for both the base case and the proposed case, prices are 2020 prices. This is important as the costs for LED luminaires have dropped significantly since the development of the 2019 Title 24, Part 6 Standards. Light emitting diode (LED) is the overwhelmingly predominant light source in use today in new nonresidential construction and the price premium for LED sources has been substantially reduced due to economies of scale and competition.

In Table 50 below, the descriptive average efficacy, average luminous flux, and average input watts are the average of the multiple luminaires that make up the averaged prototypical luminaire. Note that the average efficacy is not the same as dividing average lumens by average watts but is the simple average of the efficacies that make up the sample for the luminaire type.

Table 50: Luminaire Costs

Luminaire ID No.	Short Description	Avg Efficacy	Avg Lumen	Avg Watt	Spec Grade Cost	Contractor Grade Cost
	2022 Area Lighting					
CvA8	Cove light asymmetric 80CRI	91	2,774	40	$380	
DLg8	Downlight large 6"+ 80CRI	82	2,654	33	$162	$118
DLg8-HO	Downlight large 6"+ 80CRI Hi Output	90	5,138	57	$182	$138
DLg8w-HO	Downlight large 6"+ 80CRI Warm Hi Output	85	3,567	42	$182	$118
DLg9	Downlight large 6"+ 90CRI	78	2,840	36	$162	$138
DLg9w	Downlight large 6"+ 90CRI Warm	66	2,481	38	$162	$118
DLg9w-HO	Downlight large 6"+ 90CRI Warm Hi Output	70	4,998	72	$182	$138
DSm8	Downlight 4" and less 80CRI	76	2,401	32	$162	$118
DSm8-HO	Downlight 4" and less 80CRI Hi Output	80	5,011	62	$182	$138
DSm9	Downlight 4" and less 90CRI	83	2,373	29	$162	$118
DSm9w	Downlight 4" and less 90CRI Warm	69	2,431	36	$162	$118
LoB7	Low bay 70CRI	123	16,788	137	$270	N/A
PBc8	Pend bowl direct/indirect 80CRI	81	3,842	48	$514	N/A
PGL7	Parking garage luminaire 70CRI	111	4,576	42	$300	N/A
PGL7-HO	Parking garage luminaire 70CRI Hi Output	112	7,645	70	$300	N/A
SLl8	Linear light slot 4" or more 80CRI	104	3,499	33	$320	N/A
SLs8	Linear light slot 4" or less 80CRI	94	2,987	32	$300	N/A
StC8	Strip Under cabinet 80CRI	63	557	9	$40	N/A
StC8-HO	Strip Under cabinet 80CRI Hi Output	76	1,143	15	$40	N/A
StC9	Strip Under cabinet 90CRI	46	433	9	$40	N/A
StI8	Industrial strip 80CRI	135	4,224	32	$81	$81
StI8-HO	Industrial strip 80CRI Hi Output	122	7,229	59	$95	$95

Luminaire ID No.	Short Description	Avg Efficacy	Avg Lumen	Avg Watt	Spec Grade Cost	Contractor Grade Cost
TrB8	Troffer Basket 80CRI	116	4,288	38	$146	$95
TrB8-HO	Troffer Basket 80CRI Hi Output	112	6,759	61	$128	N/A
TrB9	Troffer Basket 90CRI	101	4,187	41	$196	N/A
TrL8	Troffer Lensed 80CRI	110	4,140	38	$126	N/A
TrL8-HO	Troffer Lensed 80CRI Hi Output	115	7,658	67	$128	N/A
	2022 Wall Washing					N/A
901S	901 Forward Throw WW (standard output)	97	2,713	28	$360	N/A
901CS	901 Forward Throw WW (standard output)	100	2,713	27	$360	N/A
903S	903 Linear Wall-Grazer (standard output)	81	2,183	27	$356	N/A
904S	904 Aperture Wall-Washer (standard output)	81	1,886	23	$228	N/A
905H	905H Linear Wall-Washer (high output)	91	4,289	47	$380	N/A
905S	905 Linear Wall-Washer (standard output)	100	2,713	27	$356	N/A
908H	908 Linear Wall-Grazer (high output)	62	2,905	47	$380	N/A
951CL	951 High CRI Forward WW (low output)	100	1,751	18	$410	N/A
951CS	951 High CRI Forward WW (standard output)	100	2,713	27	$410	N/A
951S	951 High CRI Forward WW (standard output)	82	2,288	28	$410	N/A
953S	953 High CRI Wall-Grazer (standard output)	73	1,330	18	$406	N/A
954S	954 High CRI Aperture WW (standard output)	81	1,886	23	$228	N/A
955S	955 High CRI Linear WW (standard output)	100	2,713	27	$228	N/A
955H	955 High CRI Linear WW (standard output)	91	4,289	47	$228	N/A
956H	956 High CRI Aperture WW(high output)	80	4,018	50	$282	N/A

Luminaire ID No.	Short Description	Avg Efficacy	Avg Lumen	Avg Watt	Spec Grade Cost	Contractor Grade Cost
957H	957 High CRI Linear Wall-Washer (high output)	108	4,009	37	$410	N/A
958H	958 High CRI Wall-Grazer (high output)	71	2,616	37	$444	N/A
	2019 Area Lighting Luminaires					N/A
800	Linear Rec Hi Perf Lensed (repl FL)	119	4,856	41	$129	$101
801	Downlight open (repl INC)	86	3,936	46	$157	N/A
802	Linear Wall Cove (repl FL)	81	2,128	26	$360	N/A
803	Linear WW Open (repl FL)	84	2,303	28	$318	N/A
811	PAR downlight flood	71	1,905	27	$158	$119
819	Task (repl MR)	67	498	7	$45	N/A
820	Downlight Lensed (repl CF)	77	2,296	30	$162	$118
821	WW open (repl CF)	67	1,963	30	$318	N/A
823	Indirect Pendant (repl CF)	77	9,605	124	$514	N/A
830	Linear Direct Lensed (repl FL)	106	5,089	48	$122	$94
831	Narrow Linear (repl FL)	87	2,122	25	$341	$130
835	Linear Dir/Ind (repl FL)	105	4,432	42	$372	N/A
838	Linear Industrial (repl FL)	131	7,719	59	$71	N/A
839	Task (repl FL)	67	498	7	$45	N/A
841	Downlight open (repl MH)	86	3,936	46	$157	N/A
851	PAR downlight flood	71	1,905	27	$158	$119
800-1	Linear Rec Hi Perf Lensed (repl FL in Hosp - 90+ CRI	119	4,856	41	$114	N/A
834-1	Linear Wall Cove (repl FL)	81	2,128	26	$360	N/A
859-2	High Bay (repl MH)	117	19,599	168	$240	N/A
869-2	High Bay (repl MH)	117	19,599	168	$240	N/A
853	Indirect Pendant (repl CF)	77	9,605	124	$514	N/A
859-3	Parking structure luminaire	112	6,152	55	$300	N/A
837-1	Linear WW Open (repl FL)	84	2,303	28	$88	N/A

Luminaire ID No.	Short Description	Avg Efficacy	Avg Lumen	Avg Watt	Spec Grade Cost	Contractor Grade Cost
834-2	Linear Wall Cove (repl FL)	81	2,128	26	$360	N/A
837-2	Linear WW Open (repl FL)	84	2,303	28	$88	N/A
	2019 Wall Washing Luminaires					N/A
901	Forward WW - Linear	N/A	N/A	18	$320	N/A
902	Wall Graze - Aperture	N/A	N/A	24	$282	N/A
903	Wall Graze - Linear	N/A	N/A	18	$360	N/A
904	Wall Wash - Aperture	N/A	N/A	24	$228	N/A
905	Wall Wash - Linear	N/A	N/A	18	$320	N/A
906	WW - Aperture HC	N/A	N/A	52	$282	N/A
952	CRI-Wall Graze - Aperture	N/A	N/A	34	$282	N/A
953	CRI-Wall Graze - Linear	N/A	N/A	28	$410	N/A
954	CRI-Wall Wash - Aperture	N/A	N/A	34	$282	N/A
955	CRI-Wall Wash - Linear	N/A	N/A	28	$370	N/A
956	CRI-WW - Aperture HC	N/A	N/A	72	$282	N/A

The incremental cost of each primary application area is detailed in *Appendix S: Model Cost Calculations*

3.4.4 Incremental Maintenance and Replacement Costs

Mostly luminaires will last over the 15 year period of analysis. Replacing luminaires outside of the occasional failure will be based on other considerations including a desire to change the "look" of the space. This would be especially the case in the case of a change of building use. For this analysis the Statewide CASE Team is comparing LED's with efficacies that were used to develop the 2019 Title 24, part 6 building efficiency standards with those that were evaluated for the 2022 standards. Unlike the evaluation of life cycle cost for the 2019 standards where LED life was often much longer than the incumbent (incandescent, fluorescent and metal halide lamp) technologies, the Statewide CASE Team is comparing like for like so that the maintenance cost effects are negligible. As a result, these maintenance costs are not included.

3.4.5 Cost Effectiveness

This measure proposes a change to the prescriptive LPD requirements. As a whole, this proposal 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 over the 15-year period of analysis was included. Maintenance costs were excluded as they were negligible, given that the base case and proposed case luminaires have the same expected useful life. The TDV energy cost savings from electricity 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.

The LPDs for about half of the primary function areas have not changed, thus the incremental cost is zero and the energy cost savings are zero. In the B/C ratio column, these are indicated as NC, referring to no change between the two standards.

Nine of the primary function areas have increased LPDs. These are primarily due to increasing the available illuminance for the space to more closely match current IES recommended practices. These primary function areas have a negative energy cost savings and are indicated as “EC Up” in the B/C ratio column, which indicates an energy cost increase followed by the B/C ratio. A notation of “EC up 0.00” indicates that energy costs increased, and first costs for more fixtures or for higher output fixtures which increased the lighting system cost.

When the proposed LPD is less than the 2019 Title 24, Part 6 LPD, then there are positive lighting energy savings. Typically, it is expected that saving energy requires lighting systems to cost more (incremental costs are positive), and this was true in some cases. However, for many cases, the first cost stayed the same or decreased. When the first cost decreased or stayed the same, the B/C ratio is listed as “infinite.”

Examples of reduced or zero incremental cost include:

- Product efficacy has increased but cost has stayed the same or decreased. This has been the case for ornamental lighting and is the basis of the 0.30 to 0.25 watt per ft^2 across the board changes.
- Earlier models were based on higher illuminance values. Not only were energy savings realized, but the proposed lighting system had fewer luminaires or would used lower output luminaires with either a first cost savings or the first cost staying the same (zero incremental cost).

Detailed costing of the lighting systems used in the 2019 base case model and in the 2022 proposed case model are tabulated in the last section of this report in Appendix S.

Table 51: 15-Year Cost-Effectiveness Summary Per Prototype Space

Primary Function Area	Proto-type Area (sf)	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Audience Seating Area	3,200	($11,715)	$4,073	$15,788	$0	Infinite
Auditorium Area	4,500	$7,118	$1,909	$1,909	$7,118	0.27
Auto Repair / Maintenance Area	4,800	($1,540)	$1,481	$3,021	$0	Infinite
Barber, Beauty Salon and Spa Area	1,440	$2,956	$2,321	$2,321	$2,956	0.79
Civic Meeting Place Area	540	$403	$687	$687	$403	1.70
Classroom, Lecture, Training, Vocational Area	1,064	($5,573)	$326	$5,899	$0	Infinite
Commercial/Industrial Storage: Warehouse	800	$31	$144	$144	$31	4.66
Commercial/Industrial Storage: Shipping & Handling	1,800	$0	$0	$0	$0	NC
Concourse and Atria Area	12,000	$11,032	$33,849	$33,849	$11,032	3.07
Convention, Conference, Multipurpose and Meeting Area	900	($5,824)	$1,146	$6,969	$0	Infinite
Copy Room	200	$0	$0	$0	$0	NC
Corridor Area	640	($958)	($166)	$958	$166	EC up 5.77
Dining Area: Bar/Lounge and Fine Dining	1,800	($2,439)	$3,267	$5,705	$0	Infinite
Dining Area: Cafeteria/Fast Food	1,200	$0	$0	$0	$0	NC
Dining Area: Family and Leisure	2,400	($4,622)	$4,356	$8,977	$0	Infinite
Kitchen/Food Preparation Area	450	$0	$0	$0	$0	NC
Electrical, Mechanical, Telephone Rooms	1,200	$0	$0	$0	$0	NC
Exercise/Fitness Center and Gymnasium Area	2,400	$0	$0	$0	$0	NC
Financial Transaction Area	720	($2,790)	$560	$3,351	$0	Infinite
General/Commercial & Industrial Work Area: Low Bay	4,800	$0	$0	$0	$0	NC
General/Commercial & Industrial Work Area: High Bay	12,000	$0	$0	$0	$0	NC
General/Commercial & Industrial Work Area: Precision	4,800	$0	$0	$0	$0	NC
Hotel Function Area	540	$1,209	$229	$229	$1,209	0.19
Scientific Laboratory Area	672	($7,369)	$589	$7,958	$0	Infinite

Primary Function Area	Proto-type Area (sf)	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Laundry Area	1,200	$0	$0	$0	$0	NC
Library : Reading Area	720	($2,392)	$187	$2,578	$0	Infinite
Library : Stacks Area	360	($1,870)	$187	$2,056	$0	Infinite
Main Entry Lobby	1,800	($1,198)	$3,055	$4,253	$0	Infinite
Locker Room	200	$0	$0	$0	$0	NC
Lounge, Breakroom, or Waiting Area	480	($227)	$611	$838	$0	Infinite
Museum Area: Exhibition/Display	2,184	$0	$0	$0	$0	NC
Museum Area: Restoration Room	2,400	$3,971	($2,037)	$0	$6,008	EC up 0.00
Office Area: ≤ 250 square feet	140	($123)	$36	$160	$0	Infinite
Office Area: > 250 square feet and ≤ xxx sf	600	($1,214)	$156	$1,369	$0	Infinite
Office Area: Open plan office > xxx sf	2,400	$0	$0	$0	$0	NC
Parking Garage Area: Parking Zone	7,200	$0	$0	$0	$0	NC
Parking Garage Area: Dedicated Ramps	1,920	($1,206)	$4,853	$6,060	$0	Infinite
Parking Garage Area: Daylight Adaptation Zones	1,980	($234)	($16,684)	$234	$16,684	EC up 0.01
Pharmacy Area	480	$152	$387	$387	$152	2.54
Retail Sales Area: Grocery Sales	4,800	$155	$1,934	$1,934	$155	12.46
Retail Sales Area: Retail Merchandise Sales	4,800	($15,081)	$1,934	$17,016	$0	Infinite
Retail Sales Area: Fitting Room	60	$0	$0	$0	$0	NC
Religious Worship Area	8,000	($19,777)	$3,394	$23,171	$0	Infinite
Restrooms	200	$0	$0	$0	$0	NC
Stairwell	360	($998)	$93	$1,092	$0	Infinite
Theater Area: Motion picture	1,560	$818	$3,309	$3,309	$818	4.05
Theater Area: Performance	16,000	($14,909)	$33,943	$48,852	$0	Infinite
Transportation Function : Baggage Area	5,400	$0	$0	$0	$0	NC
Transportation Function : Ticketing Area	2,000	$0	$0	$0	$0	NC
Videoconferencing Studio	828	$0	$0	$0	$0	NC

Primary Function Area	Proto-type Area (sf)	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Aging Eye/Low-vision: Main Entry Lobby	600	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Stairwell	160	($282)	($83)	$282	$83	EC up 3.40
Aging Eye/Low-vision: Corridor Area	640	($1,468)	($166)	$1,468	$166	EC up 8.84
Aging Eye/Low-vision: Lounge/Waiting Area	900	($1,505)	($410)	$1,505	$410	EC up 3.67
Aging Eye/Low-vision: Multipurpose Room	900	($1,631)	$821	$2,452	$0	Infinite
Aging Eye/Low-vision: Religious Worship Area	504	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Dining	1,600	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Restroom	216	($2,879)	($224)	$2,879	$224	EC up 12.84
Healthcare Facility and Hospitals: Exam/Treatment Room	120	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Imaging Room	224	($732)	$144	$876	$0	Infinite
Healthcare Facility and Hospitals: Medical Supply Room	1,200	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Nursery	800	-$6	$770	$776	$0	Infinite
Healthcare Facility and Hospitals: Nurse’s Station	200	$1,691	-$385	$0	$2,076	EC up 0.00
Healthcare Facility and Hospitals: Operating Room	900	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Patient Room	192	$264	($185)	$0	$449	EC up 0.00
Healthcare Facility and Hospitals: Physical Therapy Room	1,200	($858)	$770	$1,627	$0	Infinite
Healthcare Facility and Hospitals: Recovery Room	192	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class I Facility	5,000	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class II Facility	5,000	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class III Facility	5,000	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class IV Facility	5,000	$0	$0	$0	$0	NC

Key to B/C ratios:

NC: No change to the required LPD, thus both benefits and costs are 0.

Infinite: Energy costs savings with no incremental first costs or a decrease in incremental first costs.

EC up: Energy costs have increased (negative energy savings), followed by benefit cost ratio.

3.5 First-Year Statewide Impacts

3.5.1 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 3.3.3 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 area weightings were developed from building surveys that were used to develop the CBECS (US EIA Commercial Building End-Use Survey) database and were used by PNNL originally to develop the whole building weighted LPDs for the whole building approach. For offices, this was updated more recently by Michael Myer at PNNL, the Statewide CASE Team made use of this update and made some slight adjustments to better match some of the area fractions. This was done to better align with CBECS Table PBA2, which had a more granular description of building types (but with lower statistical confidence) for the building activity subcategories in CBECS 2012. One of the areas where the LPD would increase was parking garages. The Statewide CASE Team wanted to get a good description of parking garage area. Unfortunately, this has not been part of the CBECS surveys since 1992 and the Energy Commission does not include parking garages in their forecast of building areas. As a result, the Statewide CASE Team used the fraction of parking garages in the Western census region in the CBECS 1992 survey (2.1% of total building construction) to estimate the fraction of parking garages being built currently.

This proposal affects new construction but also impacts retrofits as the lighting power allowances in Section 140.6 are referenced Section 141.0(b)2I "Altered Indoor Lighting Systems."

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.

Table 52: Statewide Energy and Energy Cost Impacts – One Year's New Construction

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	NC Demand Saving (kW)	NC Energy Cost Savings (Million PV$)
Audience Seating Area	2.8	1.42	143.7	$3.6
Auditorium Area	2.4	0.40	40.2	$1.0
Auto Repair / Maintenance Area	4.8	0.68	31.0	$1.5
Barber, Beauty Salon and Spa Area	0.5	0.38	18.2	$0.9
Civic Meeting Place Area	1.4	0.70	71.0	$1.8
Classroom, Lecture, Training, Vocational Area	7.5	0.98	64.5	$2.3
Commercial/Industrial Storage: Warehouse	23.4	2.03	77.9	$4.2
Commercial/Industrial Storage: Shipping & Handling	5.7	0.00	0.0	$0.0
Concourse and Atria Area	2.0	2.52	121.8	$5.8
Convention, Conference, Multipurpose and Meeting Area	7.0	3.54	357.3	$8.9
Copy Room	0.2	0.00	0.0	$0.0
Corridor Area	11.6	-1.35	-74.7	-$3.0
Dining Area: Bar/Lounge and Fine Dining	0.5	0.34	35.6	$0.9
Dining Area: Cafeteria/Fast Food	2.2	0.00	0.0	$0.0
Dining Area: Family and Leisure	0.9	0.62	64.5	$1.6
Kitchen/Food Preparation Area	3.0	0.00	0.0	$0.0
Electrical, Mechanical, Telephone Rooms	3.3	0.00	0.0	$0.0
Exercise/Fitness Center and Gymnasium Area	2.1	0.00	0.0	$0.0
Financial Transaction Area	1.1	0.37	20.5	$0.8
General/Commercial & Industrial Work Area: Low Bay	3.0	0.00	0.0	$0.0
General/Commercial & Industrial Work Area: High Bay	0.8	0.00	0.0	$0.0
General/Commercial & Industrial Work Area: Precision	0.2	0.00	0.0	$0.0
Hotel Function Area	0.5	0.08	8.1	$0.2
Scientific Laboratory Area	0.5	0.19	12.4	$0.4
Laundry Area	0.2	0.00	0.0	$0.0
Library : Reading Area	0.8	0.09	5.0	$0.2

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	NC Demand Saving (kW)	NC Energy Cost Savings (Million PV$)
Library : Stacks Area	0.5	0.13	7.0	$0.3
Main Entry Lobby	7.6	5.12	516.5	$12.9
Locker Room	0.4	0.00	0.0	$0.0
Lounge, Breakroom, or Waiting Area	2.8	1.41	141.9	$3.5
Museum Area: Exhibition/Display	0.1	0.00	0.0	$0.0
Museum Area: Restoration Room	0.0	0.00	0.0	$0.0
Office Area: ≤ 250 square feet	11.4	1.32	72.9	$2.9
Office Area: > 250 square feet and ≤ xxx sf	5.7	0.67	36.8	$1.5
Office Area: Open plan office > xxx sf	7.4	0.00	0.0	$0.0
Parking Garage Area: Parking Zone	4.5	0.00	0.0	$0.0
Parking Garage Area: Dedicated Ramps	0.4	0.42	45.8	$1.0
Parking Garage Area: Daylight Adaptation Zones	0.1	(0.35)	(38.1)	($0.9)
Pharmacy Area	0.1	0.03	1.4	$0.1
Retail Sales Area: Grocery Sales	4.1	0.73	35.2	$1.7
Retail Sales Area: Retail Merchandise Sales	12.5	2.19	106.1	$5.0
Retail Sales Area: Fitting Room	0.3	0.00	0.0	$0.0
Religious Worship Area	3.4	0.57	57.2	$1.4
Restrooms	5.5	0.00	0.0	$0.0
Stairwell	2.3	0.27	14.8	$0.6
Theater Area: Motion picture	0.9	0.72	72.9	$1.8
Theater Area: Performance	0.7	0.58	59.0	$1.5
Transportation Function : Baggage Area	0.0	0.00	0.0	$0.0
Transportation Function : Ticketing Area	0.0	0.00	0.0	$0.0
Videoconferencing Studio	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Main Entry Lobby	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Stairwell	0.0	0.00	(0.2)	$0.0
Aging Eye/Low-vision: Corridor Area	0.0	0.00	(0.2)	$0.0
Aging Eye/Low-vision: Lounge/Waiting Area	0.0	(0.01)	(1.1)	$0.0

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	NC Demand Saving (kW)	NC Energy Cost Savings (Million PV$)
Aging Eye/Low-vision: Multipurpose Room	0.0	0.01	2.2	$0.0
Aging Eye/Low-vision: Religious Worship Area	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Dining	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Restroom	0.0	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Exam/Treatment Room	2.3	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Imaging Room	0.1	0.02	1.5	$0.1
Healthcare Facility and Hospitals: Medical Supply Room	0.1	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Nursery	0.1	0.04	2.6	$0.1
Healthcare Facility and Hospitals: Nurse's Station	0.0	(0.04)	(2.6)	($0.1)
Healthcare Facility and Hospitals: Operating Room	0.1	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Patient Room	0.3	(0.14)	(8.9)	($0.3)
Healthcare Facility and Hospitals: Physical Therapy Room	0.2	0.06	3.6	$0.1
Healthcare Facility and Hospitals: Recovery Room	0.2	0.00	0.0	$0.0
Sports Arena – Playing Area: Class I Facility	0.1	0.00	0.0	$0.0
Sports Arena – Playing Area: Class II Facility	0.0	0.00	0.0	$0.0
Sports Arena – Playing Area: Class III Facility	0.0	0.00	0.0	$0.0
Sports Arena – Playing Area: Class IV Facility	0.0	0.00	0.0	$0.0
New Construction Statewide Totals	162.7	26.73	2,123.4	$64.3

Statewide incremental construction costs are estimated to be reduced and as a result benefit cost ratio is infinite

Table 53: Statewide Energy and Energy Cost Impacts – One Year's Alterations

Primary Function Area	Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alteration Demand Saving (kW)	Alteration Energy Cost Savings (Million PV$)
Audience Seating Area	8.5	4.30	434.3	$10.8
Auditorium Area	7.3	1.23	124.2	$3.1
Auto Repair / Maintenance Area	14.8	2.09	95.3	$4.6
Barber, Beauty Salon and Spa Area	1.7	1.16	56.2	$2.7
Civic Meeting Place Area	4.1	2.09	211.4	$5.3
Classroom, Lecture, Training, Vocational Area	27.6	3.63	238.6	$8.5
Commercial/Industrial Storage: Warehouse	71.6	6.21	238.7	$12.8
Commercial/Industrial Storage: Shipping & Handling	17.2	0.00	0.0	$0.0
Concourse and Atria Area	6.2	7.68	371.7	$17.6
Convention, Conference, Multipurpose and Meeting Area	21.5	10.87	1,096.9	$27.4
Copy Room	0.6	0.00	0.0	$0.0
Corridor Area	36.7	(4.26)	(235.7)	($9.5)
Dining Area: Bar/Lounge and Fine Dining	1.4	0.99	102.7	$2.5
Dining Area: Cafeteria/Fast Food	6.9	0.00	0.0	$0.0
Dining Area: Family and Leisure	2.5	1.80	186.8	$4.5
Kitchen/Food Preparation Area	9.1	0.00	0.0	$0.0
Electrical, Mechanical, Telephone Rooms	10.5	0.00	0.0	$0.0
Exercise/Fitness Center and Gymnasium Area	7.3	0.00	0.0	$0.0
Financial Transaction Area	3.2	1.11	61.3	$2.5
General/Commercial & Industrial Work Area: Low Bay	9.2	0.00	0.0	$0.0
General/Commercial & Industrial Work Area: High Bay	2.5	0.00	0.0	$0.0
General/Commercial & Industrial Work Area: Precision	0.5	0.00	0.0	$0.0
Hotel Function Area	1.3	0.22	21.8	$0.5
Scientific Laboratory Area	1.8	0.67	44.3	$1.5
Laundry Area	0.5	0.00	0.0	$0.0
Library : Reading Area	2.5	0.29	16.0	$0.6
Library : Stacks Area	1.8	0.42	22.9	$0.9

Primary Function Area	Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alteration Demand Saving (kW)	Alteration Energy Cost Savings (Million PV$)
Main Entry Lobby	23.5	15.80	1,594.5	$39.8
Locker Room	1.5	0.00	0.0	$0.0
Lounge, Breakroom, or Waiting Area	8.7	4.39	442.8	$11.1
Museum Area: Exhibition/Display	0.3	0.00	0.0	$0.0
Museum Area: Restoration Room	0.0	0.00	0.0	$0.0
Office Area: ≤ 250 square feet	35.0	4.06	224.5	$9.1
Office Area: > 250 square feet and ≤ xxx sf	17.2	2.00	110.6	$4.5
Office Area: Open plan office > xxx sf	22.2	0.00	0.0	$0.0
Parking Garage Area: Parking Zone	13.4	0.00	0.0	$0.0
Parking Garage Area: Dedicated Ramps	1.2	1.25	137.6	$3.1
Parking Garage Area: Daylight Adaptation Zones	0.3	(1.04)	(114.7)	($2.6)
Pharmacy Area	0.3	0.10	4.8	$0.2
Retail Sales Area: Grocery Sales	12.8	2.26	109.2	$5.2
Retail Sales Area: Retail Merchandise Sales	38.6	6.79	328.7	$15.6
Retail Sales Area: Fitting Room	0.9	0.00	0.0	$0.0
Religious Worship Area	10.1	1.71	172.2	$4.3
Restrooms	17.3	0.00	0.0	$0.0
Stairwell	7.0	0.82	45.2	$1.8
Theater Area: Motion picture	2.6	2.18	219.5	$5.5
Theater Area: Performance	2.1	1.78	179.2	$4.5
Transportation Function : Baggage Area	0.1	0.00	0.0	$0.0
Transportation Function : Ticketing Area	0.1	0.00	0.0	$0.0
Videoconferencing Studio	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Main Entry Lobby	0.1	0.00	0.0	$0.0
Aging Eye/Low-vision: Stairwell	0.0	(0.01)	(0.5)	$0.0
Aging Eye/Low-vision: Corridor Area	0.1	(0.01)	(0.4)	$0.0
Aging Eye/Low-vision: Lounge/Waiting Area	0.1	(0.02)	(2.9)	$0.0
Aging Eye/Low-vision: Multipurpose Room	0.1	0.04	5.9	$0.1

Primary Function Area	Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alteration Demand Saving (kW)	Alteration Energy Cost Savings (Million PV$)
Aging Eye/Low-vision: Religious Worship Area	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Dining	0.0	0.00	0.0	$0.0
Aging Eye/Low-vision: Restroom	0.0	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Exam/Treatment Room	7.9	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Imaging Room	0.3	0.08	5.3	$0.2
Healthcare Facility and Hospitals: Medical Supply Room	0.3	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Nursery	0.3	0.14	8.9	$0.3
Healthcare Facility and Hospitals: Nurse's Station	0.2	(0.14)	(8.9)	($0.3)
Healthcare Facility and Hospitals: Operating Room	0.3	0.00	0.0	$0.0
Healthcare Facility and Hospitals: Patient Room	1.1	(0.48)	(31.1)	($1.1)
Healthcare Facility and Hospitals: Physical Therapy Room	0.7	0.19	12.3	$0.4
Healthcare Facility and Hospitals: Recovery Room	0.6	0.00	0.0	$0.0
Sports Arena – Playing Area: Class I Facility	0.2	0.00	0.0	$0.0
Sports Arena – Playing Area: Class II Facility	0.0	0.00	0.0	$0.0
Sports Arena – Playing Area: Class III Facility	0.0	0.00	0.0	$0.0
Sports Arena – Playing Area: Class IV Facility	0.0	0.00	0.0	$0.0
Alterations Statewide Totals	**506.5**	**82.37**	**6,530.2**	**$198.0**

To evaluate whether a change is "cost effective in its entirety" it is necessary to consider the statewide cost effectiveness so that the different primary function areas are weighed by their relative prevalence. This is provided below. The energy savings are calculated based upon the change in the base case and proposed LPDs, but the costs are based upon the luminaires in the 2019 and 2022 models. In some cases, the amount of delivered light increased or decreases based upon a re-evaluation of recommended illuminances. Additionally, with the improved lighting model, the Statewide CASE Team had more confidence in the results and could set the proposed LPDs closer to the model LPDs. As a result, on a statewide basis, the proposal saves energy AND has a lower first cost. Therefore, on a statewide basis, the benefit to cost ratio is infinite.

Note about half of the primary function areas have no incremental costs or energy savings as the total LPD allowance did not change.

Table 54: New Construction - Statewide Energy and Cost Savings, Incremental Cost and Benefit to Cost Ratios

Primary Function Area	NC Energy Savings (GWh/yr)	NC Energy Cost Savings (Million PV$)	NC Incremental Cost (Million $)	B/C ratio
Audience Seating Area	1.42	$3.59	($10.32)	Infinite
Auditorium Area	0.40	$1.00	$3.74	0.3
Auto Repair / Maintenance Area	0.68	$1.48	-$1.54	Infinite
Barber, Beauty Salon and Spa Area	0.38	$0.86	$1.10	0.8
Civic Meeting Place Area	0.70	$1.77	$1.04	1.7
Classroom, Lecture, Training, Vocational Area	0.98	$2.29	($39.07)	Infinite
Commercial/Industrial Storage: Warehouse	2.03	$4.19	$0.90	4.7
Commercial/Industrial Storage: Shipping & Handling	0.00	$0.00	$0.00	NC
Concourse and Atria Area	2.52	$5.77	$1.88	3.1
Convention, Conference, Multipurpose and Meeting Area	3.54	$8.92	($45.37)	Infinite
Copy Room	0.00	$0.00	$0.00	NC
Corridor Area	(1.35)	($3.02)	($17.41)	EC up 5.77
Dining Area: Bar/Lounge and Fine Dining	0.34	$0.87	($0.65)	Infinite
Dining Area: Cafeteria/Fast Food	0.00	$0.00	$0.00	NC
Dining Area: Family and Leisure	0.62	$1.57	($1.67)	Infinite
Kitchen/Food Preparation Area	0.00	$0.00	$0.00	NC
Electrical, Mechanical, Telephone Rooms	0.00	$0.00	$0.00	NC
Exercise/Fitness Center and Gymnasium Area	0.00	$0.00	$0.00	NC
Financial Transaction Area	0.37	$0.83	($4.13)	Infinite
General/Commercial & Industrial Work Area: Low Bay	0.00	$0.00	$0.00	NC
General/Commercial & Industrial Work Area: High Bay	0.00	$0.00	$0.00	NC
General/Commercial & Industrial Work Area: Precision	0.00	$0.00	$0.00	NC
Hotel Function Area	0.08	$0.20	$1.06	0.2
Scientific Laboratory Area	0.19	$0.43	($5.39)	Infinite
Laundry Area	0.00	$0.00	$0.00	NC
Library: Reading Area	0.09	$0.20	($2.58)	Infinite

Primary Function Area	NC Energy Savings (GWh/yr)	NC Energy Cost Savings (Million PV$)	NC Incremental Cost (Million $)	B/C ratio
Library: Stacks Area	0.13	$0.28	($2.83)	Infinite
Main Entry Lobby	5.12	$12.90	($5.06)	Infinite
Locker Room	0.00	$0.00	($0.00)	NC
Lounge, Breakroom, or Waiting Area	1.41	$3.54	($1.32)	Infinite
Museum Area: Exhibition/Display	0.00	$0.00	$0.00	NC
Museum Area: Restoration Room	0.00	$0.00	$0.00	EC up 0.00
Office Area: ≤ 250 square feet	1.32	$2.95	($10.02)	Infinite
Office Area: > 250 square feet and ≤ xxx sf	0.67	$1.49	($11.61)	Infinite
Office Area: Open plan office > xxx sf	0.00	$0.00	$0.00	NC
Parking Garage Area: Parking Zone	0.00	$0.00	$0.00	NC
Parking Garage Area: Dedicated Ramps	0.42	$1.04	($0.26)	Infinite
Parking Garage Area: Daylight Adaptation Zones	-0.35	($0.87)	($0.01)	EC up 0.01
Pharmacy Area	0.03	$0.07	$0.03	2.5
Retail Sales Area: Grocery Sales	0.73	$1.67	$0.13	12.5
Retail Sales Area: Retail Merchandise Sales	2.19	$5.02	($39.17)	Infinite
Retail Sales Area: Fitting Room	0.00	$0.00	$0.00	NC
Religious Worship Area	0.57	$1.43	($8.32)	Infinite
Restrooms	0.00	$0.00	$0.00	NC
Stairwell	0.27	$0.60	($6.38)	Infinite
Theater Area: Motion picture	0.72	$1.82	$0.45	4.0
Theater Area: Performance	0.58	$1.47	($0.65)	Infinite
Transportation Function: Baggage Area	0.00	$0.00	$0.00	NC
Transportation Function: Ticketing Area	0.00	$0.00	$0.00	NC
Videoconferencing Studio	0.00	$0.00	$0.00	NC
Aging Eye/Low-vision: Main Entry Lobby	0.00	$0.00	$0.00	NC
Aging Eye/Low-vision: Stairwell	0.00	($0.01)	($0.03)	EC up 3.40
Aging Eye/Low-vision: Corridor Area	0.00	($0.01)	($0.05)	EC up 8.84
Aging Eye/Low-vision: Lounge/Waiting Area	(0.01)	($0.02)	($0.07)	EC up 3.67

Primary Function Area	NC Energy Savings (GWh/yr)	NC Energy Cost Savings (Million PV$)	NC Incremental Cost (Million $)	B/C ratio
Aging Eye/Low-vision: Multipurpose Room	0.01	$0.04	($0.07)	Infinite
Aging Eye/Low-vision: Religious Worship Area	0.00	$0.00	$0.00	NC
Aging Eye/Low-vision: Dining	0.00	$0.00	$0.00	NC
Aging Eye/Low-vision: Restroom	0.00	$0.00	($0.01)	EC up 12.84
Healthcare Facility and Hospitals: Exam/Treatment Room	0.00	$0.00	$0.00	NC
Healthcare Facility and Hospitals: Imaging Room	0.02	$0.05	($0.27)	Infinite
Healthcare Facility and Hospitals: Medical Supply Room	0.00	$0.00	$0.00	NC
Healthcare Facility and Hospitals: Nursery	0.04	$0.09	$0.00	Infinite
Healthcare Facility and Hospitals: Nurse’s Station	(0.04)	($0.09)	$0.39	EC up 0.00
Healthcare Facility and Hospitals: Operating Room	0.00	$0.00	$0.00	NC
Healthcare Facility and Hospitals: Patient Room	(0.14)	($0.31)	$0.44	EC up 0.00
Healthcare Facility and Hospitals: Physical Therapy Room	0.06	$0.12	($0.14)	Infinite
Healthcare Facility and Hospitals: Recovery Room	0.00	$0.00	$0.00	NC
Sports Arena – Playing Area: Class I Facility	0.00	$0.00	$0.00	NC
Sports Arena – Playing Area: Class II Facility	0.00	$0.00	$0.00	NC
Sports Arena – Playing Area: Class III Facility	0.00	$0.00	$0.00	NC
Sports Arena – Playing Area: Class IV Facility	0.00	$0.00	$0.00	NC
New Construction Statewide Totals	**26.73**	**$64.3**	**($203.2)**	**Infinite**

Key to B/C ratios:

NC: No change to the required LPD, thus both benefits and costs are 0.

Infinite: Energy costs savings with no incremental first costs or a decrease in incremental first costs.

EC up: Energy costs have increased (negative energy savings), followed by benefit cost ratio.

Table 55: Statewide Energy and Energy Cost Impacts – First-Year New Construction, Alterations, and Additions

Construction Type	Annual Construction (Million sf/yr)	First-Year Electricity Savings (GWh/yr)	First-Year Peak Electrical Demand Reduction (MW)	15-Year PV Energy Cost Savings (PV$)
New Construction	162.7	26.7	21.2	$64.3
Additions and Alterations	506.5	82.4	6.5	$198.0
STATEWIDE TOTALS	**669.2**	**109.1**	**27.8**	**$262.2**

3.5.2 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. See Appendix C for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factors of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 56 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 160,865 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 56: First-Year Statewide GHG Emissions Impacts

Construction Type	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Ton CO2e)
New Construction	26.7	6,426
Additions and Alterations	82.4	19,802
STATEWIDE TOTAL	**109.1**	**26,227**

3.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

3.5.4 Statewide Material Impacts

The Statewide CASE Team estimated material impacts using the following methodology:

- Estimate material composition of a luminaire;
- Estimated the number of luminaires in California (based on construction estimates) if 2019 LPDs were in place;
- Estimated the number of luminaires in California (based on construction estimates) if proposed 2022 LPDs were in place;
- Found the difference in luminaires between 2019 and proposed 2022 LPDs and calculated, and therefore, difference in materials.

The Statewide CASE Team estimated material composition for luminaires by using a 2012 study on the potential impacts from metals within different lamp types, including LEDs (Lim, et al. 2013). The study included estimated amounts of different types of metals within an LED luminaire (Lim, et al. 2013). The Statewide CASE Team recognizes that this is an older study and material composition may differ in light sources and luminaires produced in 2020 versus those produced nearly 10 years ago. However, the Statewide CASE Team was unable to locate a comprehensive current study.

The Statewide CASE Team used this information to estimate the total amount of materials contained within different types of luminaires typically found in indoor spaces. Using the information from the Lim, et al. study, the Statewide CASE Team was able to develop per-unit impacts of each materials. The Statewide CASE Team then applied the per-unit impacts to statewide new construction numbers along with estimated number of luminaires needed using 2019 LPDs (at a statewide level according to new construction estimates) and number of luminaires needed using the proposed 2022 LPDs. Since the proposed 2022 LPDs are lower than the 2019 LPDs, less luminaires are needed to meet the 2022 LPDs, which results in less materials needed.[22] The Statewide CASE Team recognizes this approach uses many assumptions and does not account for others, including that designers are not likely to always reduce the number of luminaires in a space to meet the lower wattages but will instead use the same number of luminaires except with lower wattage ratings. The Statewide CASE Team recognizes these assumptions are likely to result in large margins of error for the quantitative results. However, the lower LPDs will ultimately result in reduction in materials.

The Statewide CASE Team will continue researching into the materials impacts and plans to update this analysis for the Final CASE Report.

[22] Using the Inverse Lumen Method Model, the Statewide CASE Team developed an estimate on the number of luminaires that would be needed to achieve appropriate light levels for each area category space type. The Statewide CASE Team then scaled these numbers up by using the new construction estimates to develop an estimate on the number of luminaires needed for all new construction.

Table 57: First-Year Statewide Impacts on Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Antimony	D	3.3×10^{-4}	89
Barium	D	9.6×10^{-4}	264
Cerium	D	2.0×10^{-5}	5
Chromium	D	3.2×10^{-4}	86
Copper	D	8.3×10^{-2}	22,857
Gallium	D	2.8×10^{-4}	78
Iron	D	3.2×10^{-2}	8,885
Lead	D	4.5×10^{-5}	12
Nickel	D	4.0×10^{-4}	110
Phosphorus	D	3.4×10^{-4}	92
Silver	D	4.2×10^{-4}	115
Zinc	D	1.2×10^{-2}	3,288

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

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

3.5.5 Other Non-Energy Impacts

The Statewide CASE Team does not expect any additional impacts aside from those already describe in the sections above.

3.6 Proposed Revisions to Code Language

3.6.1 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 ~~strikethroughs~~ (deletions).

In addition to the noted changes below, the primary function areas have been re-ordered to simplify looking up the application types for Table 140.6-C Area Category Method - Lighting Power Density Values (Watts/ft²). The result is most of the function areas are now in alphabetical order with the main activity listed first (i.e. scientific laboratory renamed laboratory, scientific or main entry lobby renamed lobby, main entry), kitchen is grouped immediately after the dinning values, and all the major groupings for the aged eye, healthcare facilities, and types of sports arenas are located at the end of table. For increased readability, this reordering is not shown with revision marks below when the values do not change. Parking garage Dedicated Ramps are shown as stricken as they are merged with parking zone in the combined primary function area parking garage "Parking Zone and Ramps."

Since hospitals are now within the scope of Title 24, Part 6, the introductory language to item F in Section 140.6(a)3 "Lighting wattage excluded" no longer needs to itemize the non-hospital occupancies where exam lighting might be applied.

Similarly, due to a proposal for newly regulating controlled environment horticulture, the excluded wattage items in Section 140.6(a)3 items G, H, O, P would now reference the proposed plant lighting requirements in section 120.6(h). More details can be found in the 2022 Controlled Environment Horticulture (CEH) CASE Report.

3.6.2 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

…

(b) **Definitions.** Terms, phrases, words and their derivatives in Part 6 shall be defined as specified in Section 100.1 shall be defined as specified in the "Definitions" chapters of Title 24, Parts 1 through 5 of the California Code of Regulations. Where terms, phrases, words and their derivatives are not defined in any of the references above, they shall be defined as specified in *Webster's Third New International Dictionary of the English Language, Unabridged* (1961 edition, through the 2002 addenda), unless the context requires otherwise.

…

NONRESIDENTIAL FUNCTION AREAS are those areas, rooms, and spaces within Nonresidential Buildings which fall within the following particular definitions, and are defined according to the most specific definition:

…

Barber, Beauty Salon, Spa Area is a room or area in which the primary activity is manicures, pedicures, facials, ~~or~~ the cutting or styling of hair or massage and other spa activities.

~~Main Entry~~ Lobby, Main Entry is the contiguous area in buildings including hotel/motel that is directly located by the main entrance of the building through which persons must pass, including any ancillary reception, waiting and seating areas.

~~General~~ Manufacturing, Commercial and Industrial Work Area is a room or area in which an art, craft, assembly or manufacturing operation is performed. Lighting installed in these areas is classified as follows:

> **High bay**: Where the luminaires are 25 feet or more above the floor.
>
> **Low bay**: Where the luminaires are less than 25 feet above the floor.
>
> **Precision**: Where visual tasks of small size or fine detail such as electronics assembly, fine woodworking, metal lathe operation, fine hand painting and finishing, egg processing operations, or tasks of similar visual difficulty are performed.

Parking Garage Areas include the following:

Parking Zone **and Ramps** in a Parking Garage is used for the purpose of parking and maneuvering of vehicles ~~on a single floor~~. Parking areas include sloping floors of a parking garage. Ramps are driveways specifically for the purpose of moving vehicles between floors of a parking garage. Parking areas and ramps do not include Daylight Transition Zones, ~~Dedicated Ramps,~~ or the roof of a Parking Garage, which may be present in a Parking Garage.

Daylight Adaptation Zone in a Parking Garage is the interior path of travel for vehicles ~~to enter a~~ adjacent to the entrance or exit of a parking garage ~~as needed to~~ where the transition ~~from~~ between exterior daylight levels ~~to~~ and interior light levels results in visual adaptation. Daylight ~~Transition~~ Adaptation Zones only include the path of vehicular travel and do not include adjacent Parking Areas.

~~**Dedicated Ramps** in Parking Garages are driveways specifically for the purpose of moving vehicles between floors of a parking garage and which have no adjacent parking. Dedicated ramps do not include sloping floors of a parking structure, which are considered Parking Areas.~~

~~**Scientific**~~ **Laboratory, Scientific Area** is a room or area where research, experiments, and measurement in medical and physical sciences are performed requiring examination of fine details. The area may include workbenches, countertops, scientific instruments, and associated floor spaces. ~~Scientific laboratory~~ Laboratory does not refer to film, computer, and other laboratories where scientific experiments or physical measurements are not performed.

Ornamental Lighting for compliance with Part 6 is the following:

Luminaires installed outdoor which are rated for 30 watts or less that are post-top luminaires, lanterns, pendant luminaires, chandeliers, and marquee lighting, not providing general lighting or task lighting.

Decorative Luminaires installed indoor that are chandeliers, sconces, lanterns, ~~neon and cold cathode, light emitting diodes~~, theatrical projectors, moving lights, ~~and~~ light color panels cove lighting or architectural lighting that emphasize interior building surfaces. Decorative luminaires do not ~~providing~~ provide general lighting or task lighting.

~~**Commercial and Industrial**~~ **Storage, Commercial and Industrial Area** includes the following:

Warehouse is a room or areas used for storing of items such as goods, merchandise and materials.

Shipping & Handling is a room or areas used for packing, wrapping, labelling and shipping out goods,

merchandise and materials.

SECTION 130.0 – LIGHTING SYSTEMS AND EQUIPMENT, AND ELECTRICAL POWER DISTRIBUTION SYSTEMS —GENERAL

…

(c) Luminaire classification and power. Luminaires shall be classified, and their wattage determined as follows:

…

2. For luminaires with line voltage lamp holders not containing permanently installed ballasts or transformers, the wattage ~~of such luminaires~~ shall be determined as ~~follows:~~

~~A. The~~ the maximum rated wattage ~~of the luminaire; and~~ as labeled in accordance with Section 130.0(c)1.

~~B. For recessed luminaires with line-voltage medium screw base sockets, wattage shall not be less than 50 watts per socket, or the rated wattage of the installed JA8 compliant lamps.~~

SECTION 140.6 – PRESCRIPTIVE REQUIREMENTS FOR INDOOR LIGHTING

…

(a)Calculation of Adjusted Indoor Lighting Power. The adjusted indoor Lighting Power of all proposed building areas is the total watts of all planned permanent and portable lighting systems in all areas of the proposed building; subject to the applicable adjustments under Subdivisions 1 through 4 of this subsection.

…

3. Lighting wattage excluded. The watts of the following indoor lighting applications ~~may~~ shall be excluded from Adjusted Indoor Lighting Power~~. (Indoor lighting not listed below shall comply with all applicable nonresidential indoor lighting requirements in Part 6.)~~:

…

F. ~~In office buildings with medical and clinical areas and healthcare facilities:~~ Examination and surgical lights, low-ambient night-lights, and lighting integral to medical equipment, provided that these lighting systems are additions to and separately switched from a general lighting system.

G. Lighting for plant growth or maintenance, with a lighting power density of 2 watts or less per square foot of the enclosed space and ~~if it is~~ controlled by a multi-level astronomical time-switch control that complies with the applicable provisions of Section 110.9.

H. Lighting equipment that is for sale, and controlled by automatic shut-off controls complying with Section 130.1(c).

…

O. Lighting in occupancy group U buildings less than 1,000 square feet and if used for plant growth or maintenance, complies with the requirements of Section 120.6(h)

P. Lighting in unconditioned agricultural buildings less than 2,500 square feet, and if used for plant growth or maintenance, complies with the requirements of Section 120.6(h).

…

W. Indoor Controlled Environment Horticultural Lighting or Greenhouse Horticultural Lighting. Indoor Controlled Environment Horticultural Lighting and Greenhouse Horticultural Lighting shall comply with Section 120.6(h)

4. Luminaire Classification and Power Adjustment.

A. Luminaire Classification and Power shall be determined in accordance with Section 130.0(c).

B. Small Aperture Tunable-White and Dim-to-Warm Luminaires Lighting Power Adjustment. For qualifying small aperture tunable-white and dim-to-warm LED luminaires, the adjusted indoor lighting power of these luminaires shall be calculated by multiplying their maximum rated wattage by ~~0.75~~ 0.80. Qualifying luminaires shall meet all of the following:

i. Small Aperture. Qualifying luminaires longer than 18 inches shall be no wider than four inches. Qualifying luminaires with a length of 18 inches or less shall be no wider than eight inches.

ii. Color Changing. Qualifying tunable-white luminaires shall be capable of a color change greater than or equal to 2000 Kelvin correlated color temperature (CCT). Qualifying dim-to-warm luminaires shall be capable of color change greater than or equal to 500 Kelvin CCT.

iii. Controls. Qualifying luminaires shall be connected to controls that allows color changing of the luminaires.

C. Tailored Method Display Lighting Mounting Height Lighting Power Adjustment. For wall display luminaires or floor display luminaires meeting Tailored Method Section 140.6(c)3G and H and where the bottom of luminaires are 10 feet 7 inches and greater above the finished floor, the adjusted indoor lighting power of these luminaires shall be calculated by multiplying their maximum rated wattage and the appropriated mounting height adjustment factor from TABLE 140.6-E. Luminaire mounting height is the distance from the finished floor to the bottom of the luminaire. General lighting shall not qualify for a mounting height multiplier.

…

(c) Calculation of Allowed Indoor Lighting Power. Specific Methodologies. The allowed indoor lighting power for each building type, or each primary function area shall be calculated using only one of the methods in Subsection 1, 2 or 3 below as applicable.

…

4. Tailored Method. Requirements for using the Tailored Method include all of the following:

J. Determine additional allowed power for very valuable display case lighting as follows:

…

iv. If there is qualifying very valuable display case lighting, in accordance with Section 140.6(c)3Jii, the smallest of the following separate lighting power for display cases presenting very valuable display items is permitted:

a. The product of the area of the primary function and ~~0.55~~ 0.50 watt per square foot; or

b. The product of the area of the display case and ~~8~~ 7 watts per square foot; or

c. The Adjusted Indoor Lighting Power of lighting for very valuable displays.

…

TABLE 140.6-B COMPLETE BUILDING METHOD LIGHTING POWER DENSITY VALUES

TYPE OF BUILDING	ALLOWED LIGHTING POWER DENSITY (WATTS PER SQUARE FOOT)
Assembly Building	~~0.70~~ 0.65
Financial Institution Building	0.65
Industrial/Manufacturing Facility Building	0.60
Grocery Store Building	~~0.95~~ 0.90
Gymnasium Building	~~0.65~~ 0.60
Library Building	0.70
Healthcare Facility	0.90
Office Building	~~0.65~~ 0.60
Parking Garage Building	0.13
Religious Facility Building	0.70
Restaurant Building	~~0.70~~ 0.65
Retail Store Building	0.90
School Building	~~0.65~~ 0.60
Sports Arena Building	0.75
Motion Picture Theater Building	~~0.70~~ 0.60
Performing Arts Theater Building	~~0.80~~ 0.75
All other~~s~~ buildings	0.40

TABLE 140.6-C AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (WATTS/FT^2)

Primary Function Area	Allowed Lighting Power Density for General Lighting (W/ft^2)	Additional Lighting Power[1]	
		Qualified Lighting Systems	**Additional Allowance (W/ft^2, unless noted otherwise)**
Audience Seating Area	~~0.60~~ 0.50	Ornamental	~~0.30~~ 0.25
Auditorium Area	0.70	Ornamental	~~0.30~~ 0.25
		Accent, display and feature[3]	0.20
Auto Repair / Maintenance Area	~~0.55~~ 0.50	Detailed Task Work[7]	0.20
Barber, Beauty Salon, Spa Area	~~0.80~~ 0.65	Detailed Task Work[7]	0.20
		Ornamental	~~0.30~~ 0.25
Civic Meeting Place Area	~~1.00~~ 0.90	Ornamental	~~0.30~~ 0.25
Classroom, Lecture, Training, Vocational Area	~~0.70~~ 0.60	White or Chalk Board[1]	~~4.50~~ 7 W/ft
Concourse and Atria Area	~~0.90~~ 0.60	Ornamental	~~0.30~~ 0.25
Convention, Conference, Multipurpose and Meeting Area	~~0.85~~ 0.75	Ornamental	~~0.30~~ 0.25
Copy Room	0.50	-	-
Corridor Area	~~0.60~~ 0.40	Ornamental	0.25
Dining Area – Bar/Lounge and Fine Dining	~~0.55~~ 0.35	~~Ornamental~~ Accent, display and feature[3] Decorative	~~0.30~~ 0.20 0.15
Dining Area – Cafeteria/Fast Food	~~0.40~~ 0.45	Ornamental	~~0.30~~ 0.25
Dining Area – Family and Leisure	~~0.50~~ 0.40		
Kitchen/Food Preparation Area	0.95	-	-
Electrical, Mechanical, Telephone Rooms	0.40	Detailed Task Work[7]	0.20
Exercise/Fitness Center and Gymnasium Area	0.50	-	-
Financial Transaction Area	~~0.80~~ 0.70	Ornamental	~~0.30~~ 0.25
Hotel Function Area	0.85	Ornamental	~~0.30~~ 0.25
~~Scientific~~ Laboratory~~,~~ Scientific Area	~~1.00~~ 0.90	Specialized Task Work[8]	0.35

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]	
			Qualified Lighting Systems	Additional Allowance (W/ft², unless noted otherwise)
Laundry Area		0.45	-	-
Library	Reading Area	0.80	Ornamental	~~0.30~~ 0.25
	Stacks Area	~~1.10~~ 1.00	-	-
~~Main Entry~~ Lobby, Main Entry		~~0.85~~ 0.70	Ornamental	~~0.30~~ 0.25
Locker Room		0.45	-	-
Lounge, Breakroom, or Waiting Area		~~0.65~~ 0.55	Ornamental	~~0.30~~ 0.25
~~General/~~Manufacturing, Commercial & Industrial Work Area	Low Bay	0.60	Detailed Task Work[7]	0.20
	High Bay	0.65	Detailed Task Work[7]	0.20
	Precision	0.85	Precision Specialized Work[9]	0.70
Museum Area	Exhibition/Display	0.60	Accent, display and feature[3]	~~0.50~~ 0.45
	Restoration Room	~~0.75~~ 0.70	Detailed Task Work[7]	~~0.20~~ 0.35
Office Area	≤ 250 square feet	~~0.70~~ 0.65	Portable lighting for office areas[6]	0.20
	> 250 square feet	~~0.65~~ 0.60		
	~~Open plan office~~	~~0.60~~		
Parking Garage Area	Parking Zone and Ramps	0.10	First ATM or Ticket Machine	100 W
			Additional ATM or Ticket machine	50 W each
	~~Dedicated Ramps~~	~~0.25~~	-	-
	Daylight Adaptation Zones[2]	~~0.50~~ 1.00	-	-
Pharmacy Area		~~1.10~~ 1.00	Specialized Task Work[8]	0.35
Retail Sales Area	Grocery Sales	~~1.05~~ 1.00	Accent, display and feature[3]	0.20
			Decorative	0.15

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]	
			Qualified Lighting Systems	Additional Allowance (W/ft², unless noted otherwise)
	Retail Merchandise Sales	~~1.00~~ 0.95	Accent, display and feature[3]	0.20
			Decorative	0.15
	Fitting Room	0.60	External Illuminated Mirror[5]	40 W/ea
			Internal Illuminated Mirror[5]	120 W/ea
Religious Worship Area		0.95	Ornamental	~~0.30~~ 0.25
Restrooms		0.65	Accent, display and feature[3]	0.20
			Decorative[4]	0.15
Stairwell		~~0.5~~ 0.45	Accent, display and feature[3]	0.20
			Decorative[4]	0.15
Storage, Commercial/Industrial ~~Storage~~	Warehouse	~~0.45~~ 0.40	-	-
	Shipping & Handling	0.60	-	-
Theater Area	Motion picture	~~0.60~~ 0.40	Ornamental	~~0.30~~ 0.25
	Performance	~~1.00~~ 0.80		
Transportation Function	Baggage Area	0.40	-	-
	Ticketing Area	0.45	Accent, display and feature[3]	0.20
Videoconferencing Studio[14]		0.90	Videoconferencing	1.00
Aging Eye/Low-vision[11]	Corridor Area	~~0.80~~ 0.70	Ornamental ~~Decorative~~[4]	~~0.15~~ 0.30
	Dining	0.80	Ornamental	0.30
	Lounge/Waiting Area	~~0.75~~ 0.80	Ornamental	0.30
	Main Entry Lobby	0.85	Ornamental	0.30
			Transition Lighting OFF at night[12]	0.95

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]	
			Qualified Lighting Systems	Additional Allowance (W/ft², unless noted otherwise)
	Multipurpose Room	~~0.95~~ 0.85	Ornamental	0.30
	Religious Worship Area	1.00	Ornamental	0.30
	Restroom	~~0.80~~ 1.00	Accent, display and feature[3]	0.20
	Stairwell	~~0.80~~ 0.70	Accent, display and feature[3]	0.20
Healthcare Facility and Hospitals	Exam/Treatment Room	1.15	-	-
	Imaging Room	~~1.00~~ 0.60	Accent, display and feature[3]	0.20
			Tunable white or dim-to-warm[10]	0.10
	Medical Supply Room	0.55	-	-
	Nursery	~~0.95~~ 0.80	Tunable white or dim-to-warm[10]	0.10
	Nurse's Station	~~0.75~~ 0.85	Tunable white or dim-to-warm[10]	0.10
			Detailed Task Work[7]	0.20
	Operating Room	1.90	-	-
	Patient Room	~~0.55~~ 0.70	Decorative	0.15
			Tunable white or dim-to-warm[10]	0.10
	Physical Therapy Room	~~0.85~~ 0.75	Tunable white or dim-to-warm[10]	0.10
	Recovery Room	0.90	Tunable white or dim-to-warm[10]	0.10
Sports Arena – Playing Area	Class I Facility[13]	2.25	-	-
	Class II Facility[13]	1.45	-	-
	Class III Facility[13]	1.10	-	-
	Class IV Facility[13]	0.75	-	-

Primary Function Area	Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]	
		Qualified Lighting Systems	Additional Allowance (W/ft², unless noted otherwise)
All other	0.40	-	-

Footnotes for this table are listed below.

1. White board or chalk board. – Directional lighting dedicated to a white board or chalk board.

2. Daylight Adaptation Zones shall be no longer than 66 feet from the entrance to the parking garage. In addition to the controls required by Section 130.1(c)7B, lighting shall be controlled to reduce the lighting to no more than the parking zone or dedicated ramp light levels at night from sunset to sunrise.

3. Accent, display and feature lighting – luminaires shall be adjustable or directional.

4. Decorative lighting – primary function shall be decorative and not to provide general lighting.

5. Illuminated mirrors. Lighting shall be dedicated to the mirror.

6. Portable lighting in office areas includes under shelf or furniture-mounted supplemental task lighting qualifies when controlled by a time clock or an occupancy sensor.

7. Detailed task work – Lighting provides high level of visual acuity required for activities with close attention to small elements and/or extreme close up work.

8. Specialized task work – Lighting provides for small-scale, cognitive or fast performance visual tasks; lighting required for operating specialized equipment associated with pharmaceutical/laboratorial activities.

9. Precision specialized work – Lighting for work performed within a commercial or industrial environment that entails working with low contrast, finely detailed, or fast moving objects.

10. Tunable white luminaires capable of color change greater than or equal to 2000K CCT, or dim-to-warm luminaires capable of color change greater than or equal to 500K CCT, connected to controls that allows color changing of the luminaires.

11. Aging Eye/Low-vision areas can be documented as being designed to comply with the light levels in ANSI/IES RP-28 and are or will be licensed by local or state authorities for either senior long-term care, adult day care, senior support, and/or people with special visual needs.

12. Transition lighting OFF at night. Lighting power controlled by astronomical time clock or other control to shut off lighting at night. Additional LPD only applies to area within 30 feet of an exit. Not applicable to lighting in daylit zones.

13. Class I Facility is used for competition play for 5000 or more spectators. Class II Facility is used for competition play for up to 5000 spectators. Class III Facility is used for competition play for up to 2000 spectators. Class IV Facility is normally used for recreational play and there is limited or no provision for spectators.

14. Spaces claiming the videoconferencing lighting power density shall comply with all the requirements of Section 140.6(c)2Gvii

TABLE 140.6-D TAILORED METHOD LIGHTING POWER ALLOWANCES

1	2	3	4	5
Primary Function Area	**General Illumination Level (Lux)**	**Wall Display Lighting Power Density (W/ft)**	**Allowed Combined Floor Display Power and Task Lighting Power Density (W/ft²)**	**Allowed Ornamental/ Special Effect Lighting Power Density (W/ft²)**
Auditorium Area	300	3.00	0.20	~~0.40~~ 0.35
Convention, Conference, Multipurpose, and Meeting Center Areas	300	~~2.00~~	~~0.35~~ 0.30	~~0.40~~ 0.35
Dining Areas	200	1.25	~~0.50~~ 0.45	~~0.40~~ 0.35
Exhibit, Museum Areas	150	~~11.50~~ 11.20	~~0.80~~ 0.70	~~0.40~~ 0.35
Hotel Area:				
Ballroom/Events	400	1.80	0.12	~~0.40~~ 0.35
Lobby	200	~~3.50~~ 3.40	0.20	~~0.40~~ 0.35
Main entry lobby	200	~~3.50~~ 3.40	0.20	~~0.40~~ 0.35
Religious Worship Area	300	1.30	0.40	~~0.40~~ 0.35
Retail Sales:				
Grocery	600	~~6.80~~ 6.60	~~0.70~~ 0.60	~~0.40~~ 0.35
Merchandise Sales, and Showroom Areas	500	~~11.80~~ 11.50	~~0.80~~ 0.70	~~0.40~~ 0.35
Theater Area:				
Motion picture	200	2.00	0.20	~~0.40~~ 0.35
Performance Arts	200	~~7.50~~ 7.30	0.20	~~0.40~~ 0.35

TABLE 140.6-E TAILORED WALL AND FLOOR DISPLAY MOUNTING HEIGHT ADJUSTMENT FACTORS

Height in feet above finished floor and bottom of luminaire(s)	Floor Display or Wall Display Mounting Height Adjustment Factor
< 10'-7"	1.00
10'-7" to 14'-0"	0.85
>14'-0" to 18'-0"	0.75
> 18'-0"	0.70

TABLE 140.6-F ROOM CAVITY RATIO (RCR) EQUATIONS

Determine the Room Cavity Ratio for TABLE 140.6-G using one of the following equations.
Room cavity ratio for rectangular rooms $$RCR = \frac{5 \times H \times (L + W)}{L \times W}$$
Room cavity ratio for irregular-shaped rooms $$RCR = \frac{2.5 \times H \times P}{A}$$
Where: L =Length of room; W = Width of room; H =Vertical distance from the work plane to the centerline of the lighting fixture; P = Perimeter of room, and A = Area of room

TABLE 140.6-G TAILORED METHOD GENERAL LIGHTING POWER ALLOWED – BY ILLUMINANCE AND ROOM CAVITY RATIO

	General Lighting Power Density (W/ft²) for the following RCR values[b] ~~values[b]~~			
General Illuminance Level (lux)[a]	**RCR ≤ 2.0**	**RCR > 2.0 and ≤ 3.5**	**RCR > 3.5 and ≤ 7.0**	**RCR > 7.0**
150	~~0.40~~ 0.35	~~0.45~~ 0.40	~~0.60~~ 0.50	~~00.75~~ 0.65
200	~~0.45~~ 0.40	~~0.55~~ 0.50	~~0.75~~ 0.65	~~1.00~~ 0.85
300	~~0.65~~ 0.55	~~0.80~~ 0.70	~~1.00~~ 0.85	~~1.40~~ 1.20
400	~~0.75~~ 0.65	~~0.95~~ 0.80	~~1.25~~ 1.05	~~1.50~~ 1.25
500	~~0.90~~ 0.80	~~1.05~~ 0.90	~~1.45~~ 1.25	~~1.85~~ 1.55
600	~~1.08~~ 0.90	~~1.24~~ 1.05	~~1.64~~ 1.40	~~2.38~~ 2.00
[a] Illuminance values from Column 2 of TABLE 140.6-D. [b] RCR values are calculated using applicable equations in TABLE 140.6-F.				

3.6.3 Reference Appendices

The Statewide CASE Team does not expect any changes to the Reference Appendices as a result of the LPD update.

3.6.4 NR ACM Reference Manual

The ACM Reference Manual Appendix 5.4A and compliance software would need to be updated to reflect the new LPD values. The Complete Building Method Allowed Lighting Power Density values are referenced from Appendix 5.4 TABLE BldgUseData under the variable name “IntLPDReg” (W/ft²), the Area Category Method Allowed Lighting Power

Density for General Lighting are referenced from TABLE SpaceFunctionData under the variable name “IntLPDReg” the Area Category Additional Allowances are referenced from TABLE SpaceFunctionData under the variable names “Allow Type 1” (describing what qualified lighting system can take the credit), “Allow Area 1” (containing the LPD allowance for the particular type of qualifying lighting system), Allow Type 2”, and Allow Area 2.”

Please see the table below which has the current 2019 values and the proposed 2022 values for each variable in separate columns. When the value of variable is changed, the 2019 column will have the value with strikethrough and in red font and the 2022 column will contain the variable value underlined and in red font. For variables where the value is not proposed to change, the values in the 2019 and 2022 columns will be the same and in black font.

Table 58: Nonresidential ACM Appendix 5.4A Space by Spaces LPDs and Additional Allowances

TABLE SpaceFunctionData	2019	2019	2019	2019	2019	2022	2022	2022	2022	2022
FuncType	IntLPDReg	AllowType1	AllowArea1	AllowType2	AllowArea2	IntLPDReg	AllowType1	AllowArea1	AllowType2	AllowArea2
//SpaceBySpace	W/ft²		W/ft²		W/ft²	W/ft²		W/ft²		W/ft²
Audience Seating Area	~~0.60~~	Ornamental	~~0.30~~	0	0.00	0.50	Ornamental	0.25	0	0.00
Auditorium Area	0.70	Ornamental	~~0.30~~	Accent, display and feature (Note 3)	0.20	0.70	Ornamental	0.25	Accent, display and feature (Note 3)	0.20
Auto Repair / Maintenance Area	~~0.55~~	Detailed Task Work (Note 7)	0.20	0	0.00	0.50	Detailed Task Work (Note 7)	0.20	0	0.00
Barber, Beauty Salon, Spa Treatment Area	~~0.80~~	Detailed Task Work (Note 7)	0.20	Ornamental	~~0.30~~	0.65	Detailed Task Work (Note 7)	0.20	Ornamental	0.30
Civic Meeting Place Area	~~1.00~~	Ornamental	~~0.30~~	0	0.00	0.90	Ornamental	0.30	0	0.00
Classroom, Lecture, Training, Vocational Areas	~~0.70~~	White or Chalk Board (W/ft) (Note 1)	4.50	0	0.00	0.60	White or Chalk Board (W/ft) (Note 1)	7.00	0	0.00
Commercial/Industrial Storage (Refrigerated)	0.45	0	0.00	0	0.00	0.40	0	0.00	0	0.00
Commercial/Industrial Storage (Shipping & Handling)	0.60	0	0.00	0	0.00	0.60	0	0.00	0	0.00
Commercial/Industrial Storage	0.45	0	0.00	0	0.00	0.40	0	0.00	0	0.00

(Warehouse)										
Computer Room	0.50	0	0.00	0	0.00	0.50	0	0.00	0	0.00
Concourse and Atria Area	~~0.90~~	Ornamental	~~0.30~~	0	0.00	0.60	Ornamental	0.30	0	0.00
Convention, Conference, Multipurpose and Meeting Area	~~0.85~~	Ornamental	~~0.30~~	0	0.00	0.75	Ornamental	0.30	0	0.00
Copy Room	0.50	0	0.00	0	0.00	0.50	0	0.00	0	0.00
Corridor Area	~~0.60~~	0	0.00	0	0.00	0.45	0	0.00	0	0.00
Dining Area (Bar/Lounge and Fine Dining)	~~0.55~~	Ornamental	~~0.30~~	0	0.00	0.35	Accent display, feature	0.20	Decorative	0.15
Dining Area (Cafeteria/Fast Food)	~~0.40~~	Ornamental	~~0.30~~	0	0.00	0.45	Ornamental	0.25	0	0.00
Dining Area (Family and Leisure)	~~0.50~~	Ornamental	~~0.30~~	0	0.00	0.40	Ornamental	0.25	0	0.00
Electrical, Mechanical, Telephone Rooms	0.40	Detailed Task Work (Note 7)	0.20	0	0.00	0.40	Detailed Task Work (Note 7)	0.20	0	0.00
Exercise/Fitness Center and Gymnasium Areas	0.50	0	0.00	0	0.00	0.50	0	0.00	0	0.00
Financial Transaction Area	~~0.80~~	Ornamental	~~0.30~~	0	0.00	0.70	Ornamental	0.25	0	0.00
Manufacturing ~~General~~/Commercial & Industrial Work Area (High Bay)	0.65	Detailed Task Work (Note 7)	0.20	0	0.00	0.65	Detailed Task Work (Note 7)	0.20	0	0.00
Manufacturing ~~General~~/Commercial & Industrial Work Area (Low Bay)	0.60	Detailed Task Work (Note 7)	0.20	0	0.00	0.60	Detailed Task Work (Note 7)	0.20	0	0.00
Manufacturing ~~General~~/Commercial &	0.85	Precision Work	0.70	0	0.00	0.85	Precision Work	0.70	0	0.00

Industrial Work Area (Precision)		(Note 9)					(Note 9)			
Healthcare Facility and Hospitals (Exam/Treatment Room)	1.15	0	0.00	0	0.00	1.15	0	0.00	0	0.00
Healthcare Facility and Hospitals (Imaging Room)	~~1.00~~	0	0.00	0	0.00	0.60	Accent display and feature	0.20	Tunable while or dim-to-warm (Note 10)	0.10
Healthcare Facility and Hospitals (Medical Supply Room)	0.55	0	0.00	0	0.00	0.55	0	0.00	0	0.00
Healthcare Facility and Hospitals (Nursery)	~~0.95~~	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00	0.80	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00
Healthcare Facility and Hospitals (Nurse's Station)	~~0.75~~	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00	0.85	Tunable while or dim-to-warm (Note 10)	0.10	Specialized task work (Note 8)	0.20
Healthcare Facility and Hospitals (Operating Room)	1.90	0	0.00	0	0.00	1.90	0	0.00	0	0.00
Healthcare Facility and Hospitals (Patient Room)	~~0.55~~	Decorative	0.15	Tunable while or dim-to-warm (Note 10)	0.10	0.70	Decorative	0.15	Tunable while or dim-to-warm (Note 10)	0.10
Healthcare Facility and Hospitals (Physical Therapy Room)	~~0.85~~	Tunable while or dim-to-warm	0.10	0	0.00	0.75	Tunable while or dim-to-warm	0.10	0	0.00

		(Note 10)					(Note 10)			
Healthcare Facility and Hospitals (Recovery Room)	0.90	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00	0.90	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00
High-Rise Residential Living Spaces	na	0	0.00	0	0.00	na	0	0.00	0	0.00
Hotel Function Area	0.85	Ornamental	~~0.30~~	0	0.00	0.85	Ornamental	0.25	0	0.00
Hotel/Motel Guest Room	na	0	0.00	0	0.00	na	0	0.00	0	0.00
Kitchen/Food Preparation Area	0.95	0	0.00	0	0.00	0.95	0	0.00	0	0.00
Kitchenette or Residential Kitchen	0.95	0	0.00	0	0.00	0.95	0	0.00	0	0.00
Laundry Area	0.45	0	0.00	0	0.00	0.45	0	0.00	0	0.00
Library (Reading Area)	0.80	Ornamental	~~0.30~~	0	0.00	0.80	Ornamental	0.25	0	0.00
Library (Stacks Area)	~~1.10~~	0	0.00	0	0.00	1.00	0	0.00	0	0.00
Locker Room	0.45	0	0.00	0	0.00	0.45	0	0.00	0	0.00
Lounge, Breakroom, or Waiting Area	~~0.65~~	Ornamental	~~0.30~~	0	0.00	0.55	Ornamental	0.25	0	0.00
Main Entry Lobby	~~0.85~~	Ornamental	~~0.30~~	0	0.00	0.70	Ornamental	0.25	0	0.00
Museum Area (Exhibition/Display)	0.60	Accent, display and feature (Note 3)	~~0.50~~	0	0.00	0.60	Accent, display and feature (Note 3)	0.50	0	0.00
Museum Area (Restoration Room)	~~0.75~~	Detailed Task Work	~~0.20~~	0	0.00	0.70	Detailed Task Work	0.20	0	0.00

		(Note 7)					(Note 7)			
Office Area (<250 square feet)	~~0.70~~	Portable lighting for office areas (Note 6)	0.20	0	0.00	0.65	Portable lighting for office areas (Note 6)	0.20	0	0.00
Office Area (>250 square feet)	~~0.65~~	Portable lighting for office areas (Note 6)	0.20	0	0.00	0.60	Portable lighting for office areas (Note 6)	0.20	0	0.00
~~Office Area (Open plan office)~~	~~0.60~~	~~Portable lighting for office areas (Note 6)~~	~~0.20~~	~~0~~	~~0.00~~	~~0.60~~	~~Portable lighting for office areas (Note 6)~~	~~0.20~~	~~0~~	~~0.00~~
Parking Garage Area (Daylight Adaptation Zones)	0.50	0	0.00	0	0.00	1.00	0	0.00	0	0.00
~~Parking Garage Area (Dedicated Ramps)~~	~~0.25~~	~~0~~	~~0.00~~	~~0~~	~~0.00~~	~~0.25~~	~~0~~	~~0.00~~	~~0~~	~~0.00~~
Parking Garage Area (Parking Zone and Ramps)	0.10	~~First ATM (W)~~	100.00	~~Additional ATM (50 W each)~~	50.00	0.10	First ATM or ticket machine (W)	100.00	Additional ATM or ticket machine (50 W each)	50.00
Pharmacy Area	~~1.10~~	Specialized Task Work (Note 8)	0.35	0	0.00	1.00	Specialized Task Work (Note 8)	0.35	0	0.00
Religious Worship Area	0.95	Ornamental	~~0.30~~	0	0.00	0.95	Ornamental	0.25	0	0.00

Restrooms	0.65	Accent, display and feature (Note 3)	0.20	Decorative	0.15	0.65	Accent, display and feature (Note 3)	0.20	Decorative	0.15
Retail Sales Area (Fitting Room)	0.60	External Illuminated Mirror (Note5)	40.00	Internal Illuminated Mirror (Note 5)	120.00	0.60	External Illuminated Mirror (Note5)	40.00	Internal Illuminated Mirror (Note 5)	120.00
Retail Sales Area (Grocery Sales)	~~1.05~~	Accent, display and feature (Note 3)	0.20	Decorative	0.15	1.00	Accent, display and feature (Note 3)	0.20	Decorative	0.15
Retail Sales Area (Retail Merchandise Sales)	~~1.00~~	Accent, display and feature (Note 3)	0.20	Decorative	0.15	0.95	Accent, display and feature (Note 3)	0.20	Decorative	0.15
Scientific Laboratory Area	~~1.00~~	Specialized Task Work (Note 8)	0.35	0	0.00	0.90	Specialized Task Work (Note 8)	0.35	0	0.00
Sports Arena - Playing Area (> 5,000 Spectators)	2.25	0	0.00	0	0.00	2.25	0	0.00	0	0.00
Sports Arena - Playing Area (2,000 - 5,000 Spectators)	1.45	0	0.00	0	0.00	1.45	0	0.00	0	0.00
Sports Arena - Playing Area (< 2,000 Spectators)	1.10	0	0.00	0	0.00	1.10	0	0.00	0	0.00
Sports Arena - Playing Area (Recreational)	0.75	0	0.00	0	0.00	0.75	0	0.00	0	0.00
Stairwell	~~0.50~~	Accent, display and	0.20	Decorative (Note 4)	0.15	0.45	Accent, display and	0.20	Decorative (Note 4)	0.15

		feature (Note 3)					feature (Note 3)			
Theater Area (Motion Picture)	~~0.60~~	Ornamental	~~0.30~~	0	0.00	0.40	Ornamental	0.25	0	0.00
Theater Area (Performance)	~~1.00~~	Ornamental	~~0.30~~	0	0.00	0.80	Ornamental	0.25	0	0.00
Transportation Function (Baggage Area)	0.40	0	0.00	0	0.00	0.40	0	0.00	0	0.00
Transportation Function (Ticketing Area)	0.45	Accent, display and feature (Note 3)	0.20	0	0.00	0.45	Accent, display and feature (Note 3)	0.20	0	0.00
Unleased Tenant Area	0.60	0	0.00	0	0.00	0.60	0	0.00	0	0.00
Unoccupied-Exclude from Gross Floor Area	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
Unoccupied-Include in Gross Floor Area	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
Videoconferencing Studio	0.90	Videoconferencing	1.00	0	0.00	0.90	Videoconferencing	1.00	0	0.00
Aging Eye/Low-vision (Corridor Area)	~~0.80~~	Decorative (Note 4)	~~0.15~~	0	0.00	0.70	Decorative (Note 4)	0.15	0	0.00
Aging Eye/Low-vision (Dining)	0.80	Ornamental	0.30	0	0.00	0.80	Ornamental	0.30	0	0.00
Aging Eye/Low-vision (Lounge/Waiting Area)	~~0.75~~	Ornamental	0.30	0	0.00	0.80	Ornamental	0.30	0	0.00
Aging Eye/Low-vision (Main Entry Lobby)	0.85	Ornamental	0.30	Transition Lighting OFF at night (Note 12)	0.95	0.85	Ornamental	0.30	Transition Lighting OFF at night (Note 12)	0.95
Aging Eye/Low-vision	~~0.95~~	Ornamen	0.30	0	0.00	0.85	Ornamen	0.30	0	0.00

(Multipurpose Room)		tal					tal			
Aging Eye/Low-vision (Religious Worship Area)	1.00	Ornamen tal	0.30	0	0.00	1.00	Ornamen tal	0.30	0	0.00
Aging Eye/Low-vision (Restroom)	~~0.80~~	Accent, display and feature (Note 3)	0.20	0	0.00	1.00	Accent, display and feature (Note 3)	0.20	0	0.00
Aging Eye/Low-vision (Stairwell)	~~0.80~~	0	0.00	0	0.00	0.70	Accent, display and feature (Note 3)	0.20	0	0.00
All other	0.40	0	0.00	0	0.00	0.40	0	0.00	0	0.00
_Invalid from 2016 - Corridors, Restrooms, Stairs, and Support Areas	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
_Invalid from 2016 - Police Station and Fire Station	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
_Invalid from 2016 - Housing, Public and Common Areas: Multi-family, Dormitory	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
_Invalid from 2016 - Housing, Public and Common Areas: Senior Housing	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00

3.6.5 Title 24 Nonresidential User Compliance Manuals

Since the structure of the LPDs are not changing, changes to the Nonresidential Compliance Manual would be small. Some changes might be required in the examples so that correct allowed LPDs are used in the examples. Also given the proposed changes to the exempted lighting, there should be a discussion of these changes with an emphasis that horticultural lighting requirements are contained in Section 120.6.

3.6.6 Compliance Documents (Forms)

Compliance forms do not need to change as the format of the LPD standard is not changing, just the allowable values. For interactive forms, the allowed values would change to correspond with the adopted changes in LPDs.

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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 59. 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 60. 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: https://www.energy.ca.gov/title24/participation.html.

The construction forecast presents total floorspace of newly constructed buildings in 2023 by building type and climate zone. The building types included in the Energy Commissions' forecast are summarized in Table 59. 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, will remain constant. See Table 61 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

Multi-zone Occupancy Sensing in Large Offices Measure

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 62 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 63 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone.

The measure only generates savings to a specific space type—“large offices,” or offices with a floor area greater than 250 ft^2, within nonresidential buildings. The new construction forecast provided by the Energy Commission is at the building level and does not further differentiate the composition of spaces within each building type. To calculate the square footage that would be impacted by this measure, the Statewide CASE Team used the building models in the Database for Energy Efficiency Resources (DEER) to estimate the fraction of large offices within the impacted nonresidential building types. As explained in Section 2.3.1.7, the fraction of “open offices” in the DEER model for small and large office buildings was used as the fraction of large offices in these building types. For other building types, DEER provided a fraction of general office areas without distinguishing between office types. The Statewide CASE Team made a conservative assumption on the fraction of offices that are larger than 250 ft^2 within the general office areas as summarized in Table 13.

The measure’s applicability is not dependent on climate zones, and therefore, the same percentages of large office spaces within each building type were applied to all climate zones. These percentages were applied to all forecasted new construction for 2023. To estimate affected square footage of existing building stock (alterations), the Statewide CASE Team assumed a conversion to comply with the measure over a period of 15 years. In other words, only one-fifteenth of the existing building stock would be impacted by the proposed code change. Combining all the above assumptions, the Statewide CASE Team arrived at the resulting impacted percentage of floorspace, as shown in Table 62.

Lighting power densities measure

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 62 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 63 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone.

Table 59: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)											
	Small Office	Restaurant	Retail	Food	Non-Refrigerated Warehouse	Refrigerated Warehouse	School	College	Hospital	Hotel/ Motel	Large Office	TOTAL
1	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10
2	0.09	0.00	0.03	0.00	0.02	0.00	0.02	0.01	0.01	0.00	0.40	0.58
3	0.33	0.00	0.13	0.00	0.10	0.01	0.08	0.04	0.03	0.00	2.23	2.95
4	0.17	0.00	0.07	0.00	0.05	0.00	0.04	0.02	0.02	0.00	1.17	1.53
5	0.04	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.21	0.28
6	0.24	0.00	0.09	0.00	0.08	0.00	0.04	0.02	0.02	0.00	1.54	2.04
7	0.34	0.00	0.06	0.00	0.05	0.00	0.05	0.02	0.02	0.00	0.87	1.40
8	0.32	0.00	0.13	0.00	0.11	0.00	0.06	0.03	0.02	0.00	2.31	2.99
9	0.51	0.00	0.20	0.00	0.18	0.00	0.08	0.05	0.04	0.00	4.28	5.35
10	0.44	0.00	0.13	0.00	0.15	0.00	0.09	0.03	0.02	0.00	0.88	1.74
11	0.12	0.00	0.03	0.00	0.03	0.00	0.02	0.01	0.01	0.00	0.18	0.40
12	0.62	0.00	0.14	0.00	0.14	0.01	0.09	0.03	0.03	0.00	1.82	2.88
13	0.26	0.00	0.05	0.00	0.05	0.01	0.05	0.02	0.02	0.00	0.29	0.73
14	0.09	0.00	0.03	0.00	0.03	0.00	0.02	0.01	0.01	0.00	0.30	0.48
15	0.08	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.09	0.23
16	0.03	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.08	0.14
TOTAL	**3.69**	**0.00**	**1.13**	**0.00**	**1.04**	**0.04**	**0.68**	**0.29**	**0.25**	**0.00**	**16.70**	**23.82**

Table 60: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2023 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Climate Zone	Altered Floorspace in 2023 (Million Square Feet)											
	Small Office	Restaurant	Retail	Food	Non-Refrigerated Warehouse	Refrigerated Warehouse	School	College	Hospital	Hotel/ Motel	Large Office	TOTAL
1	0.05	0.21	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.31
2	0.29	1.26	0.00	0.08	0.00	0.06	0.00	0.07	0.03	0.02	0.00	1.82
3	1.04	6.91	0.00	0.36	0.00	0.29	0.02	0.29	0.14	0.11	0.00	9.14
4	0.52	3.61	0.00	0.18	0.00	0.15	0.01	0.15	0.07	0.05	0.00	4.74
5	0.12	0.66	0.00	0.04	0.00	0.03	0.00	0.03	0.01	0.01	0.00	0.90
6	0.77	4.67	0.00	0.29	0.00	0.26	0.01	0.20	0.09	0.06	0.00	6.34
7	1.02	3.03	0.00	0.21	0.00	0.15	0.00	0.15	0.07	0.06	0.00	4.69
8	1.01	6.92	0.00	0.41	0.00	0.37	0.01	0.27	0.12	0.09	0.00	9.21
9	1.58	12.20	0.00	0.64	0.00	0.57	0.02	0.41	0.22	0.16	0.00	15.79
10	1.44	3.13	0.00	0.46	0.00	0.53	0.01	0.32	0.11	0.08	0.00	6.09
11	0.35	0.60	0.00	0.08	0.00	0.09	0.01	0.08	0.03	0.02	0.00	1.25
12	1.72	5.53	0.00	0.41	0.00	0.38	0.02	0.33	0.12	0.12	0.00	8.63
13	0.78	0.87	0.00	0.17	0.00	0.14	0.02	0.18	0.06	0.05	0.00	2.27
14	0.28	0.95	0.00	0.10	0.00	0.11	0.00	0.07	0.03	0.02	0.00	1.57
15	0.27	0.30	0.00	0.06	0.00	0.08	0.00	0.04	0.01	0.01	0.00	0.78
16	0.11	0.24	0.00	0.03	0.00	0.03	0.00	0.03	0.01	0.01	0.00	0.46
TOTAL	11.33	51.10	0.00	3.53	0.00	3.25	0.13	2.63	1.12	0.89	0.00	73.98

Table 61: Example of Redistribution of Miscellaneous Category - 2023 New Construction in Climate Zone 1

Building Type	2020 Forecast (Million Square Feet) [A]	Distribution Excluding Miscellaneous Category [B]	Redistribution of Miscellaneous Category (Million Square Feet) [C] = B × [D = 0.145]	Revised 2020 Forecast (Million Square Feet) [E] = A + C
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	N/A	0.000	0.145
TOTAL	0.686	100%	0.147	0.83370

Table 62: Percent of Floorspace Impacted by Proposed Measure, by Building Type: Multi-Zone Occupancy Sensing in Large Offices

Building Type Building sub-type	Composition of Building Type by Subtypes[a]	Percent of Square Footage Impacted[b]	
		New Construction	Existing Building Stock (Alterations)[c]
Small Office	N/A	35.66%	2.38%
Restaurant	N/A	0%	0%
Retail	N/A	3.55%	0.24%
Stand-Alone Retail	10%	0%	0%
Large Retail	75%	4.18%	0.28%
Strip Mall	5%	0%	0%
Mixed-Use Retail	10%	4.14%	0.28%
Food	N/A	0%	0%
Non-Refrigerated Warehouse	N/A	3.47%	0.23%
Refrigerated Warehouse	N/A	2.54%	0.17%
Schools	N/A	5.45%	0.36%
Primary School	60%	5.61%	0.37%
Secondary School	40%	5.20%	0.35%
College	N/A	4.43%	0.30%
Community College	5%	4.88%	0.33%
University	15%	3.98%	0.27%
Hospital	N/A	2.73%	0.18%
Hotel/Motel	N/A	0%	0%
Offices	N/A	46.02%	3.07%
Medium Office	50%	46.02%	3.07%
Large Office	50%	46.02%	3.07%

a. 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.

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

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

Table 63: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone: Multi-Zone Occupancy Sensing in Large Offices

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	14.32%	0.99%
2	14.31%	0.99%
3	15.57%	1.07%
4	15.74%	1.08%
5	14.85%	1.04%
6	15.96%	1.01%
7	14.45%	1.00%
8	16.27%	1.02%
9	17.59%	1.08%
10	10.17%	0.67%
11	10.58%	0.71%
12	14.20%	0.95%
13	9.83%	0.65%
14	12.03%	0.76%
15	9.65%	0.63%
16	11.12%	0.71%

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

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

Greenhouse Gas emissions are calculated by multiplying natural gas and electricity consumption by precalculated greenhouse emission factors. Files containing these factors can be downloaded from the California Energy Commission website: https://www.energy.ca.gov/event/workshop/2020-03/staff-workshop-2022-energy-code-compliance-metrics. The file of interest is "2020 TDV Emissions Factor CH4 Leak 20yr 15RA."[23] For natural gas there is a single value for CO2 emission factors averaged over the period of interest and by building sector. The natural emission factors are constant over the course of the year and do not vary by climate zone. The natural gas emission factors are contained in the following table.

Table 64: Natural Gas GHG Emission Factors

Fuel Source	Metric Tons CO2e per Million Therms
Gas Res (30 Year)	5,847.5
Gas Non-Res (15 Year)	5,604.3
Gas Non-Res (30 Year)	5,286.5

The GHG emission factors for electricity vary by time of day and by climate zone. Electricity savings can be converted into annual GHG emissions reductions by multiplying hourly electricity savings results by the appropriate hourly factors which differ by period of analysis and climate zone.

Both natural gas and electricity GHG emission factors are built into the 2022 research versions of the California performance approach software CBECC-com and CBECC-res for nonresidential and residential buildings respectively. Both software report annual GHG emissions.

The assumptions underlying these emission factors are contained in the Final 2022 TDV Methodology report[24] available at the same web page.

[23] https://efiling.energy.ca.gov/getdocument.aspx?tn=233260

[24] https://efiling.energy.ca.gov/getdocument.aspx?tn=233345

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 the economywide GHG abatement cost. This total abatement cost includes both the cost of cap and trade and the additional costs associated with achieving the 80 percent reduction in GHG emission by 2050. This monetization is described in the Final 2022 TDV Methodology report. Though this monetization is embedded within in the TDV factors, it is not directly reported. The Statewide CASE Team has extracted these values and found that, over the 15 year period of analysis, the economic value of reduced GHG emissions is \$106/Metric Ton CO_2e.

Water Use and Water Quality Impacts Methodology

There are no impacts on water quality or water use expected from the proposed code change.

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

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

This proposal would require a more advanced controls for large offices that reduces the full load hours of operation. Additionally, this proposal would change the allowed LPD; up for some Primary FunctionAreas and down for others. This proposal would also add the Additional [lighting power density] Allowance for certain Qualified Lighting Systems, to the Area Category Method as contained Table 140.6-C. Thus, this proposal changes both the allowed installed lighting power and the hours of operation of the lighting system in the standard design. Since the controls requirements in Section 130.1(c) are mandatory, the hours of operation would apply to both the standard design and the proposed design. Additionally, since the base case would now have a more stringent controls baseline (occupancy sensing with a zone size no greater than 600 sf), the Power Adjustment Factors (PAFs) for occupancy sensors in large offices have to be reduced to better reflect the additional savings associated with small zone occupancy sensing controls. No software updates will be needed to reflect the multi-zone occupancy sensing in large offices measure other than the updated PAFs, as the measure is mandatory and thus would not be differentiating between the baseline and proposed designs.

Description of Software Change

Background Information for Software Change

The lighting simulation in Energy Plus is primarily a function of how much lighting power is in a space as modified by an hourly lighting schedule for M-F, Sat, Sun and holidays. Additionally, for 3 dimensional models, the lighting power is further impacted by the split flux models of daylighting which estimates a daylight illuminance at up to two daylight references sensors that "measure" horizontal illuminance at defined locations in rooms that have daylighting enabled. Besides tracking the energy consumption of electric lighting, the EnergyPlus simulation "kernel" to CBECC-Com includes the convective and radiant heat gains from lighting in the thermal simulation model. These lighting gains increase cooling loads and decrease cooling depending upon the heat balance in the space for a given time step.

Existing CBECC-Com Modeling Capabilities

CBECC-Com has all the required simulation capabilities to simulate the changes proposed for the large office small zone occupancy controls as well as for the LPD changes to the area category method of calculating allowed lighting power for the standard design.

Summary of Proposed Revisions to CBECC-Com

There are 4 changes that are needed to be made to the ACM to reflect the changes proposed here:

1. The PAFs for small zone occupancy controls zones in large offices currently has three bins of values for different size controls zones. Since this proposal would put an upper limit on the allowed zone sizes to 600 sf, the largest bin of occupancy sensor bin size (251 to 500 sf) would be eliminated as this zone controls is not significantly different from the proposed mandatory controls. Similarly, for the two remaining bins (126 to 250 sf and no greater than 125 sf), the PAFs are reduced as the base case would have a reduced number of operating hours.
2. The LPD proposal would change the values for the lighting power allowance variables *IntLPDReg, AllowArea1, AllowArea2*, that are function of the "SpaceBySpaceFuncType" in the "SpaceFunctionData" table in NR ACM Appendix 5.4A. *IntLPDReg* corresponds to the "allowed Lighting Power Density (W/sf)" in Area Category LPD Table 140.6-C. *AllowArea1, AllowArea2*, corresponds to the "Additional Lighting Power Allowances" In Area Category LPD Table 140.6-C .
3. LPD proposal would add some additional allowances to more SpacebySpace Function Types. As a result, besides changing values in the *AllowArea1, AllowArea2* columns of this table, this would add allowed lighting type descriptions for the additional allowance being added to the columns in the "SpaceFunctionData" table in NR ACM Appendix 5.4A representing variables *AllowType1* and *AllowType2*.

User Inputs to CBECC-Com

No changes are needed to the CBECC-Com inputs in regard to controls requirements. The changes to Section 130.1(c)6 for occupancy sensing in large offices greater than 250 sf are mandatory requirements and thus are not available to be traded off.

The lighting Power Adjustment Factors (PAFs) for very small occupancy sensor controls zones on large offices have changed and the largest bin of zone sizes has been eliminated. This largest bin (251 to 500 square feet) must be deleted from the inputs.

In regards to the changed LPDs in Section 140.6, the wattage inputs have not changed. However, the standard design wattages would be changed as reflected in Appendix 5.4A. However, for the additional allowances, a couple of these have been added for some of the space types and these would need to be added to Appendix 5.4A. under the variables :

- AllowType1
- AllowArea1
- AllowType2
- AllowArea2

Simulation Engine Inputs

EnergyPlus Inputs

This proposal does not change any of the EnergyPlus inputs, it changes only the default schedule for large offices, the general lighting LPDs and the additional lighting LPDs. This proposal also changes the small zone occupancy sensing in large offices Power Adjustment factors and criteria but does not change the rule set of the variables that are passed to the EnergyPlus simulation kernel.

Calculated Values, Fixed Values, and Limitations

This proposal does not change the rule sets associated with LPD, schedules or the use of Power Adjustment factors. This proposal only makes changes to the values that are in the existing lighting model structure.

Simulation Engine Output Variables

The proposed code change would not alter simulation engine output variables.

Compliance Report

The proposed code change would not alter the compliance report.

Compliance Verification

Code compliance for the multi-zone occupancy sensing in large offices would be verified using the updates to the acceptance test, updated compliance documents, and increased awareness of new mandatory controls requirements for both the plans examiner and building inspector. Detailed summaries of compliance details, barriers to compliance, and updates to market actor roles can be found in Section 2.1.5 and Appendix E. The lighting ATT will need to be trained on the updated acceptance test, for which language can be found in Section 2.6.3. The compliance documents NRCI-LTI-05-E, NRCC-LTI-E, and NRCA-LTI-02-A would need to be revised to modify the PAF values accordingly and add a part describing the additional functional testing procedures. More details can be found in Section 2.6.6. The plans examiner would need to be aware of the new mandatory control requirements, how they should be supported in NRCC forms and lighting design documents, and receive training updated to include new control requirements. The building inspector would similarly need to be made aware of the new mandatory control requirements and ATT verification requirements, such as the NRCA forms. The building inspector's training would also need to be updated accordingly.

Testing and Confirming CBECC-Com Modeling

The proposed code change would not alter any inputs or assumptions for testing and confirming CBECC-Com modeling.

Description of Changes to ACM Reference Manual

For the multi-zone sensing in large offices measure, the changes to the ACM Reference Manual can be found in Section 2.6.4. The only software associated with revisions to the standards would be updating the PAFs for the appropriate zone sizes and updated PAF values, as well as updating the language to refer to "office spaces greater than 250 square feet."

The Statewide CASE Team would modify Appendix 5-4A in the ACM Reference Manual to account for the updated LPD values. As described in Section 3.6.4, the Complete Building Method and the Area Category Method both reference the table in Appendix 5-4A so new values need to be inserted. Table 65 below includes the marked up language with the new values inserted. When the value of variable is changed, the 2019 column will have the value with strikethrough and in red font and the 2022 column will contain the variable value underlined and in red font. For variables where the value is not proposed to change, the values in the 2019 and 2022 columns will be the same and in black font. Please see Section 3.6.4 for additional information.

Table 65: Nonresidential ACM Appendix 5.4A Space by Spaces LPDs and Additional Allowances

TABLE SpaceFunctionData	**2019**	**2019**	**2019**	**2019**	**2019**	**2022**	**2022**	**2022**	**2022**	**2022**
FuncType	IntLPDReg	AllowType1	AllowArea1	AllowType2	AllowArea2	IntLPDReg	AllowType1	AllowArea1	AllowType2	AllowArea2
//SpaceBySpace	W/ft²		W/ft²		W/ft²	W/ft²		W/ft²		W/ft²
Audience Seating Area	~~0.60~~	Ornamental	~~0.30~~	0	0.00	0.50	Ornamental	0.25	0	0.00
Auditorium Area	0.70	Ornamental	~~0.30~~	Accent, display and feature (Note 3)	0.20	0.70	Ornamental	0.25	Accent, display and feature (Note 3)	0.20
Auto Repair / Maintenance Area	~~0.55~~	Detailed Task Work (Note 7)	0.20	0	0.00	0.50	Detailed Task Work (Note 7)	0.20	0	0.00
Barber, Beauty Salon, Spa Treatment Area	~~0.80~~	Detailed Task Work (Note 7)	0.20	Ornamental	~~0.30~~	0.65	Detailed Task Work (Note 7)	0.20	Ornamental	0.30
Civic Meeting Place Area	~~1.00~~	Ornamental	~~0.30~~	0	0.00	0.90	Ornamental	0.30	0	0.00
Classroom, Lecture, Training, Vocational Areas	~~0.70~~	White or Chalk Boar	4.50	0	0.00	0.60	White or Chalk Boar	7.00	0	0.00

		d (W/ft) (Note 1)					d (W/ft) (Note 1)			
Commercial/Industrial Storage (Refrigerated)	0.45	0	0.00	0	0.00	0.40	0	0.00	0	0.00
Commercial/Industrial Storage (Shipping & Handling)	0.60	0	0.00	0	0.00	0.60	0	0.00	0	0.00
Commercial/Industrial Storage (Warehouse)	0.45	0	0.00	0	0.00	0.40	0	0.00	0	0.00
Computer Room	0.50	0	0.00	0	0.00	0.50	0	0.00	0	0.00
Concourse and Atria Area	~~0.90~~	Ornamental	~~0.30~~	0	0.00	0.60	Ornamental	0.30	0	0.00
Convention, Conference, Multipurpose and Meeting Area	~~0.85~~	Ornamental	~~0.30~~	0	0.00	0.75	Ornamental	0.30	0	0.00
Copy Room	0.50	0	0.00	0	0.00	0.50	0	0.00	0	0.00
Corridor Area	~~0.60~~	0	0.00	0	0.00	0.45	0	0.00	0	0.00
Dining Area (Bar/Lounge and Fine Dining)	~~0.55~~	Ornamental	~~0.30~~	0	0.00	0.35	Accent display, feature	0.20	Decorative	0.15
Dining Area (Cafeteria/Fast Food)	~~0.40~~	Ornamental	~~0.30~~	0	0.00	0.45	Ornamental	0.25	0	0.00
Dining Area (Family and Leisure)	~~0.50~~	Ornamental	~~0.30~~	0	0.00	0.40	Ornamental	0.25	0	0.00
Electrical, Mechanical, Telephone Rooms	0.40	Detailed Task	0.20	0	0.00	0.40	Detailed Task	0.20	0	0.00

		Work (Note 7)					Work (Note 7)			
Exercise/Fitness Center and Gymnasium Areas	0.50	0	0.00	0	0.00	0.50	0	0.00	0	0.00
Financial Transaction Area	~~0.80~~	Ornamental	~~0.30~~	0	0.00	0.70	Ornamental	0.25	0	0.00
Manufacturing ~~General~~/Commercial & Industrial Work Area (High Bay)	0.65	Detailed Task Work (Note 7)	0.20	0	0.00	0.65	Detailed Task Work (Note 7)	0.20	0	0.00
Manufacturing ~~General~~/Commercial & Industrial Work Area (Low Bay)	0.60	Detailed Task Work (Note 7)	0.20	0	0.00	0.60	Detailed Task Work (Note 7)	0.20	0	0.00
Manufacturing ~~General~~/Commercial & Industrial Work Area (Precision)	0.85	Precision Work (Note 9)	0.70	0	0.00	0.85	Precision Work (Note 9)	0.70	0	0.00
Healthcare Facility and Hospitals (Exam/Treatment Room)	1.15	0	0.00	0	0.00	1.15	0	0.00	0	0.00
Healthcare Facility and Hospitals (Imaging Room)	~~1.00~~	0	0.00	0	0.00	0.60	Accent display and feature	0.20	Tunable white or dim-to-warm (Note 10)	0.10
Healthcare Facility and Hospitals (Medical Supply	0.55	0	0.00	0	0.00	0.55	0	0.00	0	0.00

Room)										
Healthcare Facility and Hospitals (Nursery)	~~0.95~~	Tunable white or dim-to-warm (Note 10)	0.10	0	0.00	0.80	Tunable white or dim-to-warm (Note 10)	0.10	0	0.00
Healthcare Facility and Hospitals (Nurse's Station)	~~0.75~~	Tunable white or dim-to-warm (Note 10)	0.10	0	0.00	0.85	Tunable white or dim-to-warm (Note 10)	0.10	Specialized task work (Note 8)	0.20
Healthcare Facility and Hospitals (Operating Room)	1.90	0	0.00	0	0.00	1.90	0	0.00	0	0.00
Healthcare Facility and Hospitals (Patient Room)	~~0.55~~	Decorative	0.15	Tunable white or dim-to-warm (Note 10)	0.10	0.70	Decorative	0.15	Tunable white or dim-to-warm (Note 10)	0.10
Healthcare Facility and Hospitals (Physical Therapy Room)	~~0.85~~	Tunable white or dim-to-warm (Not	0.10	0	0.00	0.75	Tunable white or dim-to-warm (Not	0.10	0	0.00

		e 10)					e 10)			
Healthcare Facility and Hospitals (Recovery Room)	0.90	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00	0.90	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00
High-Rise Residential Living Spaces	na	0	0.00	0	0.00	na	0	0.00	0	0.00
Hotel Function Area	0.85	Ornamental	~~0.30~~	0	0.00	0.85	Ornamental	0.25	0	0.00
Hotel/Motel Guest Room	na	0	0.00	0	0.00	na	0	0.00	0	0.00
Kitchen/Food Preparation Area	0.95	0	0.00	0	0.00	0.95	0	0.00	0	0.00
Kitchenette or Residential Kitchen	0.95	0	0.00	0	0.00	0.95	0	0.00	0	0.00
Laundry Area	0.45	0	0.00	0	0.00	0.45	0	0.00	0	0.00
Library (Reading Area)	0.80	Ornamental	~~0.30~~	0	0.00	0.80	Ornamental	0.25	0	0.00
Library (Stacks Area)	~~1.10~~	0	0.00	0	0.00	1.00	0	0.00	0	0.00
Locker Room	0.45	0	0.00	0	0.00	0.45	0	0.00	0	0.00
Lounge, Breakroom, or Waiting Area	~~0.65~~	Ornamental	~~0.30~~	0	0.00	0.55	Ornamental	0.25	0	0.00
Main Entry Lobby	~~0.85~~	Ornamental	~~0.30~~	0	0.00	0.70	Ornamental	0.25	0	0.00
Museum Area (Exhibition/Display)	0.60	Accent, displ	~~0.50~~	0	0.00	0.60	Accent, displ	0.50	0	0.00

		ay and feature (Note 3)					ay and feature (Note 3)			
Museum Area (Restoration Room)	~~0.75~~	Detailed Task Work (Note 7)	~~0.20~~	0	0.00	<u>0.70</u>	Detailed Task Work (Note 7)	0.20	0	0.00
Office Area (<250 square feet)	~~0.70~~	Portable lighting for office areas (Note 6)	0.20	0	0.00	<u>0.65</u>	Portable lighting for office areas (Note 6)	0.20	0	0.00
Office Area (>250 square feet)	~~0.65~~	Portable lighting for office areas (Note 6)	0.20	0	0.00	<u>0.60</u>	Portable lighting for office areas (Note 6)	0.20	0	0.00
~~Office Area (Open plan office)~~	~~0.60~~	~~Portable lighting for office areas (Note 6)~~	~~0.20~~	~~0~~	~~0.00~~	~~0.60~~	~~Portable lighting for office areas (Note 6)~~	~~0.20~~	~~0~~	~~0.00~~
Parking Garage Area (Daylight Adaptation Zones)	0.50	0	0.00	0	0.00	<u>1.00</u>	0	0.00	0	0.00
~~Parking Garage~~	~~0.2~~	~~0~~	~~0.00~~	~~0~~	~~0.00~~	~~0.25~~	~~0~~	~~0.00~~	~~0~~	~~0.00~~

~~Area (Dedicated Ramps)~~	~~5~~									
Parking Garage Area (Parking Zone and Ramps)	0.10	~~First ATM (W)~~	100.00	~~Additional ATM (50 W each)~~	50.00	0.10	First ATM or ticket machine (W)	100.00	Additional ATM or ticket machine (50 W each)	50.00
Pharmacy Area	~~1.10~~	Specialized Task Work (Note 8)	0.35	0	0.00	1.00	Specialized Task Work (Note 8)	0.35	0	0.00
Religious Worship Area	0.95	Ornamental	~~0.30~~	0	0.00	0.95	Ornamental	0.25	0	0.00
Restrooms	0.65	Accent, display and feature (Note 3)	0.20	Decorative	0.15	0.65	Accent, display and feature (Note 3)	0.20	Decorative	0.15
Retail Sales Area (Fitting Room)	0.60	External Illuminated Mirror (Note5)	40.00	Internal Illuminated Mirror (Note 5)	120.00	0.60	External Illuminated Mirror (Note5)	40.00	Internal Illuminated Mirror (Note 5)	120.00
Retail Sales Area (Grocery Sales)	~~1.05~~	Accent, displ	0.20	Decorative	0.15	1.00	Accent, displ	0.20	Decorative	0.15

		ay and feature (Note 3)					ay and feature (Note 3)			
Retail Sales Area (Retail Merchandise Sales)	~~1.00~~	Accent, display and feature (Note 3)	0.20	Decorative	0.15	0.95	Accent, display and feature (Note 3)	0.20	Decorative	0.15
Scientific Laboratory Area	~~1.00~~	Specialized Task Work (Note 8)	0.35	0	0.00	0.90	Specialized Task Work (Note 8)	0.35	0	0.00
Sports Arena - Playing Area (> 5,000 Spectators)	2.25	0	0.00	0	0.00	2.25	0	0.00	0	0.00
Sports Arena - Playing Area (2,000 - 5,000 Spectators)	1.45	0	0.00	0	0.00	1.45	0	0.00	0	0.00
Sports Arena - Playing Area (< 2,000 Spectators)	1.10	0	0.00	0	0.00	1.10	0	0.00	0	0.00
Sports Arena - Playing Area (Recreational)	0.75	0	0.00	0	0.00	0.75	0	0.00	0	0.00
Stairwell	~~0.50~~	Accent, display and feature (Note 3)	0.20	Decorative (Note 4)	0.15	0.45	Accent, display and feature (Note 3)	0.20	Decorative (Note 4)	0.15

Theater Area (Motion Picture)	~~0.60~~	Ornamental	~~0.30~~	0	0.00	0.40	Ornamental	0.25	0	0.00
Theater Area (Performance)	~~1.00~~	Ornamental	~~0.30~~	0	0.00	0.80	Ornamental	0.25	0	0.00
Transportation Function (Baggage Area)	0.40	0	0.00	0	0.00	0.40	0	0.00	0	0.00
Transportation Function (Ticketing Area)	0.45	Accent, display and feature (Note 3)	0.20	0	0.00	0.45	Accent, display and feature (Note 3)	0.20	0	0.00
Unleased Tenant Area	0.60	0	0.00	0	0.00	0.60	0	0.00	0	0.00
Unoccupied-Exclude from Gross Floor Area	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
Unoccupied-Include in Gross Floor Area	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
Videoconferencing Studio	0.90	Videoconferencing	1.00	0	0.00	0.90	Videoconferencing	1.00	0	0.00
Aging Eye/Low-vision (Corridor Area)	~~0.80~~	Decorative (Note 4)	~~0.15~~	0	0.00	0.70	Decorative (Note 4)	0.15	0	0.00
Aging Eye/Low-vision (Dining)	0.80	Ornamental	0.30	0	0.00	0.80	Ornamental	0.30	0	0.00
Aging Eye/Low-vision (Lounge/Waiting Area)	~~0.75~~	Ornamental	0.30	0	0.00	0.80	Ornamental	0.30	0	0.00

Aging Eye/Low-vision (Main Entry Lobby)	0.85	Ornamental	0.30	Transition Lighting OFF at night (Note 12)	0.95	0.85	Ornamental	0.30	Transition Lighting OFF at night (Note 12)	0.95
Aging Eye/Low-vision (Multipurpose Room)	~~0.95~~	Ornamental	0.30	0	0.00	0.85	Ornamental	0.30	0	0.00
Aging Eye/Low-vision (Religious Worship Area)	1.00	Ornamental	0.30	0	0.00	1.00	Ornamental	0.30	0	0.00
Aging Eye/Low-vision (Restroom)	~~0.80~~	Accent, display and feature (Note 3)	0.20	0	0.00	1.00	Accent, display and feature (Note 3)	0.20	0	0.00
Aging Eye/Low-vision (Stairwell)	~~0.80~~	0	0.00	0	0.00	0.70	Accent, display and feature (Note 3)	0.20	0	0.00
All other	0.40	0	0.00	0	0.00	0.40	0	0.00	0	0.00
_Invalid from 2016 - Corridors, Restrooms, Stairs, and Support Areas	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
_Invalid from 2016 - Police Station and Fire Station	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00

_Invalid from 2016 - Housing, Public and Common Areas: Multi-family, Dormitory	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00
_Invalid from 2016 - Housing, Public and Common Areas: Senior Housing	0.00	0	0.00	0	0.00	0.00	0	0.00	0	0.00

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 2.1.5 and Section 3.1.5 could impact various market actors. Table 66 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 workflow, and ways negative impacts could be mitigated. The information contained in Table 66 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.

Multi-zone Occupancy Sensing in Large Offices

As shown in Table 90 below, the proposed compliance process would alter the workflow for most involved market actors. Some key changes include documenting compliance with the new requirement for both lighting designers and energy consultants; new equipment, training, and testing, for the controls contractors, and new testing protocols for the ATTs. Increased coordination among lighting designers, mechanical engineers/designers, energy consultants, controls contractors, and both lighting and mechanical ATTs would be important to minimize negative impacts of the compliance requirement (Sagehorn 2020). Currently, these market actors do not often coordinate. Conversations with a few California lighting designers and the Compliance Improvement Team revealed that earlier communication between both lighting and mechanical designers as well as energy consultants and controls contractors would reduce issues further along in the building and compliance process.

The proposed compliance process would likely require more time for functional testing completed by lighting ATTs, training for controls contractors, and modifications to existing documents as described in Section 2.6.6. Plans examiners' and building inspectors' roles and responsibilities are unlikely to change significantly in response to the proposed code change.

Lighting Power Densities

Proposed changes to LPDs for the Complete Building Method, The Area category Method and Tailored Method are changing the values of the lighting power allowances but do not change the structure of the allowances or how they are enforced. Thus, this proposal does not change the workflow for market actors outside of being acquainted with the new lighting power allowance values.

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Table 66: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Workflow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Lighting Designer	• Identify relevant requirements and/or compliance path. • Perform required calculations by space to confirm compliance or use energy consultant. • Coordinate design with other team members (HVAC & modeler). • Provides control narrative specifying the sequence of operation of occupancy sensors in the large office area and the actual or virtual connection between each occupancy sensor and the luminaire it controls. • Complete compliance document for permit application or use energy consultant. • Review submittals during construction. • Coordinate with	• Quickly and easily determine requirements based on scope. • Demonstrate compliance with calculations required for other design tasks. • Streamlined coordination with other team members. • Clearly communicate system requirements to contractors. • Quickly complete compliance documents or use energy consultant. • Easily identify non-compliant substitutions. • Minimize coordination during construction.	• Would need to document compliance with new requirement, as not currently being documented (large office occupancy sensors). • Lowered LPDs may dictate alterative lighting fixture selections or using alternative compliance pathways (such as tailored or performance).	• Proposed documentation methodology uses materials already produced as part of the design/construction process. No additional documentation necessary. • Modeling software would need to be updated to include proposed values. Software training updates would need to occur. • NRCC forms would need to be updated with new requirement. • Coordinate with mechanical designers or engineers and potentially controls contractor on the controls for large offices.

	commissioning agent or Acceptance Test Technician (ATT) as necessary.			
Energy Consultant	Support design team to provide guidance on energy code requirements on methods to show compliance.	Utilize compliance method determined by team to be the best method for the project and complete compliance documentation (certificate of compliance NRCC).	• Would need to document compliance with new requirement; not currently being documented (large office occupancy sensors). • Lowered LPDs may dictate alterative lighting fixture selections or using alternative compliance pathways (such as tailored or performance).	• Modeling software would need to be updated to include proposed values. Software training updates would need to occur. • NRCC forms would need to be updated with new requirements.
Controls Contractor	• Bid and install building features per the design documents (e.g., plan set, specifications, compliance documents, etc.). • Install and warranty work. • Provide certificate of installation compliance documents (NRCI) to support installed features meet the promise of the plan set/specifications/compliance documents (NRCC) • Coordinate acceptance testing of installed controls with ATT.	• Install and document lighting system as meeting mandatory requirements. • Develop NRCC compliance documents for permit submittal.	• New mandatory controls would require additional equipment, training, and testing to be successful. • Be able to support user experience with installed controls.	• Update NRCA testing criteria. • Coordinate with lighting and mechanical designers/engineers, as well as both lighting and mechanical ATTs on how the controls need to be programmed.

ATT	Verify installed controls are working per the testing criteria as supported by the certificate of acceptance (NRCA) and communicate with installing contractor if there are any “failed” controls.	Test and document installed controls are working properly.	New testing protocols would be required for controls.	• Update NRCA testing criteria. • Lighting ATT coordinate with mechanical ATT. • If commissioning is triggered, commissioning agent would work with controls contractor, mechanical contractor, lighting ATTs, and mechanical ATTs.
Plans Examiner	Confirm that plan set and compliance documents are supporting each other and that compliance is achieved.	Provide building permit and ensure supporting code requirements have been met with design documents.	Be aware of mandatory control requirements and how they should be supported in NRCC forms and in lighting design documents.	Update training to include all new control requirements.
Building Inspector	• Confirm building is meeting plan set, specifications, and/or compliance documents. • Confirm NRCI and NRCA compliance documents have been completed and made available to building owner.	Confirm controls and lighting systems are installed per the Energy Code requirements, and the NRCC/design set approved for building permit.	Be aware of new mandatory control requirements and ATT verification requirements (NRCA forms).	Update training to include all new control requirements.

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. Public stakeholders provide valuable feedback on draft analyses and help 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 provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

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 asks 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 nonresidential indoor lighting via webinar. The LPDs measure was included at both stakeholder meetings, and the multi-zone occupancy sensing in large offices measure was included at the first stakeholder meeting. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting, such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential Indoor Lighting Utility-Sponsored Stakeholder Meeting	September 12, 2019	https://title24stakeholders.com/event/nonresidential-indoor-lighting-utility-sponsored-stakeholder-meeting/
Second Round of Nonresidential Indoor Lighting Utility-Sponsored Stakeholder Meeting	March 3, 2020	https://title24stakeholders.com/event/lighting-utility-sponsored-stakeholder-meeting-2/

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 objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. 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 April 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. 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 (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 personal outreach to stakeholders identified in initial work plans who had not yet opted into 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, by phone, and in-person interviews with numerous stakeholders when developing this report.

Multi-zone Occupancy Sensing in Large Offices Communications

The Statewide CASE Team worked with a variety of stakeholders while developing this measure. Throughout 2019 and 2020, the Statewide CASE Team engaged repeatedly with four contractor organizations, three manufacturing companies, four sales representative organizations, and two design firms, as well two meetings with IALD. The manufacturing companies represent a large share of the occupancy control market and provide different niche services within the available implementation strategies for the proposed code change. Two of the sales representative organizations who participated in outreach represent two of the four largest sales representative agencies in the Bay Area. Their roles are significant due to their involvement in each stage of the design, construction, procurement, and installation process.

During the first round of outreach with these stakeholders, the Statewide CASE Team used a survey script, found in Appendix G, with specific questions based on industry role. Conversations usually lasted between 30 minutes and an hour. The information collected included current design practices, product selection, market barriers, cost estimates, perceived issues with the proposed code change, and a discussion of the potential impact on market actors based on the proposed code change. Cost estimates were then compiled into a spread sheet and stakeholders were contacted to clarify any confusion and provide any outstanding data.

A second round of outreach occurred with sensor and lighting controls distributors to gain further insight into accurate cost data. This was simply gathering product costs and using those to inform the incremental first cost analysis.

The Statewide CASE Team is currently conducting a third round of outreach with lighting representatives, controls sales representatives, and an electrical engineer to verify reasonable assumptions were made in incremental first cost design methodology and actual cost estimates, which in turn affect cost effectiveness. Preliminary results and data are included in Sections 4.1.1.1 through 4.1.1.3. The Statewide CASE Team will update the Final CASE Report based on this ongoing outreach.

Lighting Power Densities Communications

The Statewide CASE Team contacted stakeholders with experience and interest with a focus on lighting while developing this sub measure throughout 2019 and 2020. Specifically, the Statewide CASE Team engaged with lighting manufactures, lighting rep agencies and other parties both through phone interviews, internet searches and analysis as well as on-site interviews at trade shows and lighting workshops. Topics of discussion and data collected was as follows:

- Trends in luminaire performance and from factor preference by end users (designer, owners, etc.)
    - Overall performance of current luminaires versus those of 2 to 3 years ago
    - Efficacy differences between 80 CRI and 90 CRI products
    - Which downlight form factors are most popular with specifiers?
    - Which LED products are the top sellers?
    - What percentage of your sales purchase are LED versus legacy sources?
- Cost of current LED Luminaires versus legacy product and earlier generation LED product.
    - Overall cost of current luminaires versus those of 2 to 3 years ago
    - Cost differential between 80 CRI and 90 CRI products
    - Cost differential for color-tune and dim to warm product versus static product

Manufacturers, Lighting Agencies and other parties interviewed, and web searches is recapped as follows:

- Telephone Interviews
    - Two lighting comagmatic manufactures with multi-brand product offerings (representing over 100 brands)
    - Three independent manufactures specializing in downlighting and architectural and specialty lighting products
    - Three lighting rep agencies (representing over 400 manufacture brands)
- LightFair 2019, Lightshow West and IES LA 2020 Product Show
    - Four lighting comagmatic manufactures with multi-brand product offerings (representing over 150 brands)
    - Twelve independent manufactures specializing in downlighting and architectural and specialty lighting products
    - Five lighting rep agencies (representing over 600 manufacture brands)
- Online (internet website) searches on-line sales and distribution
    - Lamps Plus
    - Graybar
    - Grainger

- 1000 Bulbs
- Lumens Com
- Wayfair
- Home Depot
- Lowes
- Lights Online
- Lighting Supply com

Data for luminaire performance pricing (cost) information and analysis presented in the lighting component of this Draft Case Report were collected, evaluated and disseminated into the tables and other materials in part through the fact finding from and support of the stakeholders defined in the above listed resources.

Other Outreach Mechanisms

Meeting with International Association of Lighting Designers (IALD) & Illuminating Engineering Society (IES)

The Statewide CASE Team met with representatives from IALD and IES on January 7, 2020. Meeting notes and a spreadsheet of follow-up action items were distributed to all meeting attendees afterwards.

Concerns with the multi-zone occupancy sensing in large office measure included:

- Potential aesthetic issue if one person is still in the office while the rest of the office lights are off or dim.
- Sense of safety at night with proposed code change.

The follow-up requests made by the Statewide CASE Team to the IES and IALD representatives for the measure included:

- Seeking contacts in Illinois, Maryland, Nevada, and/or Utah who have designed or have experience with the open plan offices in 2018 IECC compliant projects.
- Connecting with lighting designers involved in the design of the similar measure in 2018 IECC via the IALD Public Policy Coordinator.
- Looking for input to determine how to implement occupancy sensing scenarios in the code and supporting good design.
- Seeking data on usage of the existing Title 24, Part 6 relevant PAFs. What is the experience designing this, the perception of the implementation, and feedback on control zone size limits?
- Seeking information on potential limitations of using PIR sensors in small zones. Can dual technology be used wirelessly?

- Seeking input on requirements for retrofit cases.

2021 IECC Committee Engagement

The Statewide CASE Team connected with three lighting designers with expertise and involvement with developments of the 2018 IECC, via email. The initial engagement was to gather their experience designing the similar measure in the 2018 IECC. The follow-up discussion was around the proposed code change and the use of “all lighting” versus “general lighting” in the 2018 IECC. The Statewide CASE Team received feedback that:

- The sequence and interaction between multi-zone occupancy sensing control and automatic daylighting control would need to be clearly specified as the functional requirements in the code language.
- There should be no issue expanding from “general lighting” to “all lighting” in Title 24, Part 6, unless to avoid a conflict such as furniture-mounted task lighting. If so, this these lights should be exempted from the code since most designs include occupancy sensors for them.

Cost Effectiveness Verification for Multi-Zone Occupancy Sensing in Large Offices

4.1.1.1 Data from Lighting Representative Incremental First Cost Estimate

A lighting representative in California provided an estimate for the incremental first cost averaged across multiple vendors and implementation methods. The calculation includes four different 2019 Title 24, Part 6 compliant wired and wireless time-switch control implementations for the baseline scenario. There are eight different proposed 2022 Title 24, Part 6 compliant wired and wireless multi-zone occupancy sensing control solutions for the proposed case. The estimate includes product and labor costs for both install and start-up, and is representative of both fixture level and zone-based solutions. The labor estimate does not include additional design hours.

Table 67: Title 24, Part 6 Baseline Case Implementation (Time-Switch)

Large Office Square Footage (ft^2)	Total Cost per Square Foot ($\$/ft^2$)	Average Total Product Cost ($)	Average Total Labor Cost ($)	Total Cost ($)
10,000	$0.99	$4,102.50	$5,760.00	$9,862.50
7,540	$1.28	$4,048.75	$5,599.69	$9,648.44
4,000	$2.12	$3,470.00	$5,000.63	$8,470.63
2,584	$2.88	$2,822.50	$4,629.38	$7,451.88

Table 68: Title 24, Part 6 Proposed Case Implementation

Large Office Square Footage (ft^2)	Total Cost per Square Foot ($/$ft^2$)	Average Total Product Cost ($)	Average Total Labor Cost ($)	Total Cost ($)
10,000	$1.64	$8,211.88	$8,181.56	$16,393.44
7,540	$1.93	$7,092.50	$7,434.84	$14,527.34
4,000	$2.75	$5,145.00	$5,835.94	$10,980.94
2,584	$3.70	$4,225.63	$5,346.56	$9,572.19

Table 69: Incremental First Measure Cost Per Square Foot

Large Office Square Footage (ft^2)	Incremental Cost per Square Foot ($/$ft^2$)
10,000	$0.65
7,540	$0.65
4,000	$0.63
2,584	$0.82
Average	**$0.69**

4.1.1.2 Data from Lighting Representative Wired and Wireless Data

A lighting representative in California provided an estimate breaking down the incremental first measure costs between wired and wireless solutions, which have a 50/50 market distribution, according to this stakeholder. The lighting representative estimated three wired solutions from multiple vendors and five wireless solutions (with batteries) from multiple vendors. These solutions represented both fixture level and zone-based solutions. The product and labor costs include install and start-up. See Section 2.4.5.1.2 for more details.

Table 70: 2022 Projected Costs Representing About 50 Percent Wired Solution Market Preference

Large Office Square Footage (ft^2)	Total Cost per Square Foot ($/$ft^2$)	Average Total Product Cost ($)	Average Total Labor Cost ($)	Total Cost ($)
10,000	$1.84	$7,826.67	$10,622.92	$18,449.58
7,540	$2.18	$6,753.33	$9,711.67	$16,465.00
4,000	$3.06	$4,880.00	$7,349.17	$12,229.17
2,584	$4.06	$4,148.33	$6,347.92	$10,496.25

Table 71: 2022 Projected Costs Representing About 50 Percent Wireless Solution Market Preference

Large Office Square Footage (ft^2)	Total Cost per Square Foot ($\$/ft^2$)	Average Total Product Cost ($)	Average Total Labor Cost ($)	Total Cost ($)
10,000	$1.52	$8,443.00	$6,716.75	$15,159.75
7,540	$1.77	$7,296.00	$6,068.75	$13,364.75
4,000	$2.56	$5,304.00	$4,928.00	$10,232.00
2,584	$3.49	$4,272.00	$4,745.75	$9,017.75

Table 72: Percent Cost Savings for Installed Wireless Systems

Large Office Square Footage (ft^2)	Total Cost Savings per Square Foot	Average Total Product Cost	Average Total Labor Cost	Total Cost
10,000	17.83%	-7.87%	36.77%	17.83%
7,540	18.83%	-8.04%	37.51%	18.83%
4,000	16.33%	-8.69%	32.94%	16.33%
2,584	14.09%	-2.98%	25.24%	14.09%
	Average	**-6.89%**	**33.12%**	**16.77%**

4.1.1.3 Data from Lighting Representative Equipment and Programming Incremental First Cost

A lighting representative in California provided an estimate using fixture embedded controls for Model Office A and external wireless battery powered controls for Model Offices B and C. This lighting representative determined that this was the most cost effective implementation to meet the proposed code change. The estimate did not include labor rates, however it did provide a scaling factor that labor rate savings from wired to wireless controls for all solutions would be reduced by 25 percent.

Table 73: Cost Components for Estimate

Cost Component	Cost Per Unit ($)	Unit
Wireless Switch	$65.00	$/hour
Embedded Control in Fixture	$42.00	$/hour
Wireless Switch	$100.00	$/1’
External Wireless Sensor	$190.00	$/item

External Wireless Relay	$143.00	$/item
Embedded Control in Fixture	$45.00	$/item
Time-Switch	$600.00	$/item
External Relay	$130.00	$/25'
Wired Switch	$145.00	$/unit
Programming (Full Day)	$1,500.00	$/day
Programming (Half Day)	$800.00	$/half day

Table 74: Base Case Equipment and Programing First Cost for Time-Switch Implementation – Model Office A

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Time-Switch	$600.00	1	$600.00
External Relay	$130.00	1	$130.00
Wired Switch	$145.00	1	$145.00
Programming (Half Day)	$800.00	1	$800.00
Total Project Cost	**N/A**	**N/A**	**$1,675.00**

Table 75: Base Case Equipment and Programing First Cost for Time-Switch Implementation – Model Office B

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Time-Switch	$600.00	1	$600.00
External Relay	$130.00	1	$130.00
Wired Switch	$145.00	1	$145.00
Programming (Full Day)	$1,500.00	1	$1,500.00
Total Project Cost	**N/A**	**N/A**	**$2,375.00**

Table 76: Base Case Equipment and Programing First Cost for Time-Switch Implementation – Model Office C

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Time-Switch	$600.00	1	$600.00
External Relay	$130.00	2	$260.00
Wired Switch	$145.00	1	$145.00
Programming (Full Day)	$1,500.00	1	$1,500.00
Total Project Cost	**N/A**	**N/A**	**$2,505.00**

Table 77: Base Case Equipment and Programing First Cost for Occupancy Sensor Implementation – Model Office A

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Wireless Switch	$65.00	1	$65.00
Embedded Control in Fixture	$42.00	28	$1,176.00
Programming (Half Day)	$800.00	1	$800.00
Total Project Cost	**N/A**	**N/A**	**$2,041.00**

Table 78: Base Case Equipment and Programing First Cost for Occupancy Sensor Implementation – Model Office B

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Wireless Switch	$100.00	1	$100.00
External Wireless Sensor	$190.00	7	$1,330.00
External Wireless Relay	$143.00	1	$143.00
Programming (Full Day)	$1,500.00	1	$1,500.00
Total Project Cost	**N/A**	**N/A**	**$3,073.00**

Table 79: Base Case Equipment and Programing First Cost for Occupancy Sensor Implementation – Model Office C

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Wireless Switch	$100.00	1	$100.00
External Wireless Sensor	$190.00	13	$2,470.00
External Wireless Relay	$143.00	2	$286.00
Programming (Full Day)	$1,500.00	1	$1,500.00
Total Project Cost	**N/A**	**N/A**	**$4,356.00**

Table 80: Proposed Case Equipment and Programing First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office A

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Wireless Switch	$65.00	1	$65.00
Embedded Control in Fixture	$42.00	28	$1,176.00
Programming (Half Day)	$800.00	1	$800.00
Total Project Cost	**N/A**	**N/A**	**$2,041.00**

Table 81: Proposed Case Equipment and Programing First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office B

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Wireless Switch	$100.00	1	$100.00
External Wireless Sensor	$190.00	7	$1,330.00
External Wireless Relay	$143.00	7	$1,001.00
Programming (Full Day)	$1,500.00	1	$1,500.00
Total Project Cost	**N/A**	**N/A**	**$3,931.00**

Table 82: Proposed Case Equipment and Programing First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office C

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
Wireless Switch	$100.00	1	$100.00
External Wireless Sensor	$190.00	13	$2,470.00
External Wireless Relay	$143.00	13	$1,859.00
Programming (Full Day)	$1,500.00	1	$1,500.00
Total Project Cost	**N/A**	**N/A**	**$5,929.00**

Appendix G: Multi-zone Occupancy Sensing in Large Office Outreach Survey Scripts and Results

Proposed Code Change General Outreach

Details of who participated in this outreach effort can be found in Appendix F. The following survey script was used during outreach calls conducted by the Statewide CASE Team. Calls usually took 30 minutes to an hour to complete. Following the survey script are office plan layouts which were used to develop cost estimates. The interview conversation was slightly different for each interviewee based on industry role: designers, contractors, sales representatives, and manufacturers. Costs were also collected for three different office layouts during interview calls. Every call was followed up with an email containing a summary of the interview main points and any relevant follow up questions. Below is the multi-zone occupancy sensing in large office outreach survey script:

Designers

In your projects, what is the general percentage of the floor area in an office space or building that is open plan office area (as opposed to private offices, conference rooms, communal areas, etc.)?

Have you ever used the occupancy sensing PAF found in Table 140.6-A in Title 24, Part 6?

> If so, how was it?
>
> What support or objections do you have for this PAF?

In the current implementation, when shut off control, is required to meet Title 24, Part 6 for an office greater than 250 square feet, how do you currently specify the controls? Time-switch and/or occupancy sensors?

> For a time-switch, would you specify the occupancy schedule? If so how? If not, who does that?
>
> > What technology do you use?
>
> For an occupancy sensing implementation (above minimal compliance)…
>
> > How do you determine how many occupancy sensors to use?
> >
> > > Seek a general description of how they decide, how do they zone the office?
> > >
> > > Are they already splitting into zones, and if so, based on what?

Do you specify where the occupancy sensor locates on the reflected ceiling plan (RCP)?

Do you specify the field of view (FOV) of the occupancy sensors?

Do you specify the exact brand and model of occupancy sensors?

Do you specify other related components, e.g. power pack?

Do you plan where to put occ sensors? How do you plan that?

What is the occupancy sensing technology you typically specify for open plan office? (Note: the answer could be standalone occ sensors + power packs, networked lighting controls (NLCs), luminaires with embedded occ sensors, etc.)

If the answer is NLC, how do s/he specify the NLC to make sure it can meet the requirements? (Note: you may need to define NLC just so there is no confusion)

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

If 2022 Title 24 requires that each occupancy sensor can control no larger than, say, 600 ft^2 of area within an open plan office, what would need to change in your design practice?

Guide the interviewee to think through this as much as possible. Using the guiding questions below as needed:

Do you need to spend more time designing which luminaires are controlled by which occ sensor, where each occ sensor should be located, etc.? How much more time?

What about cost? (General sense of how much system cost may increase, and what are the variables that the increase would be depend on?)

What is the cost for new construction vs. retrofit/alteration?

Should this be required for retrofits? All other automatic shut-off controls are required during retrofits… but would this be cost effective?

Does this streamline or make any design aspects easier?

Would you need to consider specifying a different control solution (e.g., using an NLC instead of standalone occupancy sensors)?

What changes to the proposed code change would mitigate negative impacts to the design process?

What details / specifics are most critical or sensitive?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

Would you allow each occupancy sensor to turn off the lights within the open plan office when there are still occupants working in other parts of the open plan office? What might be the ramifications of doing this?

Would you prefer the lights to dim to a background level, say 20%, in the unoccupied parts of the open plan office and then turned off when the entire open plan office is unoccupied?

If so, how you would you specify the controls to achieve this? What control solutions would you use?

If not, what are the concerns, and how would you recommend the new requirement to be?

How would this proposed code change impact the compliance process?

What would minimize any negative impacts of compliance requirement?

Contractors

In your projects, what is the general percentage of the floor area in an office space or building that is open plan office area (as opposed to private offices, conference rooms, communal areas, etc.)?

Have you ever used the occupancy sensing PAF found in Table 140.6-A in Title 24, Part 6?

If so, how was it?

What support or objections do you have for this PAF?

In the current implementation, when shut off control, is required to meet Title 24, Part 6 for an office greater than 250 square feet, how do you currently specify the controls? Time-switch and/or occupancy sensors? [If the selection of technology is pre-determined: What is the occupancy sensing technology you typically see specified for open plan offices?]

For a time-switch, would you specify the occupancy schedule? If so how? If not, who does that?

What technology do you use?

For an occupancy sensing implementation (above minimal compliance)…

How do you determine how many occupancy sensors to use?

Seek a general description of how they decide, how do they zone the office?

Are they already splitting into zones, and if so, based on what?

Do you specify where the occupancy sensor locates on the reflected ceiling plan (RCP)?

Do you specify the field of view (FOV) of the occupancy sensors?

Do you specify the exact brand and model of occupancy sensors?

Do you specify other related components, e.g. power pack?

Do you plan where to put occ sensors? How do you plan that?

What is the occupancy sensing technology you typically specify for open plan office? (Note: the answer could be standalone occ sensors + power packs, networked lighting controls (NLCs), luminaires with embedded occ sensors, etc.)

If the answer is NLC, how do s/he specify the NLC to make sure it can meet the requirements? (Note: you may need to define NLC just so there is no confusion)

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

If 2022 Title 24, Part 6 requires that each occupancy sensor can control no larger than, say, 600 ft^2 of area within an open plan office, what would need to change in your practice?

Guide the interviewee to think through this as much as possible. Using the guiding questions below as needed:

What other decisions do you need to make because of this?

Decide which luminaires to wire to which occupancy sensor?

Decide where to install the occupancy sensors?

Select a different control solution as opposed of using the one you trust and are familiar with?

What is the cost difference for changing these practices?

Is significantly more time and labor needed for installation, wiring, commissioning (e.g. adjust the occupancy sensor FOV, if adjustable)? How much more?

Is this true when using wireless controls? Have you used or do you use wireless controls?

Is it more likely to cause wiring mistakes?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

What is the cost for new construction vs. retrofit/alteration?

Should this be required for retrofits? All other automatic shut-off controls are required during retrofits, but would this be cost effective?

If not already using NLC in most projects, would you then need to consider using NLC to meet this new requirement?

A simple way to meet the requirement is for each occupancy sensor to turn off the lights within the open plan office when there are still occupants working in other parts of the open plan office. What might be the ramifications of doing this from your perspective?

Another way to meet the requirements is to dim the lights to a background level, say 20%, in the unoccupied parts of the large office and then turned off when the entire large office is unoccupied.

How would you go about to implement this? What products can you use to achieve this?

Would there be any changes in installation technique? What are they?

What are the concerns and challenges do you foresee with this approach from your perspective?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

Do you plan where to put occ sensors? How do you plan that?

Is more education needed to make sure your installers can correctly install and configure the products and to prevent mistakes?

Sales Representatives

In your projects, what is the general percentage of the floor area in an office space or building that is open plan office area (as opposed to private offices, conference rooms, communal areas, etc.)?

Have you ever used the occupancy sensing PAF found in Table 140.6-A in Title 24, Part 6?

> If so, how was it?
>
> What support or objections do you have for this PAF?

In the current implementation, when shut off control, is required to meet Title 24, Part 6 for an office greater than 250 square feet, how do you currently specify the controls? Time-switch and/or occupancy sensors? [If the selection of technology is pre-determined: What is the occupancy sensing technology you typically see specified for open plan offices?]

> For a time-switch, would you specify the occupancy schedule? If so how? If not, who does that?
>
> > What technology do you use?
>
> For an occupancy sensing implementation (above minimal compliance)…
>
> > How do you determine how many occupancy sensors to use?
> >
> > > Seek a general description of how they decide, how do they zone the office?
> > >
> > > Are they already splitting into zones, and if so, based on what?
> >
> > Do you specify where the occupancy sensor locates on the reflected ceiling plan (RCP)?
> >
> > Do you specify the field of view (FOV) of the occupancy sensors?
> >
> > Do you specify the exact brand and model of occupancy sensors?
> >
> > Do you specify other related components, e.g. power pack?
> >
> > Do you plan where to put occ sensors? How do you plan that?
> >
> > What is the occupancy sensing technology you typically specify for open plan office? (Note: the answer could be standalone occ sensors + power packs, networked lighting controls (NLCs), luminaires with embedded occ sensors, etc.)
> >
> > > If the answer is NLC, how do s/he specify the NLC to make sure it can meet the requirements? (Note: you may need to define NLC just so there is no confusion)

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

If 2022 Title 24, Part 6 requires that each occupancy sensor can control no larger than, say, 600 ft^2 of area within an open plan office, what would need to change when you recommend products?

Guide the interviewee the think through this as much as possible. Using the guiding questions below as needed:

Is more education needed to make sure your customers can correctly install and configure the products you recommend to meet the requirement?

Would you need to consider recommending a different control solution (e.g. recommending an NLC instead of standalone occupancy sensors)?

What would the cost look like? (each sensor unit and/or the entire system depending on the technology used) What is the breakdown of material/product (including additional accessories needed, e.g. wires) cost, commissioning cost?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

What is the cost for new construction vs. retrofit/alteration?

Should this be required for retrofits? All other automatic shut-off controls are required during retrofit, but would this be cost effective?

The simplest way to meet the requirement would be for each occupancy sensor to turn off the lights within the large office when there are still occupants working in other parts of the office. Would you recommend this approach to your customers? What might be the ramifications of doing this?

Another way to meet the requirement is to dim the lights to a background level, say 20%, in the unoccupied parts of the large office and then turned off when the entire office is unoccupied.

Would you recommend this approach to your customers over the simplest approach?

How many products you represent that can achieve this?

What are the concerns and challenges do you foresee with this approach from your perspective?

Manufacturer

How do you currently recommend your customers to use your product to meet occupancy sensing control for large offices?

For a time-switch, would you specify the occupancy schedule? If so how? If not, who does that?

What technology do you use?

For an occupancy sensing implementation (above minimal compliance)…

What equipment would you need and what would be the general costs?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

Are you familiar with IECC 2018? What is your perspective on the new multi-zone occupancy sensor in open plan offices section in how it impacts your work?

If 2022 Title 24, Part 6 requires that each occupancy sensor can control no larger than, say, 600 ft^2 of area within an open plan office…

The simplest way to meet the requirement would be for each occupancy sensor to turn off the lights within the open plan office when there are still occupants working in other parts of the open plan office.

Do you have a product that can achieve this?

What's the general cost of the product(s)? What would be the least expensive way to comply?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

Would you recommend this approach to your customers?

What might be the ramifications of doing this?

Another way to meet the requirement is to dim the lights to a background level, say 20 percent, in the unoccupied parts of the open plan office and then turned off when the entire open plan office is unoccupied.

Do you have a product that can achieve this?

What’s the general cost of the product(s)? What would be the least expensive way to comply?

Run through the various office scenarios to determine cost—2,592 ft^2, 3,900 ft^2, 34,304 ft^2. Try to obtain equipment, labor, and commissioning costs. If it would be easier to share a spreadsheet with them and have them email it back, do that.

Would you recommend this approach to your customers?

What might be the ramifications of doing this?

How many products you produce that can achieve this?

What are the concerns and challenges do you foresee with this approach from your perspective?

Acceptance Test Technician Surveys and Results

4.1.1.4 Pre-Draft Acceptance Test Technician Survey

Before drafting the proposed acceptance test, the Statewide CASE Team gathered input to inform the test from ATTs at the CALCTP and NLCAA. The survey titled “2022 Energy Standards – Lighting Controls Acceptance Testing” was distributed in February and March of 2020, and it received 196 responses. The responses to relevant questions are summarized below.

Question One

Have you completed lighting controls acceptance tests for indoor occupancy sensors?

171 ATTs answered this question. 91.81 percent responded “yes”, and 8.19 percent responded “no.” The results highlight that a majority of lighting ATTs are familiar with controls acceptance tests for indoor occupancy sensors.

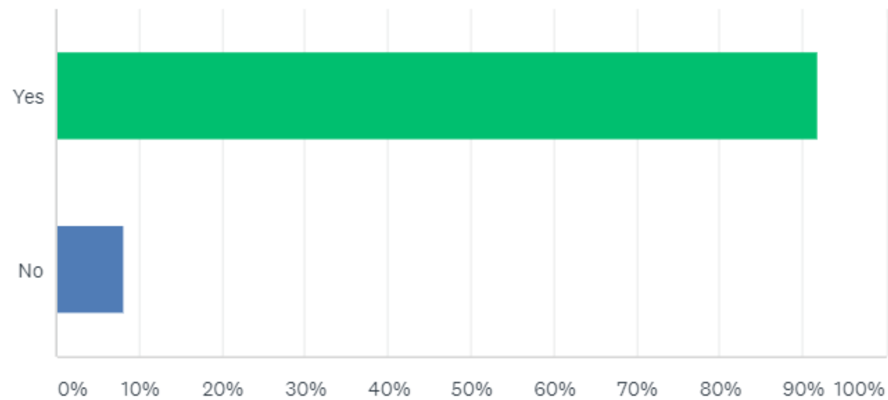


Figure 4: Results from question one in the pre-draft ATT survey.

Question Two

Have you completed acceptance tests for a project using the "Occupancy sensors serving small zones in large open plan offices" (PAF number 2 from Table 140.6-A)?

118 ATTs responded to the question. 47 percent (56) responded “yes.” 52 percent (61) responded “no.” One responded “maybe.”

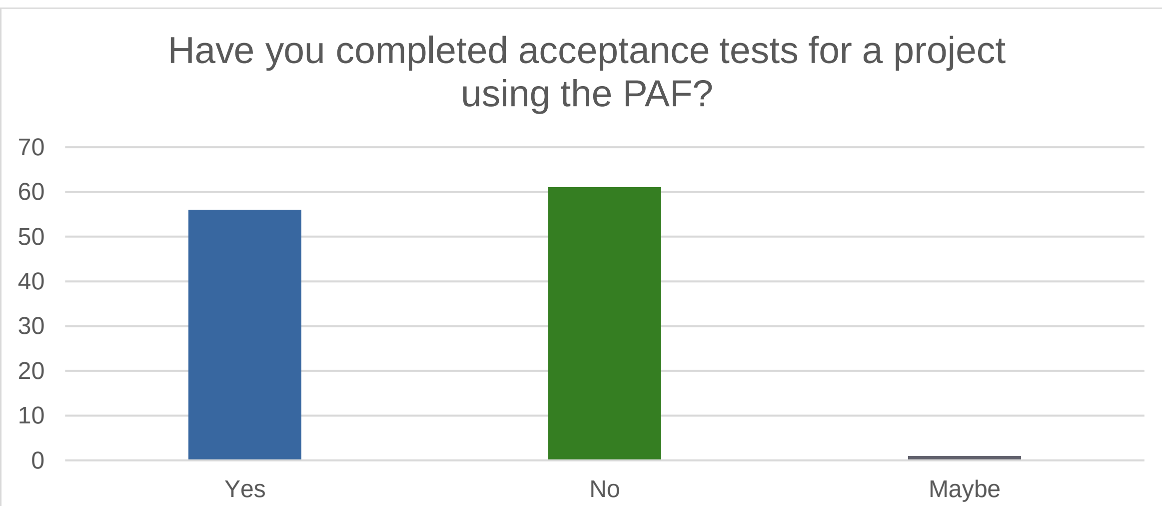


Figure 5: Results from question two in the pre-draft ATT survey.

Question Three

Do you anticipate you will in any future project?

118 ATTs responded to the question, with 52.54 percent (62) responding “yes,” 41.53 percent (49) responding “no,” and 5.93 percent (7) responding “maybe.”

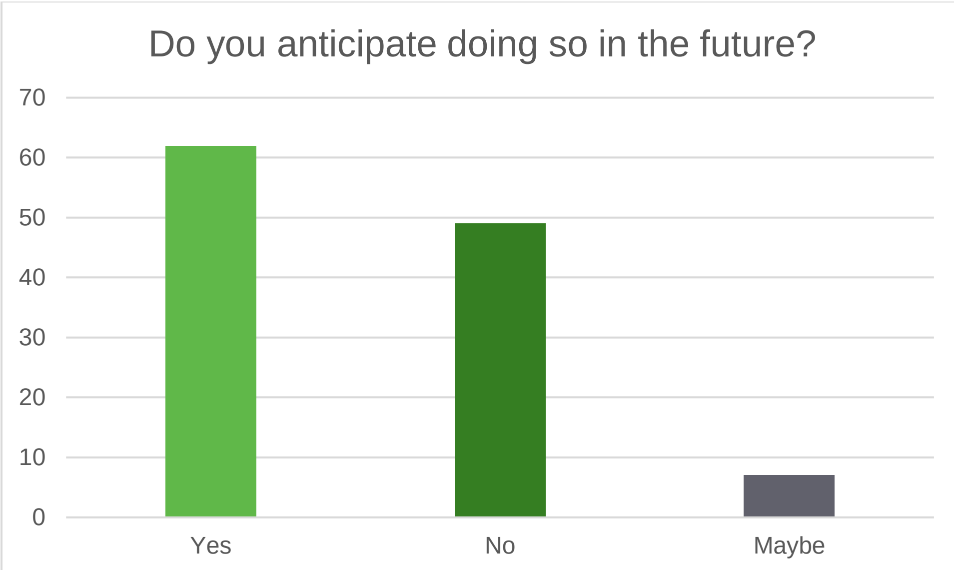


Figure 6: Results from question three in the pre-draft ATT survey.

Some comments from questions two and three are included below:

- It's hard to tell, some designers may utilize for decorative lighting in the space.
- I have not seen it on any alteration projects.
- I have not yet but anticipate it will come up. So far, my experience is that most lighting designers stay away from this requirement.
- Since LED lights are already such low wattage these small amounts of savings do not make sense compared to the cost for installation and frustration of end users looking out to an area that looks like it doesn't work properly
- Do not change the 2020 codes to require 600 Square foot zones. This is insane.
- Yes. It’s been a popular option where they have a big open area and install designer style cubicles. They have been adding more than one occupancy, but they have not divided the controlled lights. So multiple sensors do the same lights. I consider a good idea to split the lights into zones
- No, there has not been much of a need for PAF under the 2016 Standards, but with the reduction of 'Lighting Power Density Values' of Table 140.6-C in the 2019 Standards, it may become needed.
- Haven't seen PAFs used in a long time - but that might change in the future.
- No and not sure, I guess that depends on how difficult complying with wattage allowances becomes in future code.
- No, due to LED usage.

- Yes, and I will see this a lot.
- No, too costly.
- If the allowed lighting power density is reduced, the Statewide CASE Team may see engineers use the PAF to meet allowed wattage for the project.
- Not unless there is a code change or the need due to lowered LPDs.

Question Four

Functional testing requires that the passive infrared sensor's detection zone does not enter into adjacent controlled or uncontrolled zones. Would the measure as proposed need to alter this test requirement?

116 ATTs responded to the question, with 45 percent (52) responding “yes,” 42 percent (49) responding “no,” 9 percent (11) responding “unsure,” and 3 percent (4) responding “maybe.”

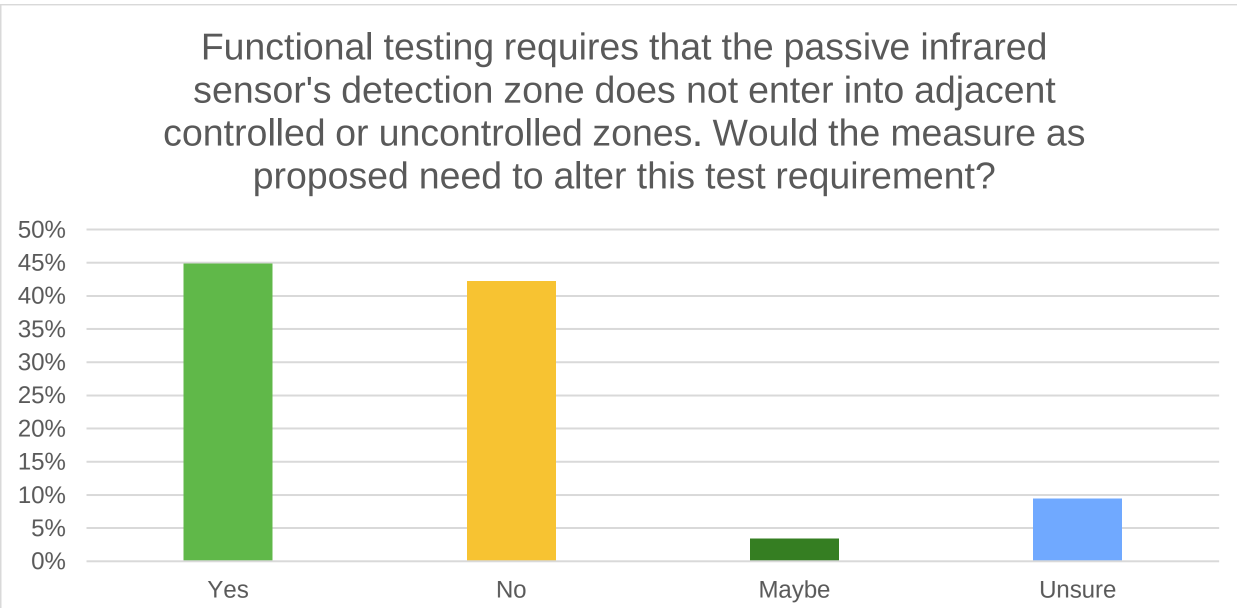


Figure 7: Results from question four in the pre-draft ATT survey.

Additional comments are included below:

- If the sensor is not equipped with masking or a shroud than the sensitivity of the sensor can be adjusted, and this is easy to determine if it senses far outside of the zone or not.
- I think it would need to be altered since most manufacturers use a 20 – 25 percent overlap on the device detection zones.
- It would depend on the layout of the other rooms in the building.

- Masking the sensors is very difficult.
- This would not only alter testing but require additional sensors/controls to maintain smaller areas. Each zone would be equivalent to a separate office.
- Most of the time when designing you overlap coverage patterns. If this is the test, then now you are required to make holes in the coverage pattern.
- Yes, it is very difficult to achieve the goal and calibrate the sensors to not interfere with another zone.
- We already make sure there is no false trigger, it has already been implemented.
- Without overlap of zones, nuisance tripping is so prevalent that we get constant warranty call backs to adjust the sensitivity of the devices in open office areas because the lights turn off so often. It works in theory, but not practically. If I walk in between two zones, they both better turn on.
- Just include language something to the effect of, "Adjacent zones in open office may overlap sensor detection within themselves, but not into adjacent enclosed spaces like conference rooms, private offices, etc."
- Yes, it is a challenge when using DT sensors in offices to pick up minor movement that the US or Microphonic travels outside the control zone. There may be the need to allow adjacent zones to be triggered like in walkthrough mode due to the device's detection zones varying in coverage.

Question Five

How difficult is it to discern an occupancy sensor's control zone boundary in open office areas?

129 ATTs responded to the question. The highest response was "neither easy nor difficult" at 36.4 percent (47), the next was "difficult" with 26.4 percent (34), followed by "easy" at 18.6 percent (24), "very difficult" at 10.1 percent (13), "very easy" at 4.7 percent (6), "I don't know" at 3.9 percent (5).

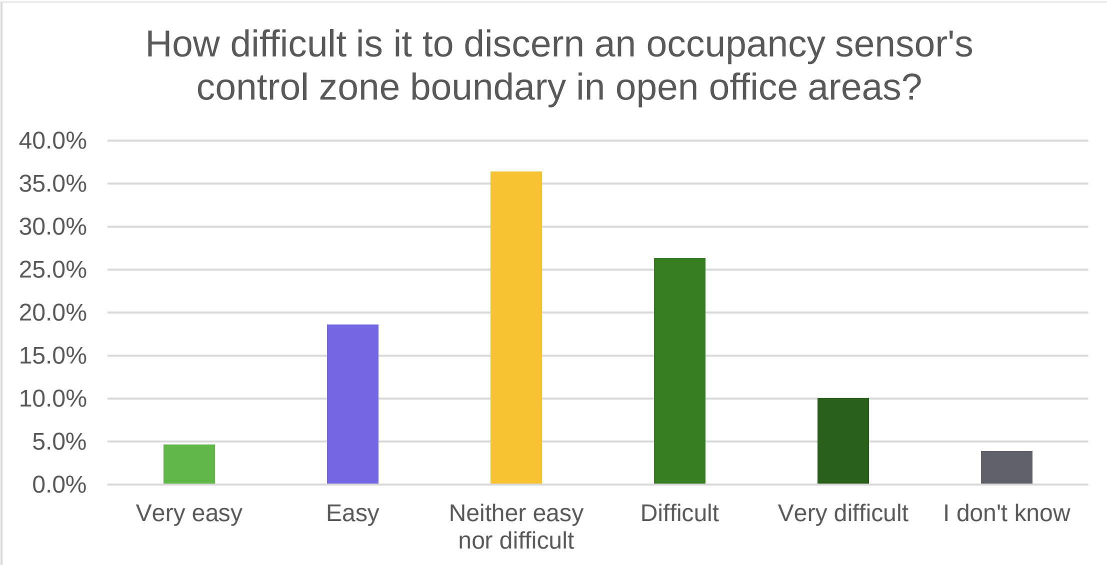


Figure 8: Results from question five in the pre-draft ATT survey, as a bar chart.

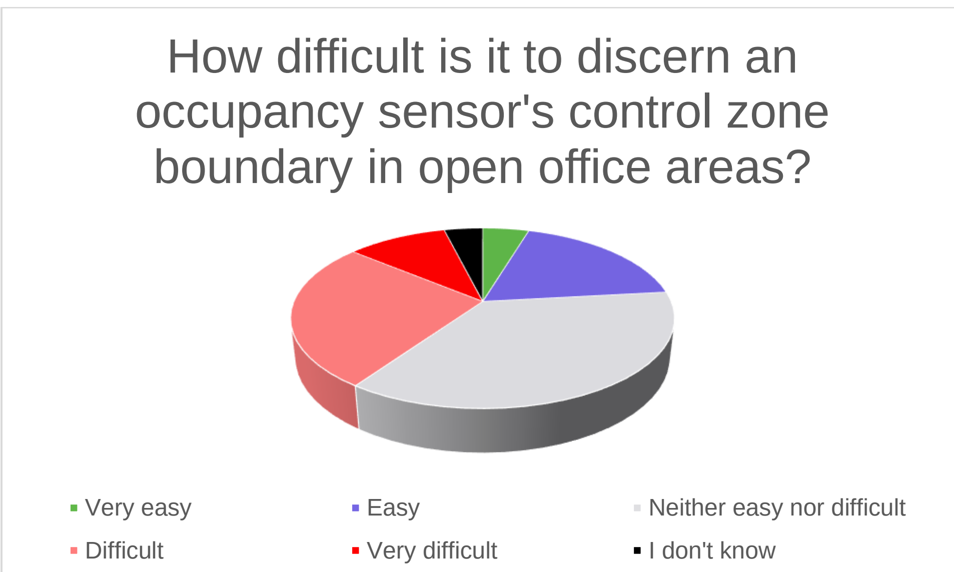


Figure 9: Results from question five in the pre-draft ATT survey, as a pie chart.

Question Six

What documents, if any, help you discern occupancy zones? (e.g., Floorplans)

113 ATTs responded to the question, with 93 percent (105) providing one or more recommended documents, and 7 percent (8) responding no documents would help discern occupancy zones.

Table 83 summarizes the recommended documents, in order of prevalence in the responses. Note: respondents could specify more than one type of document.

Table 83: ATT Responses to Which Documents Would Help Discern Occupancy Zones

Document	Number of Response Mentions
Floorplans	54
Lighting Plans	19
Electrical Plans	8
Reflected Ceiling Plan (RCP)	7
Lighting Control Plans	5
Sensor Specification	5
Title 24 Approved Plans	4
Architectural Plans	3
Zoning Plans	3
Design Plans	2
Furniture Layout	2
Specification Sheet	2

Question Seven

What would be important to consider in development of an additional acceptance test should one be required to make the proposed code change feasible?

86 ATTs responded to this question with widely varying answers. The most popular answers are summarized below in Table 84.

Table 84: ATT Recommendations for Important Considerations for Developing an Additional Acceptance Test

Response	Number of Response Mentions
Unsure	12
Objection to proposed code change	7
No changes to tests need to be considered	6
Cost to end user	5
Zone overlap allowed to eliminate coverage gaps	5
Don’t require additional testing	4
Test clarity (instructions, definitions, objective)	4
Batch testing for large spaces	4
Sensor placement	3
Sensor sensitivity	3
Clear control zone definition on documents	3

Feasible test	3
Soften sensor distance to HVAC supply requirement	2
Installation team training and feedback	2
ATT training class	2
Vacancy during testing	2
Enforcement; discipline for violations of compliance	1

4.1.1.5 Post-Draft California Energy Commission's Acceptance Test Technician Reviewer Feedback

The following comments were provided to the Statewide CASE Team by the California Energy Commission's ATT Reviewers regarding the proposed acceptance test language. The Statewide CASE Team's response is summarized for each comment.

Choose "power" or "light" rather than using both terms in the language.

The Statewide CASE Team reviewed the proposed acceptance test language for inconsistency upon receiving the comment and determined the language is clear and does not use "power" and "light" interchangeably. The acceptance test as written is intended to improve compliance and reduce challenges during testing. The language is designed to allow either the measurement of power or lighting to provide flexibility for the ATTs, who have mentioned the importance of test feasibility as denoted in the previous section. By using light level as a proxy for power, the acceptance test will enable further compliance. In response to this comment, the Statewide CASE Team added a note in the drafted code language of the Reference Appendices to improve clarity.

Has the Statewide CASE Team considered how the Internet of Things, Human Centric Lighting, and other integrative lighting applications may affect power consumption and the efficacy of the proposed acceptance test?

Yes, the Statewide CASE Team considered all of these suggestions in the previous code cycle, especially for "Power over Ethernet." There are also use-it-or-lose-it adders for color tunable luminaires in the LPD submeasure that address some of these concerns.

Consider how luminaire distribution in modern office spaces is often non-uniform and photometric outcomes may rely on light contribution from adjacent zones.

The proposed code change intentionally leaves flexibility to designers for how to define and design the control zones. Other than the proposed 600 ft^2 upper limit, the requirement does not specify that control zones must not overlap or determine the exact way control zones must be defined. The acceptance test did not prohibit zone overlap when this comment was received. Due to this feedback and the suggestions in Question Four of Section 4.1.1.4, the Statewide CASE Team inserted a note into the drafted acceptance test language explicitly explaining zone overlap is allowed. The Statewide CASE Team is seeking feedback from reviewers if there is an implicit implication that control zone overlap is prohibited. If there is any confusion from reviewers, the Statewide CASE Team will determine how to edit the language to minimize confusion.

Consider including control zone definitions on engineering drawings, similar to daylit zones.

Because the proposed code change is not prescribing locations of occupancy sensors in large offices, designers would be given the flexibility to interpret the code and meet the requirement. Designers and lighting engineers have the option to include control zone definitions on engineering drawings, and the Statewide CASE Team has suggested doing so would be beneficial in the compliance process.

Address task lighting, as it could be a significant contributor to energy use due to the proliferation of personal control strategies.

This is outside of the scope of the current measure and could be bought up in a future code cycle.

Include a requirement testing Exception 2 to Section 130.1(c) regarding egress illumination.

The 2019 Reference Nonresidential Appendix Section NA7.6.2.1 General Requirements states that the shut-off control should be “fully functional in accordance with each applicable requirement in Section 130.1(c), or that the application meets one of the exceptions.” This language addresses the concern about Exception 2 to Section 130.1(c), as it requires the shut-off control to meet each applicable requirement in Section 130.1(c) and gives a pathway to list the specific exception claimed.

Appendix H: Multi-zone Occupancy Sensing in Large Offices Energy Savings Calculation Details

Model offices

Three model offices were used in the energy savings calculations. The details of each model office, sampled occupancy patterns and energy savings are described herein.

Model Office A

Figure 10 shows the floor plan of the Model Office A, a smaller, "open plan" office area. The square footage of the office is 2,584 ft^2, and twenty-eight 30W 2'-by-4' luminaires are installed in a 10'-by-10' grid.

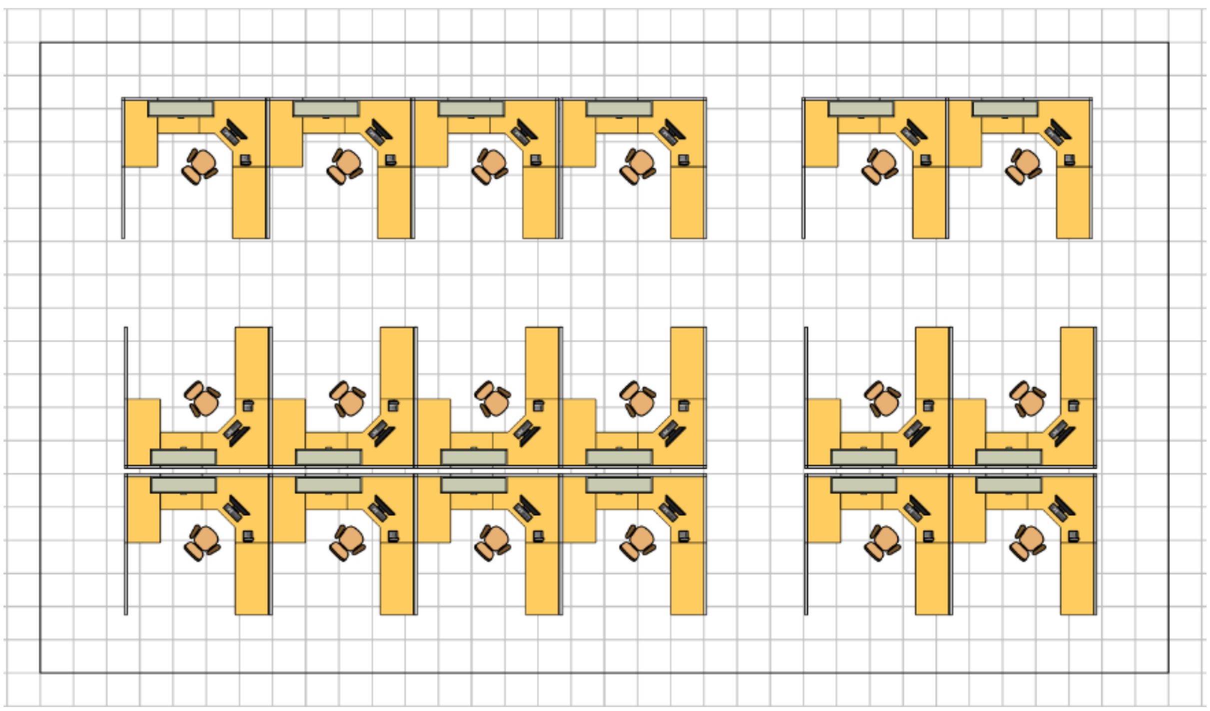


Figure 10: Floor plan of Model Office A.

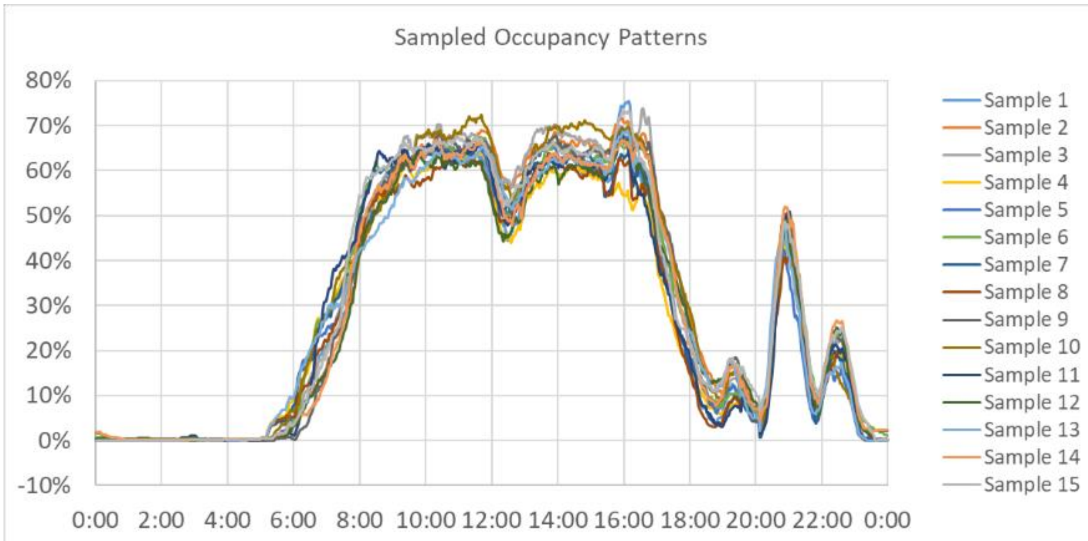


Figure 11: Average daily occupancy pattern of 15 random samples of 18 occupants.

Table 85: Per-unit energy savings of the sample runs for Model Office A.

Per-unit Energy Savings (kW/ft^2/yr)		
Sample Run	**Worst Case**	**Best Case**
Sample Run 1	0.790	0.337
Sample Run 2	0.860	0.395
Sample Run 3	0.725	0.273
Sample Run 4	0.980	0.512
Sample Run 5	0.940	0.483
Sample Run 6	0.805	0.336
Sample Run 7	0.777	0.334
Sample Run 8	0.765	0.319
Sample Run 9	0.734	0.276
Sample Run 10	0.739	0.297
Sample Run 11	0.822	0.385
Sample Run 12	0.967	0.487
Sample Run 13	0.756	0.271
Sample Run 14	0.963	0.508
Sample Run 15	0.772	0.290
Average of all Sample Runs	**0.826**	**0.367**

Model Office B

Figure 12 shows the floor plan of the Model Office B, a medium “open plan” office area. The square footage of the office is 4,000 ft^2, and forty 30W 2’-by-4’ luminaires are installed in a 10’-by-10’ grid.

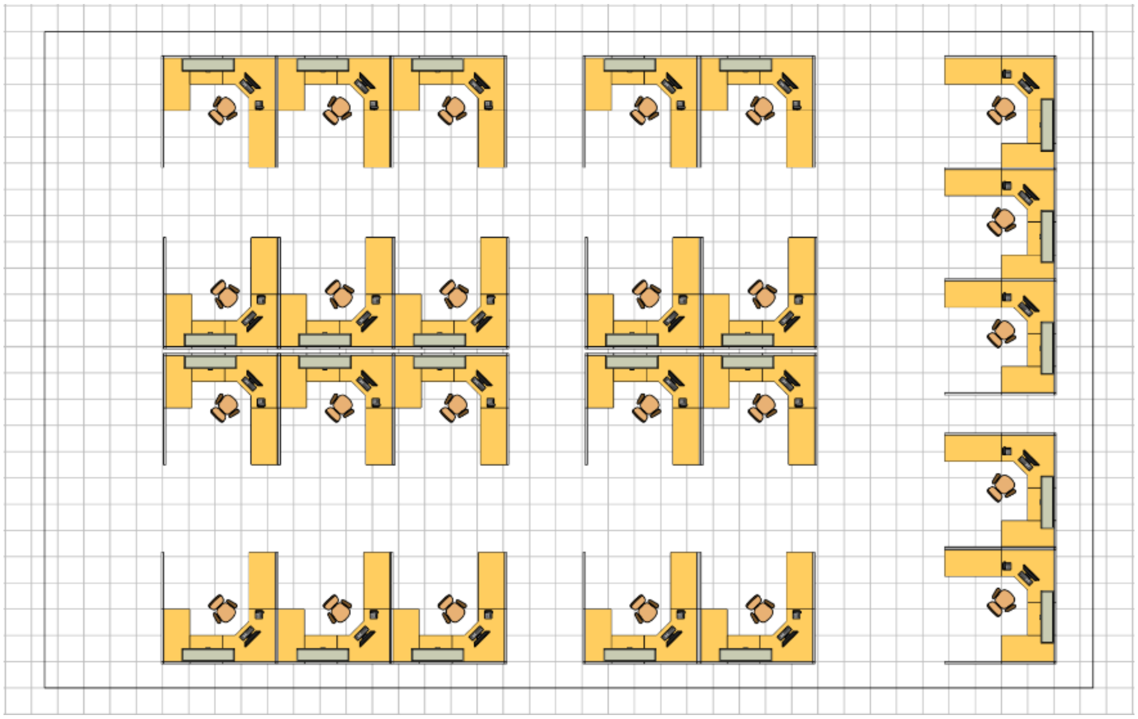


Figure 12: Floor plan of Model Office B.

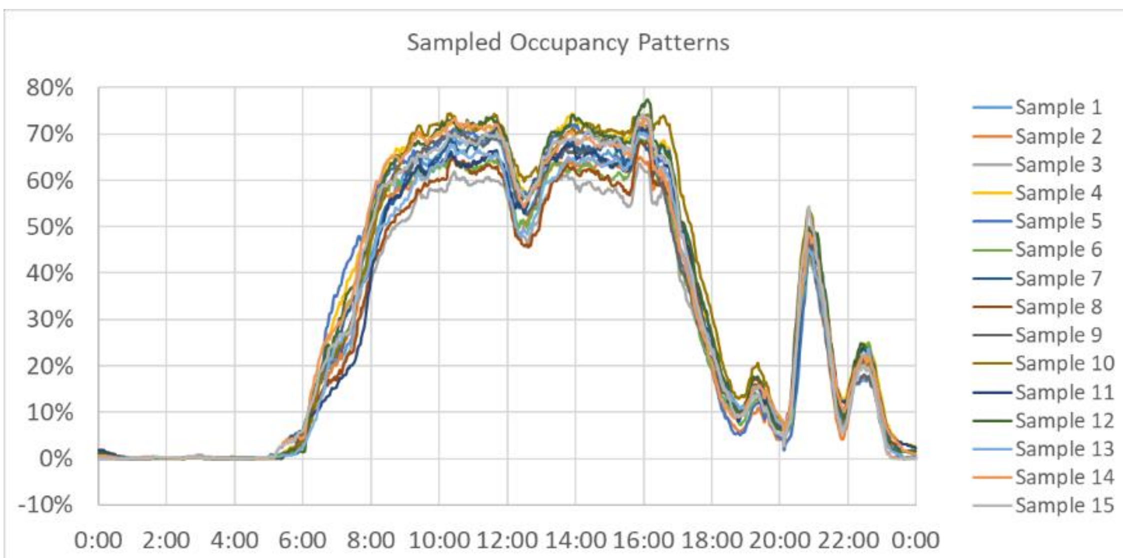


Figure 13: Average daily occupancy pattern of 15 random samples of 25 occupants.

Table 86: Per-unit energy savings of the sample runs in Model Office B.

	Per-unit Energy Savings ($kW/ft^2/yr$)	
Sample Run 1	0.724	0.331
Sample Run 2	0.880	0.506
Sample Run 3	0.799	0.363
Sample Run 4	0.777	0.380
Sample Run 5	0.725	0.361
Sample Run 6	0.843	0.443
Sample Run 7	0.867	0.473
Sample Run 8	0.900	0.487
Sample Run 9	0.757	0.371
Sample Run 10	0.844	0.464
Sample Run 11	0.872	0.483
Sample Run 12	0.655	0.273
Sample Run 13	0.877	0.479
Sample Run 14	0.785	0.387
Sample Run 15	0.673	0.294
Average of all Sample Runs	**0.798**	**0.387**

Model Office C

Figure 14 shows the floor plan of the Model Office C, a large "open plan" office area within a large building. The square footage of the office is 7,540 ft^2, and seventy-six 30W 2'-by-4' luminaires are installed in a 10'-by-10' grid.

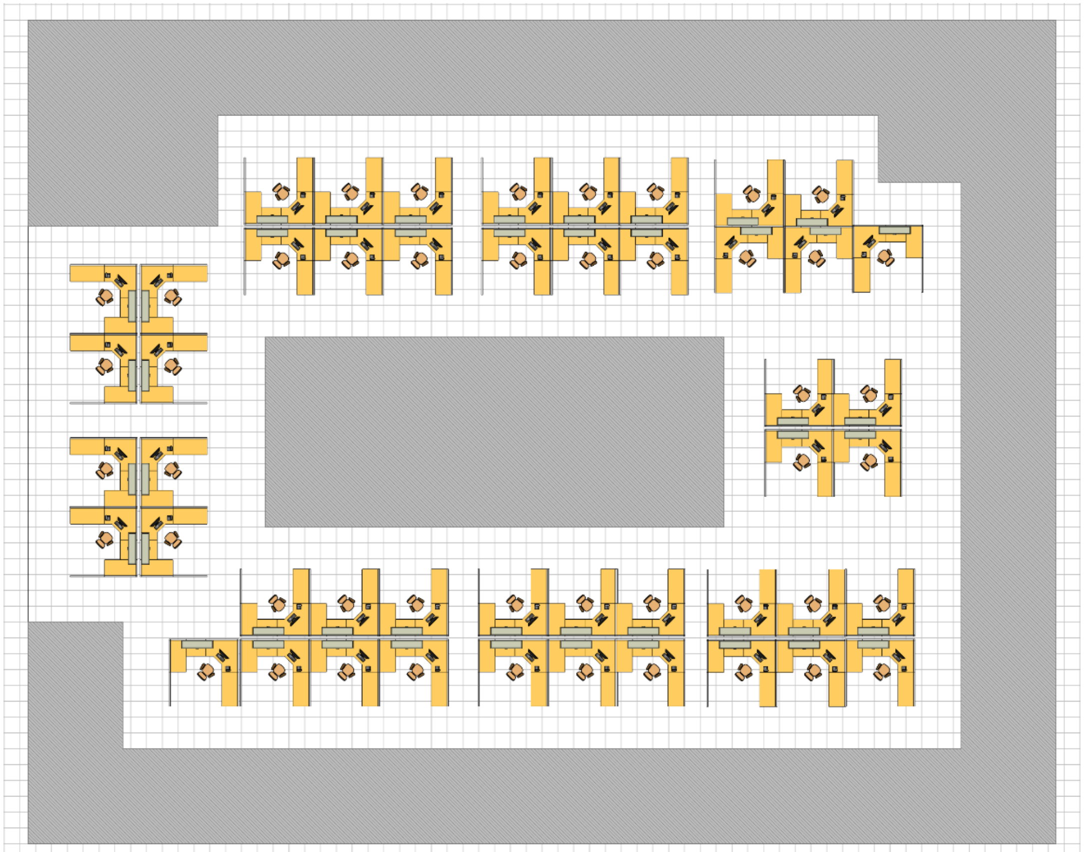


Figure 14: Floor plan of Model Office C for a large open-plan office area.

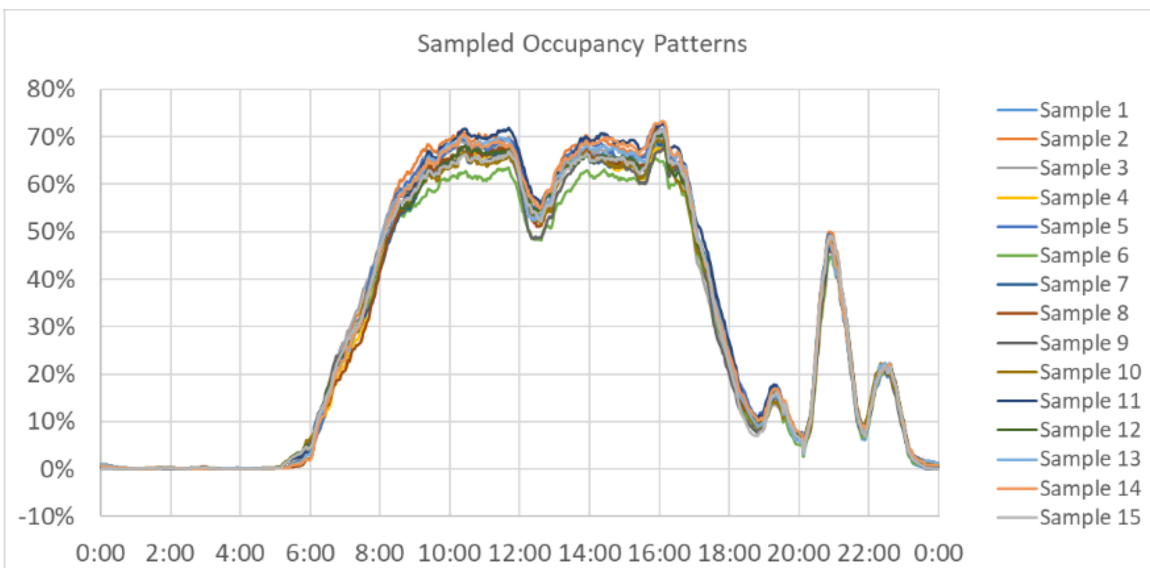


Figure 15: Average daily occupancy pattern of 15 random samples of 48 occupants.

Table 87: Per-unit energy savings of the sample runs in the Model Office C.

	Per-unit Energy Savings (kW/ft²/yr)	
Sample Run 1	0.938	0.521
Sample Run 2	0.926	0.514
Sample Run 3	0.914	0.504
Sample Run 4	0.887	0.467
Sample Run 5	0.926	0.511
Sample Run 6	0.973	0.536
Sample Run 7	0.827	0.399
Sample Run 8	0.886	0.469
Sample Run 9	0.948	0.526
Sample Run 10	0.945	0.518
Sample Run 11	0.923	0.508
Sample Run 12	0.937	0.512
Sample Run 13	0.932	0.521
Sample Run 14	0.773	0.361
Sample Run 15	0.822	0.403
Average of all Sample Runs	**0.904**	**0.485**

Appendix I: Luminaire Data

The following tables includes information on the lumen output range of luminaires inserted into the inverse lumen method model used to develop the LPDs.

Table 88: Luminaire Data

Luminaire Type	Standard Lumens	High Lumens	Low Lumens
TrV - Troffer Vandal Proof	3001 to 5499	5500 or more	3000 and less
TrB - Troffer Basket	3001 to 5499	5500 or more	3000 and less
TrL - Troffer Lensed	3001 to 5499	5500 or more	3000 and less
DLg - Downlight large 6"+	1501 to 3499	3500 or more	1500 and less
DSm - Downlight 4" and less	1501 to 3499	3500 or more	1500 and less
HiB - High Bay	16001 to 34999	35000 or more	16000 and less
LoB - Low bay	12001 to 20499	20500 or more	12000 and less
HBA - Aisle lighter	3001 to 9999	10000 or more	3000 and less
PGL - Parking garage luminaire		7000 or more	3000 and less
CvO - Cove light omnidir	Not Used	NA	NA
CvA - Cove light asymmetric	1501 to 3999	4000 or more	1500 and less
StI - Industrial strip	1801 to 6499	6500 or more	1800 and less
StW - Strip wrap-around	1801 to 6499	6500 or more	1800 and less
PKL - Puck light	101 to 399	400 or more	100 and less
StC - Strip Under cabinet		900 or more	350 and less
PDI - Pendant direct/indirect	1801 to 6499	6500 or more	1800 and less
PID - Pendant Indirect/direct	1801 to 6499	6500 or more	1800 and less
PIn - Pendant Indirect only	1601 to 4999	5000 or more	1600 and less
PDr - Pendant Direct Only	1401 to 3999	4000 or more	1400 and less
SCU - Sconce Uplight	801 to 2399	2400 or more	800 and less
ScD - Sconce Downlight	801 to 2399	2400 or more	800 and less
ScO - Sconce Omnidirectional	999 to 2799	2800 or more	1000 and less

SLs - Linear light slot 4" or less	2001 to 5999	6000 or more	2000 and less
SLI - Linear light slot 4" or more	2001 to 5999	6000 or more	2000 and less
Pcy - Pendant cyl direct/indirect	2801 to 6999	7000 or more	2800 and less
PBc - Pend bowl direct/indirect	2801 to 6999	7000 or more	2800 and less
DLT - Desk light task	401 to 899	900 or more	400 and less

Table 89: 2x2 and 2x4 Troffers

Manufacturer	2 X 2 Low/High Lumen Output	Lumens per Watt	2 X 2 Low/High Lumen Output	Lumens per Watt	Comments/Remarks/Notes
Manufacturer A[a]	2,000 to 4,800 lumens	109 to 130 per watt	3,000 to 12,000 lumens	112 to 137 per watt	Sampling of 8 different product types – Lensed & Basket (not all have full range)
Manufacturer B[b]	1,400 to 4,800 lumens	111 to 143 per watt	2,400 to 9,200 lumens	118 to 147 per watt	Sampling of 8 different product types – Lensed & Basket (not all have full range)
Manufacturer C	2,000 to 6,500 lumens	102 to 129 per watt	3,400 to 13,000 lumens	106 to 136 per watt	Sampling of 4 different product types – Lensed & Basket (not all have this full range)
Manufacturer D[c]	1,000 to 6,000 lumens	86 to 156 per watt	2,000 to 12,000 lumens	99 to 178 per watt	Sampling of 6 different product types – Lensed & Basket (not all have full range)
Manufacturer E	2,300 to 4,500 lumens	94 to 130 per watt	3,200 to 7,800 lumens	97 to 135 per watt	Sampling of 8 different product types – Lensed & Basket (not all have full range)
Manufacturer F[d]	3,400 to 6,500 lumens	66 to 94 per watt	3,900 to 9,200 lumens	66 to 122 per watt	Sampling of 4 different product types – Lensed & Basket (not all have full range)
Average of 5 Manufacturers[d]	1,740 to 5,320 lumens	100 to 138 per watt	2,800 to 10,800 lumens	98 to 142 per watt	Sampling of 38 different product types (not all have full range)

Max. Range 5 Manufacturers[d]	1,000 to 6,500 lumens	86 to 156 per watt	2,000 to 13,000 lumens	97 to 178 per watt	Sampling of 38 different product types (not all have full range)
Average efficacy		112		121	

a. Sampling: Lensed 2 X 2 model TL: 2000lm at 115LPW / 4000LPW at 111LPW; 2 X 4 basket model VTL: 3200lm at 141LPW / 12000lm at 130LPW. Note: Lowest LPW for 2X4: 8000lm and 10000lm at 112LPW; Lowest efficacy for 2 X 2 of 109LPW is for product with 2000lm output.

b. Sampling: 2 X 2: 1400lm at 127LPW for 80CRI / 3500K; 2 X :2 4300lm at 143LPW for 80CRI / 3500K. Note: Results for 2 X 4 luminaires similar to those of the 2 X 2.

c. Sampling: High Efficiency 2 X 2 1000lm; High Efficiency 2 X 2: 156LPW for 80CRI / 3500K / 6000lm at 142LPW 80CRI / 3500K; Normal 2 X 2 1000lm at 128LPW; Normal 2 X 2 6000lm at 134LPW. Note: Low 96lm / 97lm product is for driver options – 3 per luminaire, but unclear why this option is offered. Manufacture A and B luminaire efficacy declines as lumen output increases (like legacy fluorescent product). However, manufacturer D efficacy increases as lumen output increases. Unclear why this manufacturer efficacy curve does not track with manufactures A and B.

d. Average and maximum range of lumen outputs and LPW exclude products from manufacturer F as these troffers are high abuse (vandal resistant) and will be averaged in the Vandal Resistant luminaires category, not the 2 X 2 and 2 X 4 troffers group.

Appendix J: Inverse Lumen Model Inputs

The Statewide CASE Team used the light levels from the 2019 code cycle as a starting point but updated for the 2022 code cycle. The Statewide CASE Team mapped out general task, supplemental and wall washing (vertical) lighting light level to the appropriate IES Referenced Standard as shown in Table 90 below. Note that these light levels are the recommended light levels for conducting certain tasks but they do not include the ornamental and architectural lighting to enhance the amenity of the space. In general the ornamental additional lighting power is in addition to the recommended illuminance targets listed below.

Below each maintained design illuminance level for Circulation, Task, and Supplemental lighting is a fraction which indicates the fraction of the room illuminated to the particular illuminance value. The fraction listed under the wall wash design illuminance level is the fraction of wall areas illuminated to the design light level.

Note that there several applications where there is listed a circulation illuminance levels but the fraction of room illuminated to this task level is zero percent. What this indicates is that there are higher task lighting requirements and the entire space is illuminated to the task lighting value rather than the circulation levels. In a couple of cases, a recommended task or supplemental illuminance is listed but the illumination is provided by portable lighting or other exempted lighting. In these cases, the fraction of the room illuminated is zero percent.

For most applications the sum of room fractions add up to 100 percent, in a couple of cases, the data is displayed as 100 percent general lighting with an additional layer of lighting that results in higher illuminance values and greater than 100 percent of total room area illuminated.

Table 90: 2022 Lumen Method Model Lighting Foot-candle Levels, Fraction of Area Illuminated and Referenced Standards

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Audience Seating Area	10 100%	HB Table 24.2 - Auditoria lecture hall circ & audience and HB Table 28.2 Theater Stage audience ore/post show	5 100%	15 fc HB Table 28.2 -H & E theater: housekeeping - 5 fc layered on top	0	na	10 67%	IES HB Misc. Applications Table 31.2 City Hall – Audience gen. horizontal FC

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Auditorium Area	15 0%	HB Table 24.2 - Auditoria Pre-function - pre/post event	30 100%	HB Table 24.2 - Auditoria Testing/combination (read/write)	0	na	15 64%	IES HB Education Table 24.2 Auditoria gen. horizontal FC (pre/post events)
Auto Repair / Maintenance Area	15 90%	RP-7 Industrial	0	Basic task included with circulation	100 10%	HB Table 24.2 Classroom/Shop -work table/bench	0	0
Barber, Beauty Salon and Spa Area	10 20%	Cosmetology Industry (Freestyle Systems): General	50 65%	Cosmetology Industry (Freestyle Systems): Task	100 15%	Cosmetology Industry (Freestyle Systems): Hair Styling	10 36%	IES DG-25-12 Table B1: Salon general horizontal FC)
Civic Meeting Place Area	10 30%	RP 3 Table 3g Circulation	30 70%	RP 3 Table 3g Conferencing	0	na	10 50%	IES HB Misc. Applications Table 31.2 City Hall – Audience gen. horizontal FC
Classroom, Lecture, Training, Vocational Area	10 0%	RP3 Table 3c Classroom General: Average of AV and dedicated VDT screen	40 100%	RP3 Table 3c Classroom Hardcopy and writing	0	na	10 36%	IES HB Educational Table 24.2. General classrooms Ave horizontal tasks (5 FC to 40 FC)
Commercial/Industrial Storage: Warehouse	10 100%	HB Table 31.2 - Support/Storage	0	Task included with circulation	0	na	0	
Commercial/Industrial Storage: Shipping & Handling	10 40%	HB Table 22.2 - Support Spaces: Shipping Dock	30 60%	HB Table 22.2 - Support Spaces: Shipping - Receiving Staging	0	na	0	0
Concourse and Atria Area	10 80%	RP 2 Table J2 Interior Mall - Concourse	30 20%	RP 2 Table J2 Interior Mall - Kiosk (sales)	0	na	10 66%	IES HB Common Applications Table 22.2 Atria (Transition space) general horizontal FC
Convention, Conference, Multipurpose and Meeting Area	10 30%	RP 3 Table 3g Circulation	30 70%	RP 3 Table 3g Conferencing	0	na	10 50%	IES HB Educational Table 24.2. General classrooms Ave horizontal tasks (5 FC to 40 FC)
Copy Room	10 60%	RP 1 Table B1k Support Copy/Print room: General	30 40%	RP 1 Table B1k Support Copy/Print room: Machines	0	na	0	0

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Corridor Area	5 100%	HB Table 22.2 - Transition Space; Corridor	0	Task included with circulation	0	na	5 47%	IES HB Common Applications Table 22.2 Stairways typical horizontal FC
Dining Area: Bar/Lounge and Fine Dining	3 85%	HB Table 22.2 - food service; Dinning areas	7.5 10%	IES-RP-10-19 (Common Appl.) Table Food Service: Dining Area, Relaxed or Fine	30 5%	IES-RP-10-19 (Common Appl.) Table Food Service: Serveries, Cashier	3 (7.5) 42%	IES HB Common Applications Table 22.2 Fine dining general horizontal FC
Dining Area: Cafeteria/Fast Food	10 60%	HB Table 22.2 - food service; Dinning areas	15 30%	IES-RP-10-19 (Common Appl.) Table Food Service: Dining Area, Cafeteria or Fast food	30 10%	IES-RP-10-19 (Common Appl.) Table Food Service: Serveries, Cashier	10 36%	IES HB Common Applications Table 22.2 Fast-food general horizontal FC
Dining Area: Family and Leisure	3 50%	HB Table 22.2 - food service; Dinning areas	10 40%	IES-RP-10-19 (Common Appl.) Table Food Service: Dining Area, Fast Casual.	50 10%	IES-RP-10-19 (Common Appl.) Table Food Service: Serveries, Cashier	5 35%	IES HB Common Applications Table 22.2 Casual dining horizontal FC
Kitchen/Food Preparation Area	20 40%	HB Table 22.2 - Food service/General	0	Basic tasks included with circulation	50 60%	RP-10-19 - Food Preparation/ Handling & Cleaning	0	0
Electrical, Mechanical, Telephone Rooms	20 100%	HB Table 22.2 - support spaces	0	portable	0	na	0	0
Exercise/Fitness Center and Gymnasium Area	30 100%	HB Table 24.2 ports/Gym - General activities	0	Task included with circulation	0	na	0	0
Financial Transaction Area	10 60%	HB Table 31.2 Financial Facilities - Banking lobby: General	30 30%	HB Table 31.2 Financial Facilities - Banking lobby: Teller Window	50 10%	HB Table 31.2 Financial Facilities - Banking lobby: processing, inspection	10 42%	IES HB Misc. Applications Table 31.2 Bank lobbies gen. horizontal FC target
General/Commercial & Industrial Work Area: Low Bay	15 60%	RP7 Table A3 Industrial - General shop areas	30 30%	IES-RP-7 (Industrial) Table A3 Industrial Component manufacturing: Large	100 10%	IES-RP-7 (Industrial) Table A3 Industrial Component manufacturing: Fine or Assembly: Difficult	0	0
General/Commercial & Industrial Work Area: High Bay	15 60%	RP7 Table A3 Industrial - General shop areas	30 30%	IES-RP-7 (Industrial) Table A3 Industrial Component manufacturing: Large	100 10%	IES-RP-7 (Industrial) Table A3 Industrial Component manufacturing: Fine or Assembly: Difficult	0	0

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
General/Commercial & Industrial Work Area: Precision	15 45%	RP7 Table A3 Industrial - General shop areas	100 50%	RP7 (Industrial) Table A3 - Building Lighting: General Shop Area	300 5%	RP7 (Industrial) Table A3 - Assembly: Exacting	0	0
Hotel Function Area	10 30%	RP 3 Table 3g Circulation	30 70%	RP 3 Table 3g Conferencing	0	na	10 50%	IES DG-25-12 Table B1 social function horizontal task
Scientific Laboratory Area	50 100%	RP-7 Table A3 Lab-General	0	Task included with circulation	100 0%**	WH - NA, RP-7 Table A3 Lab-Benches	0	0
Laundry Area	30 100%	HB Table 28.2 -H & E support area	20 20%	Layered for 50 fc for HB 28.2 sewing (fine tasks)	0	na	0	0
Library : Reading Area	50 100%	RP 4 Table 1c Library Proper- Reading room/areas	0	Task included with circulation	0	na	0	0
Library : Stacks Area	20 40%	RP 4 Table 1b Library Stacks - General	30 60%	RP 4 Table 1b Library Stacks on shelves	0	na	0	0
Main Entry Lobby	10 60%	DG -25 hotel/hospitality Table B1 Lobbies	15 25%	DG -25 hotel/hospitality Table B1 Lobbies (desk top & general reading)	50 15%	DG -25 Table B1: hotel/hospitality Reading Writing (Maximum)	10 50%	IES HB Common Applications Table 22.2 Lobbies gen. horizontal FC
Locker Room	5 80%	HB Table 31.2 - Locker Rooms - General/lockers	0	Basic tasks included with circulation	15 20%	HB Table 31.2 - Locker Rooms - Vanity/mirrors	0	0
Lounge, Breakroom, or Waiting Area	10 90%	HB Table 22.2 Support Spaces: Break/lunch rooms	30 10%	IES-RP-10-19 (Common Appl.) Table Food Service: Serveries, Cashier	0	na	10 36%	IES HB Offices Table 32.2 Lounges gen. horizontal FC
Museum Area: Exhibition/Display	5 90%	RP 30 Table 8 Museum display - medium to sensitive fading products	0	Task included with circulation	20 10%	RP 30 Table 8 Museum display - Low sensitivity to fading products	0	0
Museum Area: Restoration Room	50 90%	Not Identified in Museum Lighting used MFR Laboratory target (RP7 Table A3)	0	Task included with circulation	100 10%	Not Identified in Museum Lighting used MFR Laboratory target (RP7 Table A3)s	0	0
Office Area: ≤ 250 square feet	10 40%	RP 1 Table B1l - Transition/circulation	30 50%	RP 1 Table B1j - Reading/writing Typical tasks	50 0%*	RP 1 Table B1j - Reading/writing detail/difficult tasks	0	0

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Office Area: > 250 square feet and ≤ xxx sf	10 40%	RP 1 Table B1l - Transition/circulation	30 60%	RP 1 Table B1j - Reading/writing Typical tasks	50 0%*	RP 1 Table B1j - Reading/writing detail/difficult tasks	10 35%	IES HB Offices Table 32.2 Ave horizontal 7.5 – 30 FC
Office Area: Open plan office > xxx sf	10 40%	RP 1 Table B1l - Transition/circulation	30 60%	RP 1 Table B1j - Reading/writing Typical tasks	50 0%*	RP 1 Table B1j - Reading/writing detail/difficult tasks	10 35%	IES HB Offices Table 32.2 Ave horizontal 7.5 – 30 FC
Parking Garage Area: Parking Zone	1 (5) 100%	From safety reports, 5 fc. 1 fc RP8-18 Table 17.3 Parking Structures, 6 fc G1-16 for high security parking garages	5 0%	RP 20 Table 4 Parking Structures - Elevator lobby/zone & Stairs. Combined with parking	0	na	0	0
Parking Garage Area: Dedicated Ramps	2 (4) 100%	RP-8-18 Sec 17.5.1.1 Ramps/Entrances	0	na	0	na	0	0
Parking Garage Area: Daylight Adaptation Zones	50 100%	RP-8-18 Table 17.3	0	na	50	RP8-18. Page 17-13	0	0
Pharmacy Area	50 80%	RP 9 Table 2m Pharmacy - General	100 15%	RP 9 Table 2m Pharmacy - Filling/Assembly	150 5%	RP 9 Table 2m Pharmacy - Compounding	0	0
Retail Sales Area: Grocery Sales	20 20%	RP 2 Table J2 (from handbook) Grocery store circulation	60 76%	RP 2 Table 3 Grocery/Supermarket General Illumination	300 4%	RP-2 task and focal lighting	10 36%	Foot-candle target - IES RP-2 Table 3 (Ave. of vertical)
Retail Sales Area: Retail Merchandise Sales	15 20%	RP 2 Table J2 (from handbook) Department indoor circulation	40 70%	RP 2 Table 3 Retail Indoor Sales floor (max allowed retail sales types)	200 10%	RP-2 task and focal lighting	30 36%	Foot-candle target - IES RP-2 Table 3 (Ave. of vertical)
Retail Sales Area: Fitting Room	30 100%	RP 2 Table J2 Retail Indoor - Fitting Rooms	0	Task included with circulation	0	na	30 31%	Foot-candle target - IES RP-2 Table 3 (Vertical baseline)
Religious Worship Area	0	No circulation lighting.	40 80%	HB Table 37.2 Worship Blend of Contemporary/Traditional & Transitional Secondary Focal	75 20%	HB Table 37.2 Worship Blend of Contemporary/Traditional & Transitional Primary Focal - Sermon	5 36%	IES HB Worship Table 37.2 Congregation general horizontal pre/post worship

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Restrooms	5 60%	HB Table 31.2 - toilets	15 40%	HB Table 31.2 - toilets	0	na	5 34%	IES HB Common Applications Table 22.2 Toilet/Locker Rm general FC
Stairwell	10 100%	HB Table 22.2 - Transition Space; Stairs: High Activity					5 17%	IES HB Common Applications Table 22.2 Stairways typical horizontal FC
Theater Area: Motion picture	5 0%	HB Table 28.2 -H & E theater: circulation & task (seating)	15 100%	HB Table 28.2 -H & E theater: housekeeping	0	na	5 70%	IES DG-25-12 Table B1: Theaters/Film post/preshow horizontal FC target
Theater Area: Performance	10 0%	HB Table 28.2 -H & E theater, stage - audience pre/post intermission	15 100%	HB Table 28.2 -H & E theater, stage - cleanup	0	na	10 62%	IES HB Hospitality Table 28.2 Theaters/Stage post/preshow
Transportation Function: Baggage Area	10 70%	HB Table 36.2 - baggage claim	20 30%	HB Table 36.2 - baggage claim	0	na	10 35%	IES HB Transport Table 36.2 Aviation baggage claim gen Horizontal FC target
Transportation Function: Ticketing Area	5 (10) 70%	HB Table 36.2 - trans/ticketing: queuing	30 30%	HB Table 36.2 - trans/ticketing: agent counter	0	na	10 42%	IES HB Transport Table 36.2 Aviation (Ave horizontal FC of all tasks)
Videoconferencing Studio	0	No circulation lighting.	50 100%	Non IES Reference : Video Conf Specialist ELP (Hedberg)	0	na	30 50%	Video Conf Specialist ELP (Hedberg)
Aging Eye/Low-vision: Main Entry Lobby	50 100%	IES RP-28-16 Table 1: 100 fc daytime but 1/2 light from daylight; 10 FC nightline target (horizontal	0	na	0	na	50 50%	IES RP-28-16 Table 1: 100 fc daytime but 1/2 light from daylight; 10 FC nightline target (horizontal
Aging Eye/Low-vision: Stairwell	20 100%	RP 28 Table 1 - Visually impaired corridor	0	na	0	na	20 17%	IES RP-28-16 Table 1: 10 FC nightline target (horizontal)
Aging Eye/Low-vision: Corridor Area	20 100%	RP 28 Table 1 - Visually impaired corridor	0	na	0	na	20 45%	IES RP-28-16 Table 1: No vertical FC target given

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Aging Eye/Low-vision: Lounge/Waiting Area	30 50%	RP 28 Table 1 - Visually impaired Common living area	50 50%	RP 28 Table 1 - Visually impaired Common living area	0	na	30 38%	IES RP-28-16 Table 1: 20 FC daytime target (horizontal)
Aging Eye/Low-vision: Multipurpose Room	30 50%	RP 28 Table 1 - Visually impaired Common living area	50 50%	RP 28 Table 1 - Visually impaired Common living area	0	na	10 50%	IES RP-28-16 Table 1: 20 FC daytime target (horizontal)
Aging Eye/Low-vision: Religious Worship Area	10 40%	RP 28 Table 1 - Visually impaired chapel	30 60%	RP 28 Table 1 - Visually impaired chapel	0	na	20 45%	IES RP-28-16 Table 1: 20 FC Ave horizontal target
Aging Eye/Low-vision: Dining	20 40%	RP 28 Table 1 - Visually impaired dinning	50 60%	RP 28 visually impaired	0	na	20 38%	IES RP-28-16 Table 1: 20 FC daytime target (horizontal)
Aging Eye/Low-vision: Restroom	20 60%	RP 28 Table 1 - Visually impaired restroom	50 40%	RP 28 visually impaired	0	na	20 35%	IES RP-28-16 Table 1: 20 FC daytime target (horizontal)
Healthcare Facility and Hospitals: Exam/Treatment Room	10 40%	RP 29 Table 2f General/circulation	50 30%	RP 29 Table 2f Diagnostic/Treatment - General Exam	100 30%	RP 29 Table 2f Diagnostic/Treatment - Injections. Etc.	0	0
Healthcare Facility and Hospitals: Imaging Room	10 70%	RP 29 Table 2d Imaging -booth/general	50 30%	RP 29 Table 2d Imaging - Diagnostic/reading	0	na	0	0
Healthcare Facility and Hospitals: Medical Supply Room	20 50%	RP-29 Table 2i - Linens, Surgical Gauze, Supplies	30 30%	RP 29 Table 2m Pharmacy Storage & Support Medication storage (equipment)	50 20%	RP 29 Table 2m Pharmacy Storage & Support Medication storage (controlled drugs)	0	0
Healthcare Facility and Hospitals: Nursery	10 0%	RP 29 Table 2l Nursery - General	30 80%	RP 29 Table 2l Nursery - Observation	50 20%	RP 29 Table 2l Nursery - Treatment	0	0
Healthcare Facility and Hospitals: Nurse's Station	30 80%	RP 29 Table 2j Nurses Station - General	50 20%	RP 29 Table 2j Nurses Station - Desk	0	na	10 34%	IES RP-29-16 Table 2a: Nighttime horizontal FC (30 FC daytime)
Healthcare Facility and Hospitals: Operating Room	200 0%	RP 29 Table 2o Surgical Setup/cleanup	200 100%	RP 29 Table 2o Surgical General	na	Exempt - in equipment	0	0
Healthcare Facility and Hospitals: Patient Room	10 30%	RP 29 Table 2k Patient room - General	40 60%	RP 29 Table 2k Patient room - Reading	75 10%	RP 29 Table 2k Patient room - Examination	10 0%	IES RP-29-16 Table 2a: General horizontal FC target

2022 T-24 Combined Name	Circulation (fc)	Circulation IES Ref	Task horiz (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
Healthcare Facility and Hospitals: Physical Therapy Room	20 80%	RP 29 Table 2h Therapy - General/Group therapy	50 20%	RP 29 Table 2h Therapy - Table and Individual	0	na	20 50%	IES RP-29-16 Table 2a : Ave of 10 FC/50 FC horizontal
Healthcare Facility and Hospitals: Recovery Room	0	Basic tasks included with circulation	30 80%	RP 29 Table 2k Special Care/Critical - General	100 20%	RP 9 Table 2k Special Care/Critical - Exam/treatment	5 35%	IES RP-29-16 Table 2a: General horizontal FC target (at rest)
Sports Arena – Playing Area: Class I Facility	0	All lighting is task	150 100%	RP 6 Table 9 - Sports lighting	0	na	0	0
Sports Arena – Playing Area: Class II Facility	0	All lighting is task	100 100%	RP 6 Table 9 - Sports lighting	0	na	0	0
Sports Arena – Playing Area: Class III Facility	0	All lighting is task	75 100%	RP 6 Table 9 - Sports lighting	0	na	0	0
Sports Arena – Playing Area: Class IV Facility	0	All lighting is task	50 100%	RP 6 Table 9 - Sports lighting	0	na	0	0

* Included in portable lighting

** Plug-in or part of equipment such as internal to fume hoods

The table below contains the dimensions, their nominal room cavity ratio (RCR) and the ceiling, wall and floor reflectances. The RCR is nominal as for a given space, the work plane might be on the floor for circulation, and workplan for task lighting might be at desk height. Similarly, in the same space one might have general lighting which is suspended below the ceiling, but have task lighting downlights that are recessed into the ceiling plane. Thus, the detailed calculations will be calculating specific room cavity ratios for their specific lighting system. The illuminances listed below are the average reflectances of the modeled surfaces. The models do not directly use these reflectances but rather effective reflectances are calculated based upon ceiling and floor cavity geometry and surface reflectances.

Table 91: Prototypical Primary Function Area: Dimensions, RCR and Reflectances

Primary Function Area	Ht.	Width (ft)	Len-gth (ft)	Work Plane ht (ft)	Nom. RCR	Ceil. Ref	Wall Ref	Floor Ref
Audience Seating Area	20	40	80	2.0	3.4	70%	30%	10%
Auditorium Area	30	50	90	2.0	4.4	70%	50%	20%
Auto Repair / Maintenance Area	18	60	80	0.0	2.6	40%	40%	10%
Barber, Beauty Salon and Spa Area	11	24	60	2.5	2.5	70%	50%	20%
Civic Meeting Place Area	11	18	30	2.5	3.8	80%	50%	20%
Classroom, Lecture, Training, Vocational Area	10	28	38	2.5	2.3	80%	50%	20%
Commercial/Industrial Storage: Warehouse	28	8	100	0.0	18.9	40%	40%	10%
Commercial/Industrial Storage: Shipping & Handling	24	30	60	0.0	6.0	40%	40%	10%
Concourse and Atria Area	30	60	200	0.0	3.3	50%	30%	20%
Convention, Conference, Multipurpose and Meeting Area	11	30	30	2.5	2.8	80%	50%	20%
Copy Room	10	10	20	2.5	5.6	80%	50%	20%
Corridor Area	10	8	80	0.0	6.9	80%	50%	20%
Dining Area: Bar/Lounge and Fine Dining	10	30	60	2.0	2.0	40%	40%	10%
Dining Area: Cafeteria/Fast Food	11	30	40	2.5	2.5	70%	50%	10%
Dining Area: Family and Leisure	11	40	60	2.5	1.8	70%	50%	10%
Kitchen/Food Preparation	11	15	30	2.5	4.3	70%	50%	20%

Primary Function Area	Ht.	Width (ft)	Len-gth (ft)	Work Plane ht (ft)	Nom. RCR	Ceil. Ref	Wall Ref	Floor Ref
Area								
Electrical, Mechanical, Telephone Rooms	18	30	40	3.0	4.4	70%	30%	10%
Exercise/Fitness Center and Gymnasium Area	12	40	60	0.0	2.5	40%	40%	10%
Financial Transaction Area	11	12	60	3.5	3.8	70%	50%	10%
General/Commercial & Industrial Work Area: Low Bay	16	60	80	3.0	1.9	50%	40%	20%
General/Commercial & Industrial Work Area: High Bay	30	100	120	3.0	2.5	50%	40%	20%
General/Commercial & Industrial Work Area: Precision	28	60	80	3.0	3.6	70%	50%	10%
Hotel Function Area	11	18	30	2.5	3.8	80%	50%	20%
Scientific Laboratory Area	11	21	32	3.0	3.2	80%	50%	20%
Laundry Area	11	40	30	3.5	2.2	70%	50%	20%
Library : Reading Area	11	24	30	2.5	3.2	80%	50%	10%
Library : Stacks Area	12	6	60	2.5	8.7	70%	30%	20%
Main Entry Lobby	20	60	30	2.5	4.4	70%	40%	10%
Locker Room	11	10	20	0.0	8.3	80%	40%	20%
Lounge, Breakroom, or Waiting Area	10	16	30	2.5	3.6	80%	50%	20%
Museum Area: Exhibition/Display	14	42	52	0.0	3.0	50%	30%	20%
Museum Area: Restoration Room	12	40	60	0.0	2.5	80%	50%	20%
Office Area: ≤ 250 square feet	9	10	14	2.5	5.6	80%	50%	20%
Office Area: > 250 square feet and ≤ xxx sf	10	20	30	2.5	3.1	80%	50%	20%
Office Area: Open plan office > xxx sf	10	40	60	2.5	1.6	80%	50%	20%
Parking Garage Area: Parking Zone	9	60	120	0.0	1.1	40%	40%	10%
Parking Garage Area: Dedicated Ramps	9	24	80	0.0	2.4	40%	40%	10%
Parking Garage Area: Daylight Adaptation Zones	9	30	66	0.0	2.2	40%	40%	10%

Primary Function Area	Ht.	Width (ft)	Len-gth (ft)	Work Plane ht (ft)	Nom. RCR	Ceil. Ref	Wall Ref	Floor Ref
Pharmacy Area	11	16	30	3.0	3.8	80%	50%	20%
Retail Sales Area: Grocery Sales	11	60	80	2.5	1.2	70%	50%	20%
Retail Sales Area: Retail Merchandise Sales	11	60	80	2.5	1.2	70%	50%	20%
Retail Sales Area: Fitting Room	9	6	10	0.0	12.0	70%	50%	20%
Religious Worship Area	30	80	100	2.5	3.1	70%	50%	10%
Restrooms	11	10	20	3.5	5.6	80%	50%	20%
Stairwell	10	12	30	0.0	5.8	40%	40%	20%
Theater Area: Motion picture	16	26	60	2.0	3.9	30%	10%	20%
Theater Area: Performance	40	100	160	2.0	3.1	50%	30%	20%
Transportation Function : Baggage Area	12	60	90	3.0	1.3	70%	50%	10%
Transportation Function : Ticketing Area	10	20	100	3.0	2.1	80%	50%	20%
Videoconferencing Studio	10	23	36	2.5	2.7	80%	50%	20%
Aging Eye/Low-vision: Main Entry Lobby	12	20	30	0.0	5.0	80%	50%	20%
Aging Eye/Low-vision: Stairwell	10	8	20	0.0	8.8	80%	50%	20%
Aging Eye/Low-vision: Corridor Area	10	8	80	0.0	6.9	80%	50%	20%
Aging Eye/Low-vision: Lounge/Waiting Area	11	30	30	2.5	2.8	80%	50%	20%
Aging Eye/Low-vision: Multipurpose Room	11	30	30	2.5	2.8	80%	50%	20%
Aging Eye/Low-vision: Religious Worship Area	12	18	28	3.0	4.1	70%	50%	20%
Aging Eye/Low-vision: Dining	11	40	40	2.5	2.1	80%	50%	20%
Aging Eye/Low-vision: Restroom	10	12	18	2.5	5.2	80%	50%	20%
Healthcare Facility and Hospitals: Exam/Treatment Room	10	10	12	3.0	6.4	80%	50%	20%
Healthcare Facility and Hospitals: Imaging Room	11	14	16	2.5	5.7	80%	50%	20%
Healthcare Facility and Hospitals: Medical Supply	12	40	30	3.0	2.6	80%	50%	20%

Primary Function Area	Ht.	Width (ft)	Len-gth (ft)	Work Plane ht (ft)	Nom. RCR	Ceil. Ref	Wall Ref	Floor Ref
Room								
Healthcare Facility and Hospitals: Nursery	11	20	40	3.0	3.0	80%	50%	20%
Healthcare Facility and Hospitals: Nurse's Station	11	10	20	0.0	8.3	80%	50%	20%
Healthcare Facility and Hospitals: Operating Room	12	30	30	3.0	3.0	80%	50%	20%
Healthcare Facility and Hospitals: Patient Room	10	12	16	3.0	5.1	80%	50%	20%
Healthcare Facility and Hospitals: Physical Therapy Room	11	30	40	3.0	2.3	80%	50%	20%
Healthcare Facility and Hospitals: Recovery Room	10	12	16	3.0	5.1	80%	50%	20%
Sports Arena – Playing Area: Class I Facility	40	50	100	0.0	6.0	50%	40%	20%
Sports Arena – Playing Area: Class II Facility	40	50	100	0.0	6.0	50%	40%	20%
Sports Arena – Playing Area: Class III Facility	24	50	100	0.0	3.6	50%	40%	20%
Sports Arena – Playing Area: Class IV Facility	24	50	100	0.0	3.6	50%	40%	20%

Appendix K: Color Tuning Analysis

The Statewide CASE Team conducted a detailed analysis on color tuning fixtures to determine efficacy changes since the 2019 code cycle. The analysis showed that efficacy has continued to increase for color tuning luminaires which has led the Statewide CASE Team to propose updated color tuning additional allowances. See the tables below for more details on the specific analyses and results.

Table 92 and Table 93 show the differences in efficacy between large aperture, color tuning 80 CRI 2x2 and 2x4 troffers. The Statewide CASE Team examined 112 color tuning products from five different manufacturers and calculated the efficacy difference compared to the static color versions by the same manufacturers. This was accomplished by developing average efficacies for each manufacturer comparing the efficacy differences between the static and color tuning products. The Statewide CASE Team found that the average loss in efficacy was only five percent as compared to nine percent in the 2019 code cycle. The Statewide CASE Team interpreted this analysis similarly to the 2019 code cycle, which is it verifies that no additional wattage adders are needed for large aperture, color tuning products because the efficacy losses are so minimal.

Table 92: 2x2 and 2x4 Troffers – 80 CRI Color Tuning Large Aperture

Manufacturer	Number of Products	2700K (LPW)	3000K (LPW)	3500K (LPW)	4000K (LPW)	4500K (LPW)	5000K (LPW)	5700K (LPW)	6500K (LPW)	Average LPW	Loss (%)
Manufacturer A	10	118	121	126	130	133	134	135	130	128	0%
Manufacturer B	10	118	121	123	127				128	123	4%
Manufacturer C	72		115	123	121		126			121	10%
Manufacturer D	8	91	89	95	98		102		110	98	9%
Manufacturer E	12	111	116	118	120		125		121	119	2%
Total	**112**										**5%**[a]

a. Average loss from the 2019 code cycle was 9%

Table 93: 2x2 and 2x4 Troffers – 80 CRI Static Color Large Aperture

Manufacturer	Number of Products	2700K (LPW)	3000K (LPW)	3500K (LPW)	4000K (LPW)	4500K (LPW)	5000K (LPW)	5700K (LPW)	6500K (LPW)	Average LPW	Baseline
Manufacturer A	28			126	130					128	100
Manufacturer B	40		124	127	132					128	100
Manufacturer C	72		131	133	136		141			135	100
Manufacturer D	20		105	108	112					108	100
Manufacturer E	48		116	119	121		129			121	100
Total	**208**										

Table 94 shows the differences in efficacy between small aperture (4 inch and 6 inch), color tuning 90 CRI luminaires and small aperture, static color 90 CRI luminaires. The Statewide CASE Team examined 166 color tuning products from six different manufacturers and calculated the efficacy difference compared to the static color versions by the same manufacturers. The Statewide CASE Team found that the average loss in efficacy was only 19 percent as compared to the 34 percent efficacy difference in the 2019 code cycle. This has shown that efficacy for small aperture, color tuning luminaires has almost doubled since the 2019 code cycle. The Statewide CASE Team has reduced the additional allowances for these products as this analysis has shown that additional wattage is still needed, but not nearly as much as in the 2019 code cycle.

Table 94: 90 CRI Color Tuning Small Aperture (4 inch / 6 inch) versus 90 CRI Static Color

Manufacturer	Number of Products	Average Loss (%)
Manufacturer A	45	26%
Manufacturer B	12	9%
Manufacturer C	58	18%
Manufacturer D	12	32%
Manufacturer E	21	24%
Manufacturer F	18	12%
Total	**166**	**19%**[a]

a. Average loss from the 2019 code cycle was 34%

Table 95 shows the differences in efficacy between small aperture (4 inch and 6 inch), dim-to-warm 90 CRI luminaires and small aperture, static color 90 CRI luminaires. The Statewide CASE Team examined 148 color tuning products from six different manufacturers and calculated the efficacy difference compared to the static color versions by the same manufacturers. The Statewide CASE Team found that the average loss in efficacy was only 14 percent as compared to the 21 percent efficacy difference in the 2019 code cycle. This has shown that efficacy for small aperture, dim-to-warm luminaires has increased substantially since the 2019 code cycle. The Statewide CASE Team has reduced the additional allowances for these products as this analysis has shown that additional wattage is still needed, but not nearly as much as in the 2019 code cycle.

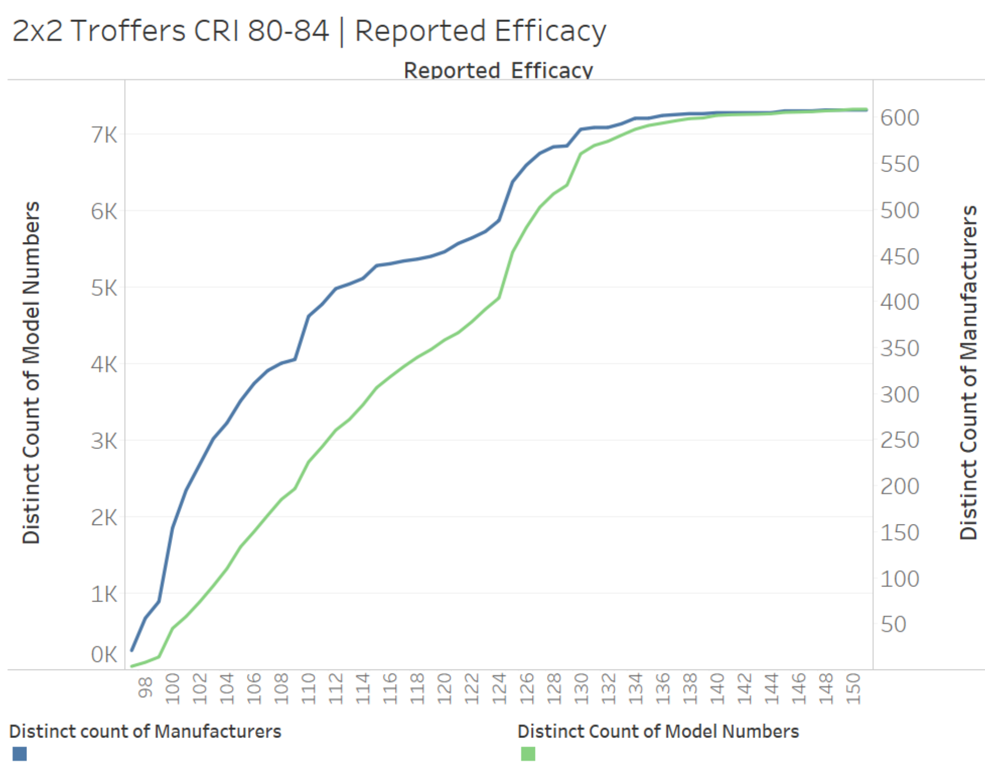
Table 95: 90 CRI Dim-to-Warm Small Aperture (4 inch / 6 inch) versus 90 CRI Static Color

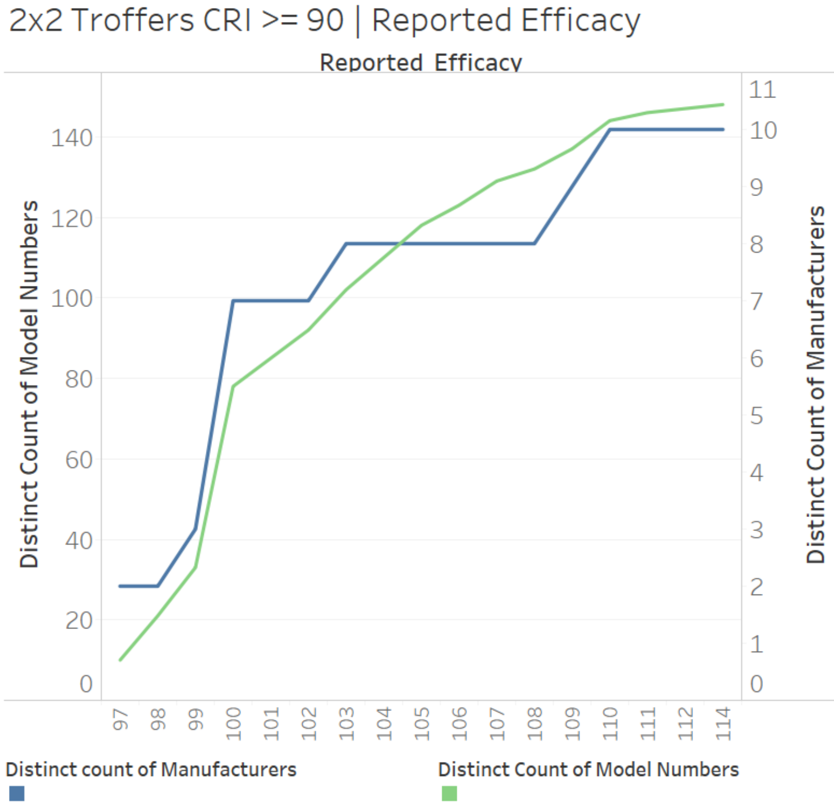
Manufacturer	Number of Products	Average Loss (%)
Manufacturer A	45	14%
Manufacturer B	12	5%
Manufacturer C	58	7%
Manufacturer D	12	27%
Manufacturer E	21	2%
Total	**148**	**14%**[a]

a. Average loss from the 2019 code cycle was 21%

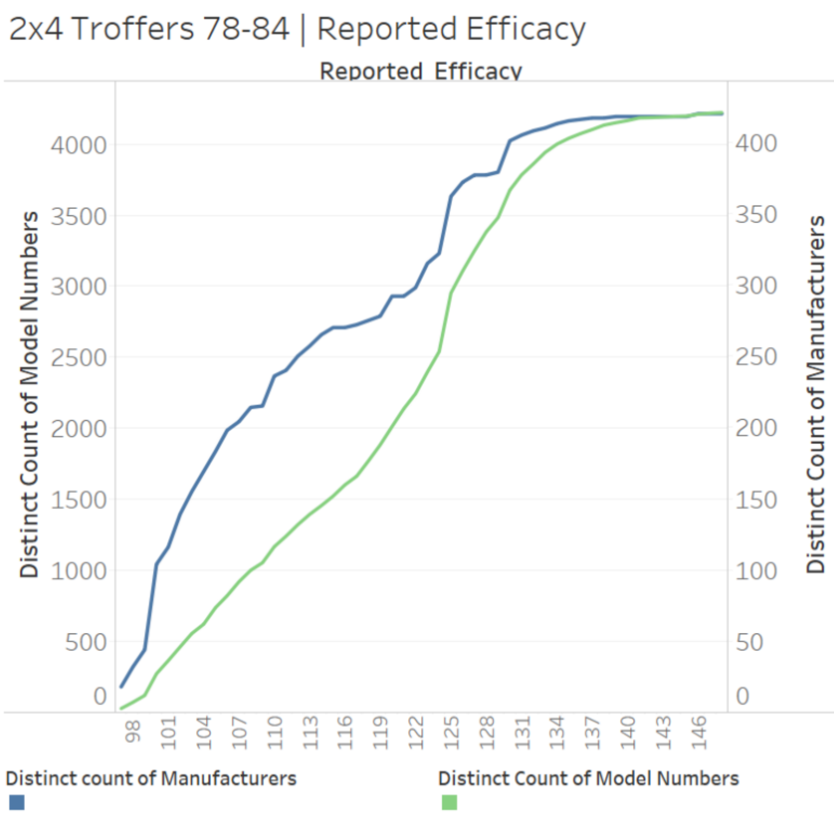
Appendix L: Market Analysis Data

Data was extracted from DLC on December 18th, 2019 and will be updated with an updated data extraction for the final CASE Report.

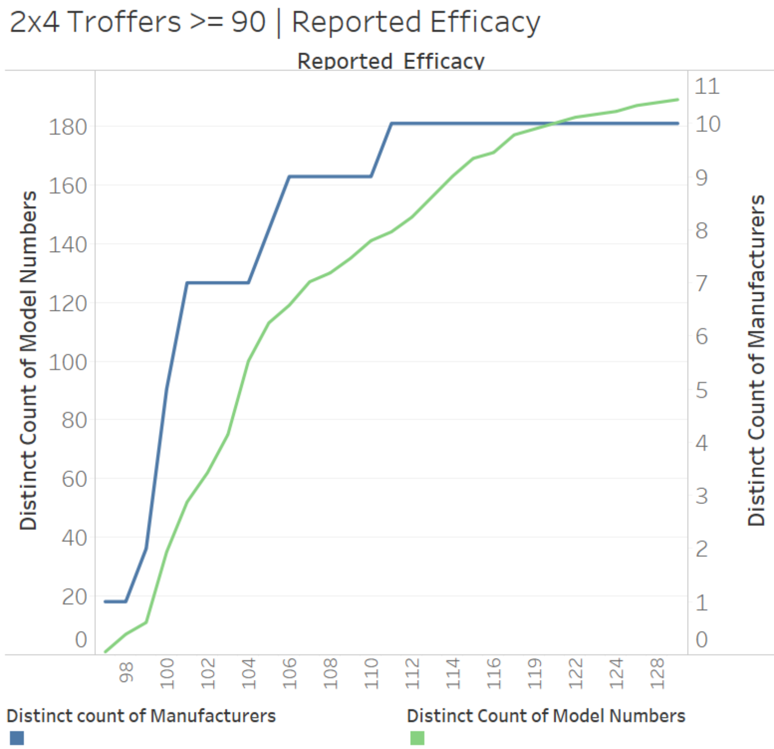




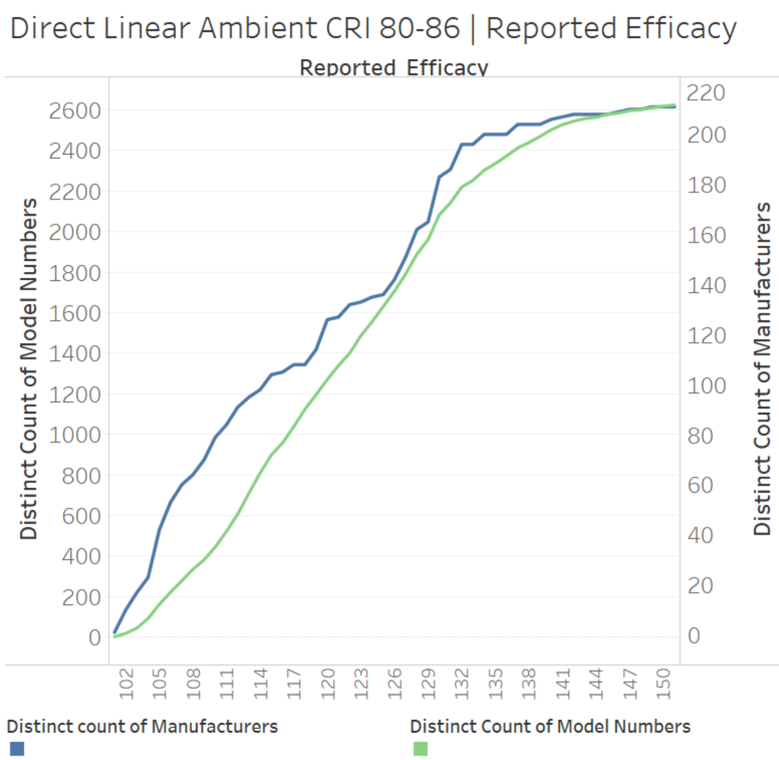
2x2 Troffers CRI >= 90 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
7
8
9
10
11
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
114
Distinct count of Manufacturers
Distinct Count of Model Numbers



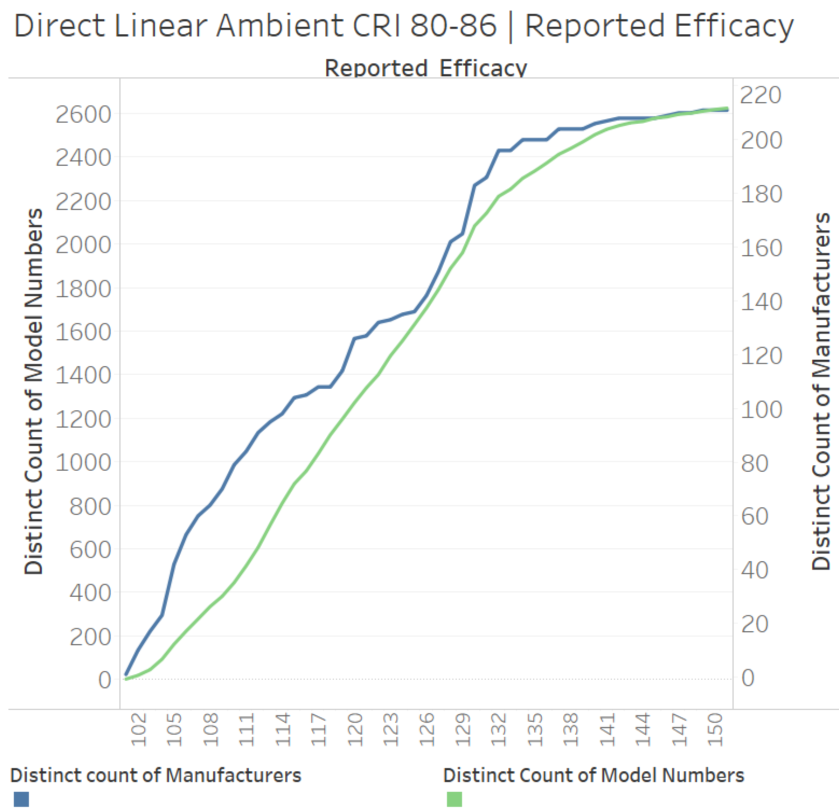
2x4 Troffers 78-84 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
0
500
1000
1500
2000
2500
3000
3500
4000
0
50
100
150
200
250
300
350
400
98
101
104
107
110
113
116
119
122
125
128
131
134
137
140
143
146
Distinct count of Manufacturers
Distinct Count of Model Numbers

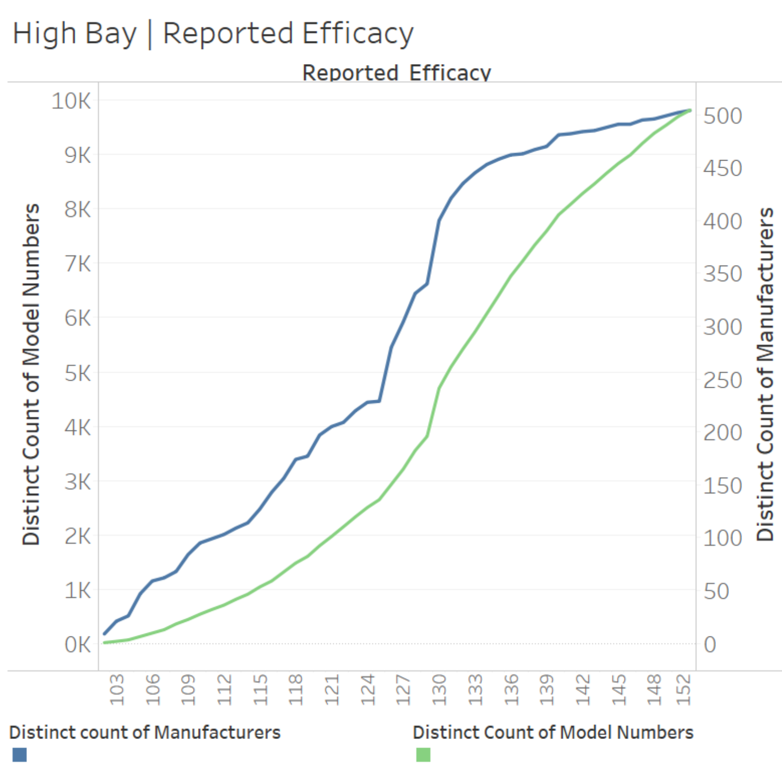


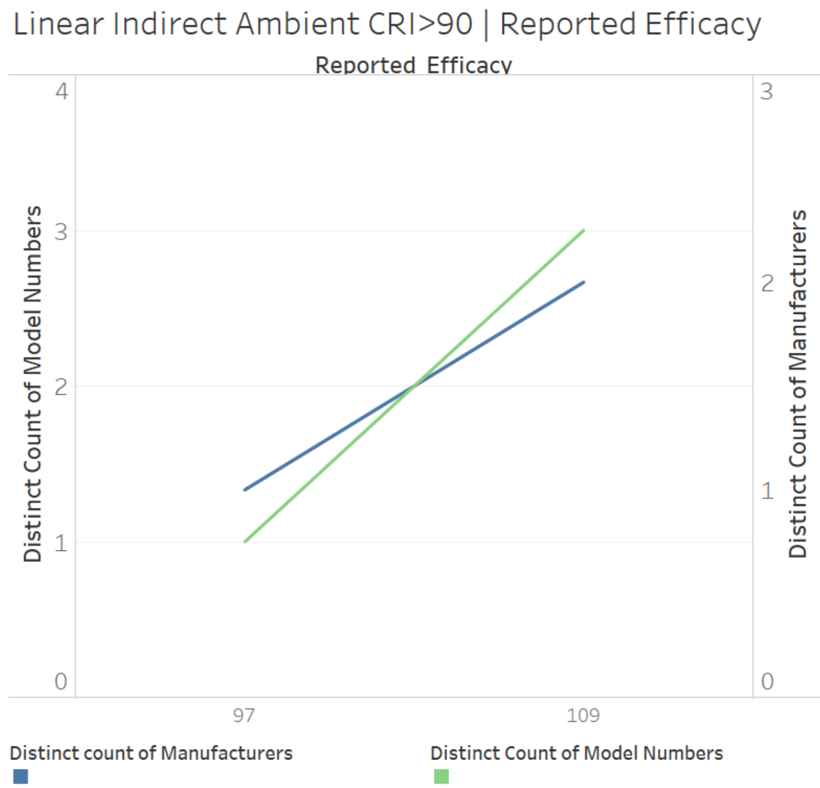
2x4 Troffers >= 90 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
0
20
40
60
80
100
120
140
160
180
0
1
2
3
4
5
6
7
8
9
10
11
98
100
102
104
106
108
110
112
114
116
119
122
124
128
Distinct count of Manufacturers
Distinct Count of Model Numbers



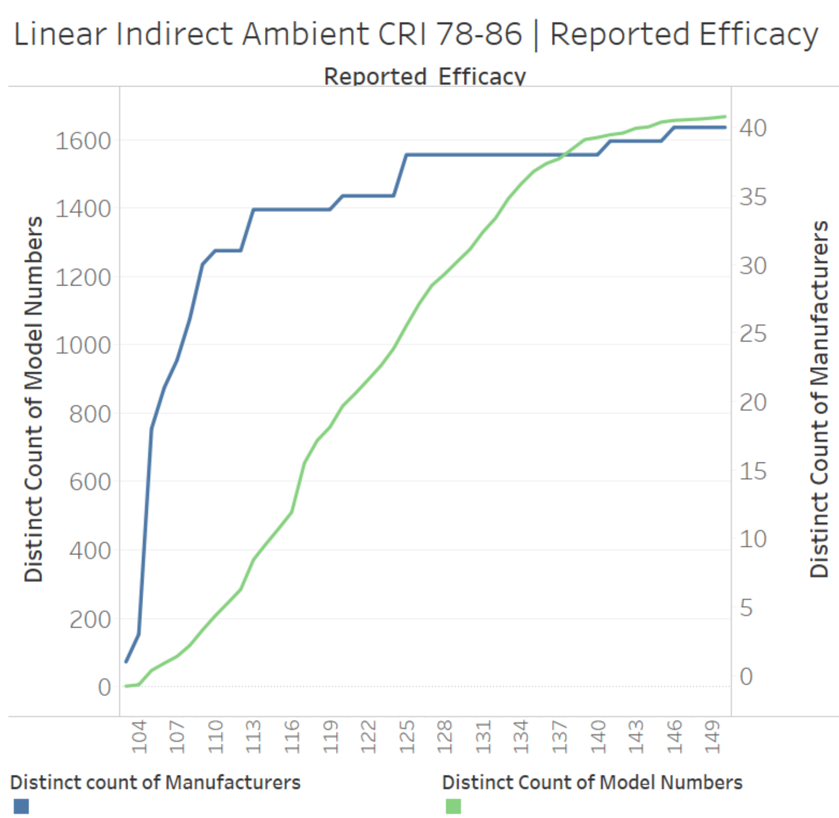
Direct Linear Ambient CRI 80-86 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
0
20
40
60
80
100
120
140
160
180
200
220
102
105
108
111
114
117
120
123
126
129
132
135
138
141
144
147
150
Distinct count of Manufacturers
Distinct Count of Model Numbers


Direct Linear Ambient CRI 80-86 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
220
200
180
160
140
120
100
80
60
40
20
0
102
105
108
111
114
117
120
123
126
129
132
135
138
141
144
147
150
Distinct count of Manufacturers
Distinct Count of Model Numbers


High Bay | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
10K
9K
8K
7K
6K
5K
4K
3K
2K
1K
0K
500
450
400
350
300
250
200
150
100
50
0
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
152
Distinct count of Manufacturers
Distinct Count of Model Numbers

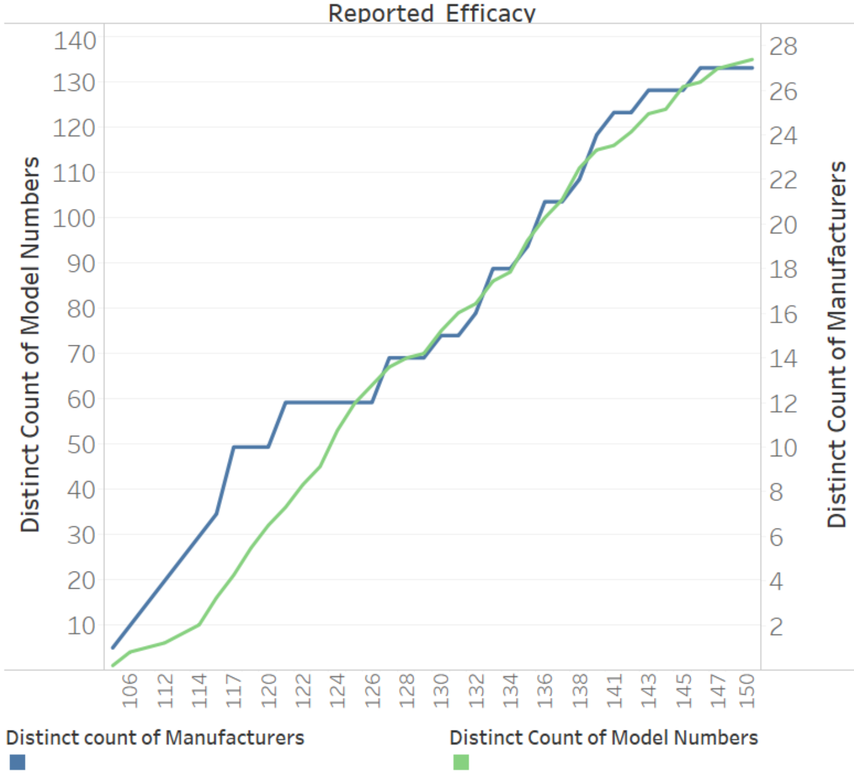


Linear Indirect Ambient CRI>90 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
4
3
2
1
0
97
109
Distinct count of Manufacturers
Distinct Count of Model Numbers

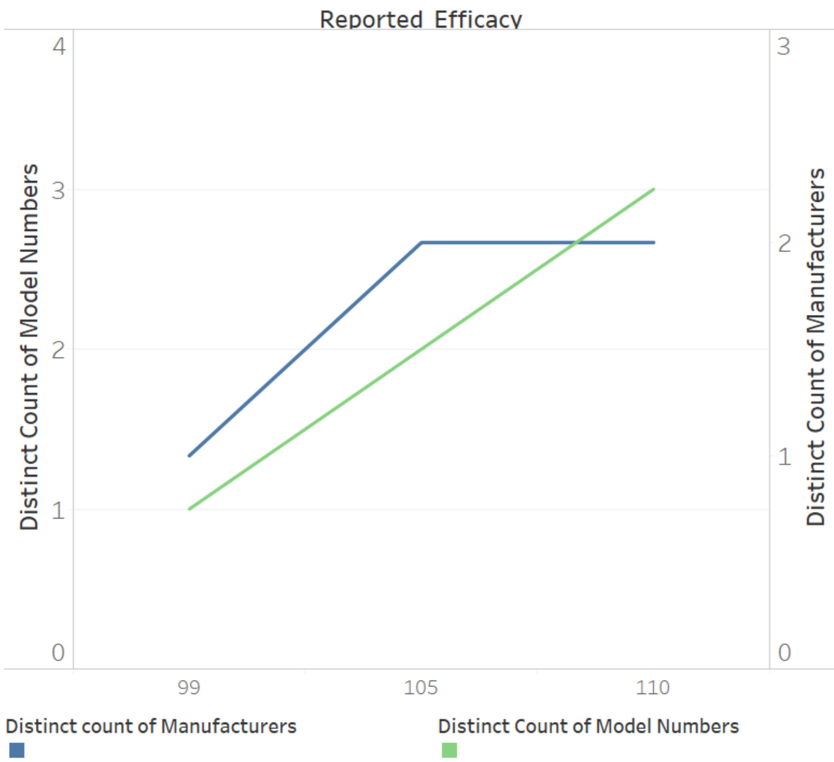


Linear Indirect Ambient CRI 78-86 | Reported Efficacy
Reported Efficacy
Distinct Count of Model Numbers
Distinct Count of Manufacturers
1600
1400
1200
1000
800
600
400
200
0
40
35
30
25
20
15
10
5
104
107
110
113
116
119
122
125
128
131
134
137
140
143
146
149
Distinct count of Manufacturers
Distinct Count of Model Numbers

Low Bay | Reported Efficacy



Sports Flood | Reported Efficacy



Appendix M: Nominal TDV Energy Cost Savings

In Section 2.4 and Section 3.4 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 presents 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.

Multi-Zone Occupancy in Large Offices Nominal TDV Energy Cost Savings

Table 96. Office Models Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction, Alterations, and Additions for Multi-Zone Occupancy in Large Offices

Model Office Floor Plan	**Climate Zone**	**15-Year TDV Electricity Cost Savings (Nominal $)**	**15-Year TDV Natural Gas Cost Savings (Nominal $)**	**Total 15-Year TDV Energy Cost Savings (Nominal $)**
Model Office A (2,584 ft^2)	All	$1.98	N/A	$1.98
Model Office B (4,000 ft^2)	All	$2.04	N/A	$2.04
Model Office C (7,540 ft^2)	All	$2.36	N/A	$2.36
Average	All	$2.13	N/A	$2.13

Table 97: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction, Alterations, and Additions

Impacted Prototypical Building Types	Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
Small Office	All	$0.76	N/A	$0.76
Large Office	All	$0.98	N/A	$0.98
Retail	All	$0.08	N/A	$0.08
Non-Refrigerated Warehouse	All	$0.07	N/A	$0.07
Refrigerated Warehouse	All	$0.05	N/A	$0.05
Schools	All	$0.12	N/A	$0.12
Colleges	All	$0.09	N/A	$0.09
Hospitals	All	$0.06	N/A	$0.06

Lighting Power Densities Nominal TDV Energy Cost Savings

Table 98: Statewide Nominal Energy Cost Savings Over 15-Year Period of Analysis

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nom $)	1st Yr Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nom $)
Audience Seating Area	2.8	1.4	$5.1	8.5	4.3	$15.3
Auditorium Area	2.4	0.4	$1.4	7.3	1.2	$4.4
Auto Repair / Maintenance Area	4.8	0.7	$2.1	14.8	2.1	$6.4
Barber, Beauty Salon and Spa Area	0.5	0.4	$1.2	1.7	1.2	$3.8
Civic Meeting Place Area	1.4	0.7	$2.5	4.1	2.1	$7.4
Classroom, Lecture, Training, Vocational Area	7.5	1.0	$3.2	27.6	3.6	$11.9
Commercial/Industrial Storage: Warehouse	23.4	2.0	$5.9	71.6	6.2	$18.1
Commercial/Industrial Storage: Shipping & Handling	5.7	0.0	$0.0	17.2	0.0	$0.0
Concourse and Atria Area	2.0	2.5	$8.1	6.2	7.7	$24.8
Convention, Conference, Multipurpose and Meeting Area	7.0	3.5	$12.6	21.5	10.9	$38.6
Copy Room	0.2	0.0	$0.0	0.6	0.0	$0.0
Corridor Area	11.6	-1.4	-$4.3	36.7	-4.3	-$13.4
Dining Area: Bar/Lounge and Fine Dining	0.5	0.3	$1.2	1.4	1.0	$3.5
Dining Area: Cafeteria/Fast Food	2.2	0.0	$0.0	6.9	0.0	$0.0
Dining Area: Family and Leisure	0.9	0.6	$2.2	2.5	1.8	$6.4

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nom $)	1st Yr Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nom $)
Kitchen/Food Preparation Area	3.0	0.0	$0.0	9.1	0.0	$0.0
Electrical, Mechanical, Telephone Rooms	3.3	0.0	$0.0	10.5	0.0	$0.0
Exercise/Fitness Center and Gymnasium Area	2.1	0.0	$0.0	7.3	0.0	$0.0
Financial Transaction Area	1.1	0.4	$1.2	3.2	1.1	$3.5
General/Commercial & Industrial Work Area: Low Bay	3.0	0.0	$0.0	9.2	0.0	$0.0
General/Commercial & Industrial Work Area: High Bay	0.8	0.0	$0.0	2.5	0.0	$0.0
General/Commercial & Industrial Work Area: Precision	0.2	0.0	$0.0	0.5	0.0	$0.0
Hotel Function Area	0.5	0.1	$0.3	1.3	0.2	$0.8
Scientific Laboratory Area	0.5	0.2	$0.6	1.8	0.7	$2.2
Laundry Area	0.2	0.0	$0.0	0.5	0.0	$0.0
Library : Reading Area	0.8	0.1	$0.3	2.5	0.3	$0.9
Library : Stacks Area	0.5	0.1	$0.4	1.8	0.4	$1.3
Main Entry Lobby	7.6	5.1	$18.2	23.5	15.8	$56.2
Locker Room	0.4	0.0	$0.0	1.5	0.0	$0.0
Lounge, Breakroom, or Waiting Area	2.8	1.4	$5.0	8.7	4.4	$15.6
Museum Area: Exhibition/Display	0.1	0.0	$0.0	0.3	0.0	$0.0
Museum Area: Restoration Room	0.0	0.0	$0.0	0.0	0.0	$0.0
Office Area: ≤ 250 square feet	11.4	1.3	$4.2	35.0	4.1	$12.8
Office Area: > 250 square feet and ≤ xxx sf	5.7	0.7	$2.1	17.2	2.0	$6.3
Office Area: Open plan office > xxx sf	7.4	0.0	$0.0	22.2	0.0	$0.0

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nom $)	1st Yr Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nom $)
Parking Garage Area: Parking Zone	4.5	0.0	$0.0	13.4	0.0	$0.0
Parking Garage Area: Dedicated Ramps	0.4	0.4	$1.5	1.2	1.3	$4.4
Parking Garage Area: Daylight Adaptation Zones	0.1	-0.3	-$1.2	0.3	-1.0	-$3.7
Pharmacy Area	0.1	0.0	$0.1	0.3	0.1	$0.3
Retail Sales Area: Grocery Sales	4.1	0.7	$2.4	12.8	2.3	$7.3
Retail Sales Area: Retail Merchandise Sales	12.5	2.2	$7.1	38.6	6.8	$21.9
Retail Sales Area: Fitting Room	0.3	0.0	$0.0	0.9	0.0	$0.0
Religious Worship Area	3.4	0.6	$2.0	10.1	1.7	$6.1
Restrooms	5.5	0.0	$0.0	17.3	0.0	$0.0
Stairwell	2.3	0.3	$0.8	7.0	0.8	$2.6
Theater Area: Motion picture	0.9	0.7	$2.6	2.6	2.2	$7.7
Theater Area: Performance	0.7	0.6	$2.1	2.1	1.8	$6.3
Transportation Function : Baggage Area	0.0	0.0	$0.0	0.1	0.0	$0.0
Transportation Function : Ticketing Area	0.0	0.0	$0.0	0.1	0.0	$0.0
Videoconferencing Studio	0.0	0.0	$0.0	0.0	0.0	$0.0
Aging Eye/Low-vision: Main Entry Lobby	0.0	0.0	$0.0	0.1	0.0	$0.0
Aging Eye/Low-vision: Stairwell	0.0	0.0	$0.0	0.0	0.0	$0.0
Aging Eye/Low-vision: Corridor Area	0.0	0.0	$0.0	0.1	0.0	$0.0
Aging Eye/Low-vision: Lounge/Waiting Area	0.0	0.0	$0.0	0.1	0.0	-$0.1

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nom $)	1st Yr Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nom $)
Aging Eye/Low-vision: Multipurpose Room	0.0	0.0	$0.1	0.1	0.0	$0.1
Aging Eye/Low-vision: Religious Worship Area	0.0	0.0	$0.0	0.0	0.0	$0.0
Aging Eye/Low-vision: Dining	0.0	0.0	$0.0	0.0	0.0	$0.0
Aging Eye/Low-vision: Restroom	0.0	0.0	$0.0	0.0	0.0	$0.0
Healthcare Facility and Hospitals: Exam/Treatment Room	2.3	0.0	$0.0	7.9	0.0	$0.0
Healthcare Facility and Hospitals: Imaging Room	0.1	0.0	$0.1	0.3	0.1	$0.3
Healthcare Facility and Hospitals: Medical Supply Room	0.1	0.0	$0.0	0.3	0.0	$0.0
Healthcare Facility and Hospitals: Nursery	0.1	0.0	$0.1	0.3	0.1	$0.4
Healthcare Facility and Hospitals: Nurse's Station	0.0	0.0	-$0.1	0.2	-0.1	-$0.4
Healthcare Facility and Hospitals: Operating Room	0.1	0.0	$0.0	0.3	0.0	$0.0
Healthcare Facility and Hospitals: Patient Room	0.3	-0.1	-$0.4	1.1	-0.5	-$1.5
Healthcare Facility and Hospitals: Physical Therapy Room	0.2	0.1	$0.2	0.7	0.2	$0.6
Healthcare Facility and Hospitals: Recovery Room	0.2	0.0	$0.0	0.6	0.0	$0.0
Sports Arena – Playing Area: Class I Facility	0.1	0.0	$0.0	0.2	0.0	$0.0
Sports Arena – Playing Area: Class II	0.0	0.0	$0.0	0.0	0.0	$0.0

Primary Function Area	Statewide New Construction (M sf/yr)	NC Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nom $)	1st Yr Statewide Alterations (M sf/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nom $)
Facility						
Sports Arena – Playing Area: Class III Facility	0.0	0.0	$0.0	0.0	0.0	$0.0
Sports Arena – Playing Area: Class IV Facility	0.0	0.0	$0.0	0.0	0.0	$0.0
Statewide Totals	**162.7**	**26.7**	**$90.6**	**506.5**	**82.4**	**$279.1**

Appendix N: Very Valuable Display LPD Models

The following models were used by the Statewide CASE Team to update the very valuable display case LPDs under the tailored method. The Statewide CASE Team used the same models utilized during the 2019 analysis with updated values to reflect new lamp and luminaire values. Table 99 and provide a summary of the analysis.

Table 99: Summary of Analysis for Very Valuable Display Lighting Power Density Update

Models	2019 Wattage	2022 Wattage
Model A	5.75 W	5.00 W
Model B	9.75 W	8.50 W
Model C	8.00 W	7.00 W
Model D	8.50 W	7.20 W
Model Average	8.05 W	6.93 W

Table 100: Types of Lighting and Wattages Used in Model A for Very Valuable Display Lighting Power Densities

Model A Item	2019 Model	Factor	2022 Model
Rail Light	22 W	0.864	19 W
Down Lights	24 W	0.877	21 W
Total Watts / Average Factor	46 W	0.871	40 W
Size / Footprint	8 ft^2		8 ft^2
Case Top LPD	5.75 W		5.00 W

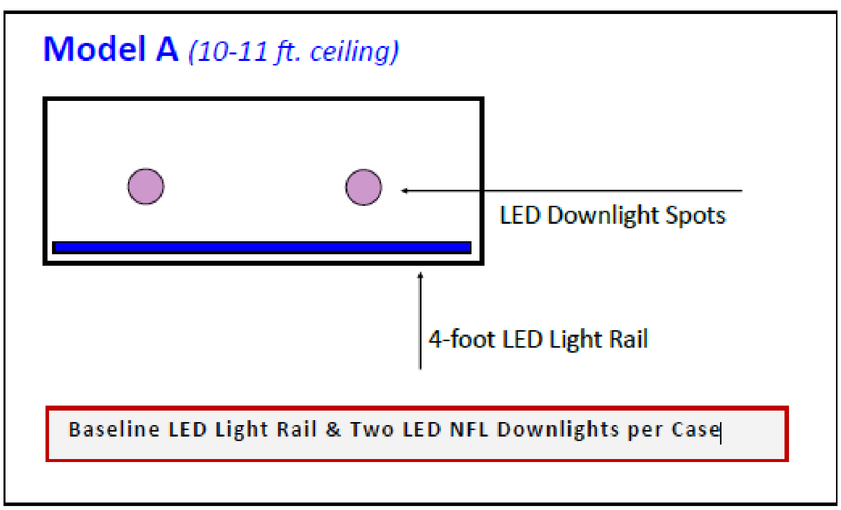


Figure 16: Model A (10’ to 11’ ceiling) used for updating very valuable display lighting power densities.

Table 101: Types of Lighting and Wattages Used in Model B for Very Valuable Display Lighting Power Densities

Model B Item	2019 Model	Factor	2022 Model
Rail Light	26 W	0.864	22 W
Down Lights	52 W	0.877	46 W
Total Watts / Average Factor	78 W	0.871	68 W
Size / Footprint	8 ft^2		8 ft^2
Case Top LPD	9.75 W		8.50 W

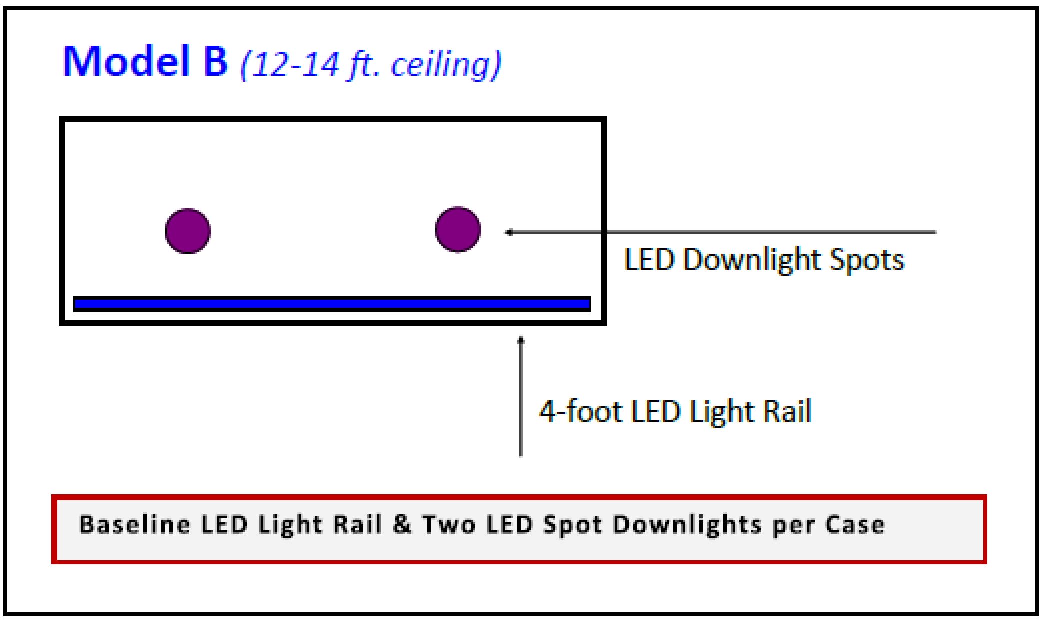


Figure 17: Model B (12' to 14' ceiling) used for updating very valuable display lighting power densities.

Table 102: Types of Lighting and Wattages Used in Model C for Very Valuable Display Lighting Power Densities

Model A Item	2019 Model	Factor	2022 Model
Front Rail Light	11 W	0.864	10 W
Rear Rail Light	9 W	0.864	8 W
Casework Accents	12 W	0.822	10 W
Total Watts / Average Factor	32 W	0.850	28 W
Size / Footprint	4 ft^2		4 ft^2
Case Top LPD	8.00 W		7.00 W

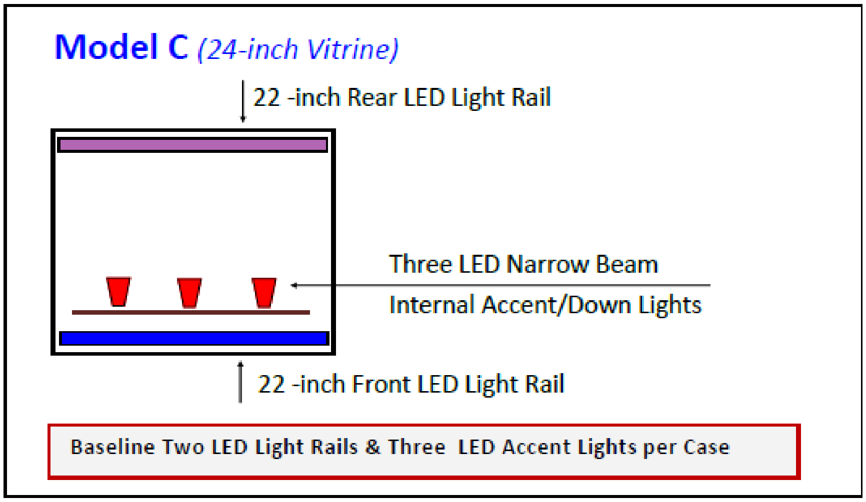


Figure 18: Model C (24" vitrine) used for updating very valuable display lighting power densities.

Table 103: Types of Lighting and Wattages Used in Model D for Very Valuable Display Lighting Power Densities

Model A Item	2019 Model	Factor	2022 Model
Rail Light A	27 W	0.864	10 W
Rail Light B	27 W	0.864	8 W
Casework Pucks	48 W	0.822	10 W
Total Watts / Average Factor	102 W	0.850	28 W
Size / Footprint	12 ft^2		4 ft^2
Case Top LPD	8.50 W		7.20 W

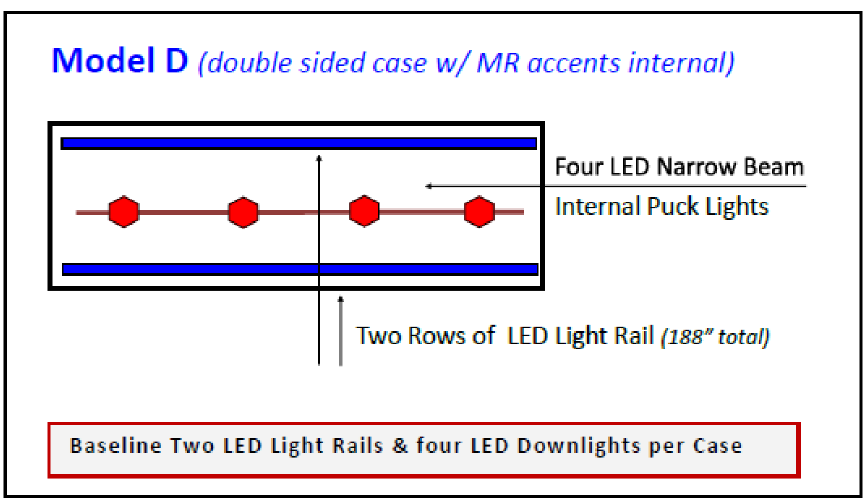


Figure 19: Model D (double sided case with internal multifaceted reflector lamps) used for updating very valuable display lighting power densities.

Appendix O: Tailored Method General Lighting Power Allowed Calculations

Though average efficacy of LEDs has not changed much in the last three years, the efficacy of high CRI (defined as having a CRI of 90 or above) has increased. An assumption used for the tailored lighting models in the 2019 and 2022 standards development is that designers who require more lighting power to have a more layered lighting design are likely to require high CRI for their designs. Thus the basis of the general lighting allowance for the tailored lighting method is high CRI downlights. The Statewide CASE Team evaluated the 5 downlight products that were the basis of the general lighting allowance for the tailored lighting method used for the development of the 2019 Title 24 standards and compared that wattage with the wattage required to provide the same luminous flux from similar products available in 2020. The ratio of the 2022 wattage to the 2019 is the wattage factors given in the table below.

Table 104: 2019 90 CRI vs 2022 90 CRI luminaires for Tailored Compliance General Lighting

2019 Luminaire Models	Watts	Lumens	2022 Luminaire Models	Watts	Lumens	Wattage Factor
Downlight Model 1	22	1455	Downlight Model 1	22	2050	0.72
Downlight Model 2	17	1350	Downlight Model 2	17	1550	0.84
Downlight Model 3	29	2460	Downlight Model 3	29	2718	0.90
Downlight Model 4	44	2660	Downlight Model 4	44	3690	0.75
Downlight Model 5	36	2750	Downlight Model 5	36	3020	0.88
Average Power Adjustment Factor						**0.818**

During the development of the 2019 standards 8 inch and 6 inch diameter downlights were used in the model used for developing the tailored lighting general lighting power allowances. This reflected common practice for LED downlights at that time as the extra diameter was desirable for rejecting heat so the LEDs could operate efficiently. With improvements in LED technology, the loss in efficacy of LED downlights is not as significant as it was in 2019 and thus as a result, more 4 inch diameter downlights are being used. The table below summarizes the findings of the Statement CASE Team's analysis of the efficacies of 53 currently available products that were either 4", 6" or 8" from 6 manufacturers. Overall currently available 4" diameter products have an efficacy that is 89.5% that of 6" and 8" diameter products. As a result, for the same light output these 4" downlights require 13 percent more power.

Table 105: Efficacy Impact of Decreasing Downlight diameter from 6" or 8" to 4"

Manufacturer	Relative Efficacy	Wattage Factor
Manuf A	0.990	1.010
Manuf B	0.950	1.053
Manuf C	1.020	0.980
Manuf D	0.750	1.333
Manuf E	0.850	1.176
Manuf F	0.810	1.235
Average	**0.895**	**1.131**

The updated model accounts for this design shift by assuming that 25 percent of the downlights in these models would be converted from 6" or 8" to 4" diameter. When the wattage factor accounting for the efficacy increase of 90 CRI products from the development of the 2019 standard to those evaluated for the 2022 is combined with wattage adjustment to account for greater use of 4" diameter downlights, the overall wattage adjustment factor is 0.845 as shown in the table below.

Table 106: Calculation of overall 2019 to 2022 and diameter wattage ratio

Variable Descriptions	Values
90 CRI downlights 2019 to 2022 wattage ratio	82%
6" and 8" diameter vs 4" diameter wattage ratio	113%
Fraction downlights converted to 4" diameter	25%
Weighted 8/6" diameter to 4" dia wattage ratio	1.03
Total adjustment 2022 and diameter	**0.845**

This adjustment factor was applied to the prior 2019 tailored lighting method models for 20, 40 and 70 footcandles (200, 400 and 700 lux) highlighted in yellow below. The other illuminance values (150, 300, 500, and 600 lux) are interpolated from the models as are the values for room cavity ratios (RCR) greater than 7. Note that almost all of the 2022 proposed general LPDs are greater than the adjusted 2019 models and rounded to multiples of 0.05 W/sf.

Table 107: 2019 Tailored Lighting General Illuminance Model Adjusted by Overall 2019 to 2022 and Diameter Wattage Ratio

RCR <2						
Illuminance (lux)	**2019 Model**	**2019 Adopted**	**2022 Factor**	**2019 Model x Factor**	**2022 Proposed**	**2019 Adopted x Factor**
150	0.30	0.40	0.845	0.25	0.35	0.34
200	**0.40**	0.45	**0.845**	**0.34**	0.40	0.38
300	0.60	0.65	0.845	0.51	0.55	0.55
400	**0.72**	0.75	**0.845**	**0.61**	0.65	0.63
500	0.90	0.90	0.845	0.76	0.80	0.76
600	1.08	1.08	0.845	0.91	0.90	0.91
700	**1.26**		0.845	1.06		
RCR >2 & <3.5						
Illuminance (lux)	**2019 Model**	**2019 Adopted**	**Factor**	**2022 Model**	**2022 Proposed**	**2019 Adopted x Factor**
150	0.33	0.45	0.845	0.28	0.40	0.38
200	**0.44**	0.55	**0.845**	**0.37**	0.50	0.46
300	0.64	0.80	0.845	0.54	0.70	0.68
400	**0.84**	0.95	**0.845**	**0.71**	0.80	0.80
500	1.05	1.05	0.845	0.89	0.90	0.89
600	1.26	1.24	0.845	1.06	1.05	1.05
700	**1.42**		0.845	**1.20**		
RCR >3.5 & <7.0						
Illuminance (lux)	**2019 Model**	**2019 Adopted**	**Factor**	**2022 Model**	**2022 Proposed**	**2019 Adopted x Factor**
150	0.42	0.60	0.845	0.35	0.50	0.51
200	**0.56**	0.75	**0.845**	**0.47**	0.65	0.63
300	0.84	1.00	0.845	0.71	0.85	0.84
400	**1.12**	1.25	**0.845**	**0.95**	1.05	1.06
500	1.40	1.45	0.845	1.18	1.25	1.23
600	1.64	1.64	0.845	1.39	1.40	1.39
700	**1.83**		0.845	**1.55**		
RCR > 7.0						
Illuminance (lux)	**Extrapolated 2019 Model**	**2019 Adopted**	**Factor**	**2022 Model**	**2022 Proposed**	**2019 Adopted x Factor**
150	0.63	0.75	0.845	0.53	0.65	0.63
200	0.85	1.00	0.845	0.72	0.85	0.84
300	1.32	1.40	0.845	1.12	1.20	1.18
400	2.08	1.50	0.845	1.76	1.25	1.27
500	2.32	1.85	0.845	1.96	1.55	1.56
600	2.60	2.38	0.845	2.20	2.00	2.01

Appendix P: Tailored Method Floor and Wall Lighting Power Allowed Calculations

Figure 20 and Table 108 within this appendix document the results of applying the models that were used by the Statewide Case Team for the 2019 code cycle to update the Floor and Wall Lighting Power Allowed LPD's under the tailored method. The Statewide CASE Team used the same models employed during the 2019 analysis with updated values to reflect new lamp and luminaire efficacy gains. Table 108 illustrates the efficacy improvements of 90+ CRI LED lamps and luminaires since the modeling for the 2019 code.

These improved efficacy of 90+ CRI product resulted in 13% gain for Floor display and 3% gain for Wall display lumen output for the same LPD allowed under Tailored Lighting 2019 code. Converting these percentage improvements were converted to factors of 0.87 for floor accent lighting and 0.97 for wall accent lighting that were then applied to the 2019 allowed LPD for Floor and Wall Accent Lighting to determine the allowed LPD,s indicated on Table 140.6D within Section 3.6.2 of this case report.

FLOOR ACCENT & DISPLAY (Sq. Ft. Basis)

	Baseline LED T24-2019 9Ft. To 11Ft. Ceilings				Improved Efficacy LED-T24-2020 (90+CRI)				2020 LED Adjustment	
	LAMP	WATTS	LUMENS	CRI	LAMP	WATTS	LUMENS	CRI	AVE W	AVE lm
	MR16 Equiv.	9	430	90-96	MR LED	7.5	410	90-96	8.25	450
	PAR20 Equiv.	11	520	90-96	PAR LED	6.5	580	90-96	8.5	560
	PAR30 Equiv.	14	850	90+	LED Sp/Fl	12	990	90-96	13	1105
	PAR28 Equiv.	18	1320	90+	LED Sp/Fl	16	1360	90+	16	1320

Figure 20: Tailored method floor, accent, and display lighting power density calculations on a square foot basis.

Table 108: Tailored Method Floor, Accent, and Display Lighting Power Density Calculations on a Square Foot Basis – Improved Efficacy LEDs

Lamp	Watts	Lumens	CRI	Average Watts	Average Lumens
MR LED	7.5	410	90-96	8.25	450

PAR LED	6.5	580	90-96	8.5	560
LED Sp/Fl	12	990	90-96	13	1105
LED Sp/Fl	16	1,360	90+	16	1320

Appendix Q: Tailored Lighting Ornamental/Special Effect Lighting

Figure 21, Figure 22, Figure 23 and Table 109, within this appendix, document the results of updating the Ornament /Special Effects Lighting models that were used by the Statewide Case Team in developing the 2019 code cycle to reflect the efficiency improvements of the 90+ CRI lamps and luminaires used for the 2019 modeling.

Table 109 contains the results of the efficacy improvements of various LED luminaires and lamps since the 2019 modeling was conducted. These efficacy improvements were converted to adjustment factors for each model type and a weighted average applied to which resulted in the 0.883 factor used to determine the LPD for Allowed Ornamental/ Special Effect Lighting indicted on Table 140.6D within Section 3.6 of this case report.

Candelabra

Title 24 2011-2016			Title 24 2019 Model	Title 24 2022 Model
25 W	Halogen	20%		
7 W	CFL	80%		
11 W	AVE	100%	4 to 6 W 90+CRI	3 to 5 W 90+CRI
			5 W Ave	4 W Ave
			5 2019 Baseline	FACTOR: 0.80

Shade

Title 24 2011-2016			Title 24 2019 Proposed	Title 24 2022 Model
43 W	Halogen	10%		
13 W	CFL	90%		
19 W	AVE	100%	10 to 14 W 90+CRI	9 to 12 W 90+CRI
			12 W Ave	11.5 W 90+CRI
			12 2019 Baseline	FACTOR: 0.96

Pendant

Title 24 2011-2016			Title 24 2019 Proposed	
43 W	Halogen	10%		
13 W	CFL	90%		
16 W	AVE	100%	12 to 14 W 95+-CRI	9 to 12 W 90+CRI
			13 W Ave	11.5 W 90+CRI
			13 2019 Baseline	FACTOR: 0.89

Figure 21: Wall Sconce and Pendant Models

Candelabra

Title 24 2011-2016			Title 24 2019 Model	Title 24 2022 Model
150 W	Halogen	40%		
54 W	CFL	60%		
92 W	AVE	100%	36 to 50 W 90+CRI	30 to 36 W 90+CRI
			43 W Ave	36 W Ave
			43 2019 Baseline	FACTOR: 0.84

Shade

Title 24 2011-2016			Title 24 2019 Model	Title 24 2022 Model
432 W	Halogen	10%		
178 W	CFL	90%		
202 W	AVE	100%	105 W 90+CRI	96 to 102 W 90+CRI
			105 W Ave	99.5 W Ave
			105 2019 Baseline	FACTOR: 0.95

Large Up-Light

Title 24 2011-2016			Title 24 2019 Model	Title 24 2022 Model
200 W	HP-CFL	85%		
300 W	CMH	15%		
215 W	AVE	100%	178 W 80+CRI	144 to 170 W 90+CRI
			178 W Ave	157 W 90+CRI
			178 2019 Baseline	FACTOR: 0.88

Figure 22: Chandelier Models

4-foot X 10-foot Model

Title 24 2011-2016		Title 24 2019 Proposed		Title 24 2022 Model
142 W	100% LED	136 W	100% LED	
	80CRI		90CRI	
		12 to 14 W	95+-CRI	120 W 90+CRI
				120 W Ave
		136 2019 Baseline		FACTOR: 0.88

Figure 23: Luminous Wall Panel Model

Table 109: Ornamental Special Effect Lighting Summary

Type of Lighting System	LED Factor
Candelabra Wall Sconce	0.80
Shade Wall Sconce	0.96
Pendant	0.89
Ave. For Sconces & Pendants	**0.88**
Candelabra Chandelier	0.84
Shade Chandelier	0.95
Large Up-Light Chandelier	0.88
Ave. For Chandeliers	**0.89**
Luminous Light Panels	**0.88**
AVE ORNAMENTAL LIGHTING	**0.883**

Appendix R: Narrative on LPD Changes

The following table shows the calculated LPD from the 2022 Lumen Method model with and without wall washing, the previous 2019 Area Category General and Additional Allowed LPDs and the proposed 2022 Area Category LPDs.

Table 110: Lighting Power Density Results of 2022 Lumen Method Model with Existing and Proposed Lighting Power Densities.

Primary Function Area	Model without Wall Wash (W/sf)	Model with Wall Wash (W/sf)	2019 Allowed General LPD (W/sf)	2019 Added Lighting Power (W/sf)	2022 Allowed General LPD (W/sf)	2022 Added Lighting Power (W/sf)
Audience Seating Area	0.29	0.46	0.60	0.30	0.50	0.25
Auditorium Area	0.60	1.11	0.70	0.50	0.70	0.45
Auto Repair / Maintenance Area	0.41	0.41	0.55	0.20	0.50	0.20
Barber, Beauty Salon and Spa Area	0.90	1.02	0.80	0.50	0.65	0.45
Civic Meeting Place Area	0.45	0.69	1.00	0.30	0.90	0.25
Classroom, Lecture, Training, Vocational Area	0.58	0.68	0.70	4.5 lf	0.60	7 W/lf
Commercial/Industrial Storage: Warehouse	0.33	0.33	0.45		0.40	
Commercial/Industrial Storage: Shipping & Handling	0.50	0.50	0.60		0.60	
Concourse and Atria Area	0.25	0.50	0.90	0.30	0.60	0.25
Convention, Conference, Multipurpose and Meeting Area	0.45	0.63	0.85	0.30	0.75	0.25
Copy Room	0.34	0.34	0.50		0.50	
Corridor Area	0.21	0.26	0.60		0.40	0.25
Dining Area: Bar/Lounge and Fine Dining	0.12	0.22	0.55	0.30	0.35	0.35

Primary Function Area	Model without Wall Wash (W/sf)	Model with Wall Wash (W/sf)	2019 Allowed General LPD (W/sf)	2019 Added Lighting Power (W/sf)	2022 Allowed General LPD (W/sf)	2022 Added Lighting Power (W/sf)
Dining Area: Cafeteria/Fast Food	0.31	0.40	0.40	0.30	0.45	0.25
Dining Area: Family and Leisure	0.20	0.23	0.50	0.30	0.40	0.25
Kitchen/Food Preparation Area	0.97	0.97	0.95		0.95	
Electrical, Mechanical, Telephone Rooms	0.36	0.36	0.40		0.40	
Exercise/Fitness Center and Gymnasium Area	0.36	0.36	0.50		0.50	
Financial Transaction Area	0.40	0.60	0.80	0.30	0.70	0.25
General/Commercial & Industrial Work Area: Low Bay	0.52	0.52	0.60	0.20	0.60	0.20
General/Commercial & Industrial Work Area: High Bay	0.51	0.51	0.65	0.20	0.65	0.20
General/Commercial & Industrial Work Area: Precision	1.28	1.28	0.85	0.70	0.85	0.70
Hotel Function Area	0.49	0.71	0.85	0.30	0.85	0.25
Scientific Laboratory Area	0.75	0.75	1.00	0.35	0.90	0.35
Laundry Area	0.35	0.35	0.45		0.45	
Library : Reading Area	0.67	0.67	0.80	0.30	0.80	0.25
Library : Stacks Area	0.72	0.72	1.10		1.00	
Main Entry Lobby	0.34	0.59	0.85	0.30	0.70	0.25
Locker Room	0.36	0.36	0.45		0.45	
Lounge, Breakroom, or Waiting Area	0.20	0.46	0.65	0.30	0.55	0.25
Museum Area: Exhibition/Display	0.13	0.13	0.60	0.50	0.60	0.50

Primary Function Area	Model without Wall Wash (W/sf)	Model with Wall Wash (W/sf)	2019 Allowed General LPD (W/sf)	2019 Added Lighting Power (W/sf)	2022 Allowed General LPD (W/sf)	2022 Added Lighting Power (W/sf)
Museum Area: Restoration Room	0.76	0.76	0.75	0.20	0.70	0.35
Office Area: ≤ 250 square feet	0.44	0.44	0.70	0.20	0.65	0.20
Office Area: > 250 square feet	0.29	0.39	0.65	0.20	0.60	0.20
Office Area: Open plan office	0.40	0.45	0.60	0.20	0.60	0.20
Parking Garage Area: Parking Zone	0.09	0.09	0.10		0.10	
Parking Garage Area: Dedicated Ramps	0.10	0.10	0.25		0.10	
Parking Garage Area: Daylight Adaptation Zones	0.96	0.96	0.50		1.00	
Pharmacy Area	1.01	1.01	1.10	0.35	1.00	0.35
Retail Sales Area: Grocery Sales	0.98	1.03	1.05	0.35	1.00	0.35
Retail Sales Area: Retail Merchandise Sales	0.80	0.98	1.00	0.35	0.95	0.35
Retail Sales Area: Fitting Room	0.85	1.52	0.60	40/120 W mirror	0.60	40/120 W mirror
Religious Worship Area	0.87	0.97	0.95	0.30	0.95	0.25
Restrooms	0.26	0.33	0.65	0.35	0.65	0.35
Stairwell	0.21	0.23	0.50	0.35	0.45	0.35
Theater Area: Motion picture	0.37	0.54	0.60	0.30	0.40	0.25
Theater Area: Performance	0.31	0.62	1.00	0.30	0.80	0.25
Transportation Function : Baggage Area	0.21	0.25	0.40		0.40	
Transportation Function : Ticketing Area	0.27	0.36	0.45	0.20	0.45	0.20

Primary Function Area	Model without Wall Wash (W/sf)	Model with Wall Wash (W/sf)	2019 Allowed General LPD (W/sf)	2019 Added Lighting Power (W/sf)	2022 Allowed General LPD (W/sf)	2022 Added Lighting Power (W/sf)
Videoconferencing Studio	0.68	2.04	0.90	1.00	0.90	1.00
Aging Eye/Low-vision: Main Entry Lobby	1.37	1.83	0.85	1.25	0.85	1.25
Aging Eye/Low-vision: Stairwell	0.50	0.50	0.80		0.70	0.20
Aging Eye/Low-vision: Corridor Area	0.44	0.69	0.80	0.15	0.70	0.30
Aging Eye/Low-vision: Lounge/Waiting Area	0.63	1.02	0.75	0.30	0.80	0.30
Aging Eye/Low-vision: Multipurpose Room	0.61	0.78	0.95	0.30	0.85	0.30
Aging Eye/Low-vision: Religious Worship Area	0.50	1.31	1.00	0.30	1.00	0.30
Aging Eye/Low-vision: Dining	0.69	1.03	0.80	0.30	0.80	0.30
Aging Eye/Low-vision: Restroom	0.89	1.16	0.80	0.20	1.00	0.20
Healthcare Facility and Hospitals: Exam/Treatment Room	1.11	1.11	1.15		1.15	
Healthcare Facility and Hospitals: Imaging Room	0.44	0.44	1.00		0.60	0.30
Healthcare Facility and Hospitals: Medical Supply Room	0.47	0.47	0.55		0.55	
Healthcare Facility and Hospitals: Nursery	0.47	0.47	0.95	0.10	0.80	0.10

Primary Function Area	Model without Wall Wash (W/sf)	Model with Wall Wash (W/sf)	2019 Allowed General LPD (W/sf)	2019 Added Lighting Power (W/sf)	2022 Allowed General LPD (W/sf)	2022 Added Lighting Power (W/sf)
Healthcare Facility and Hospitals: Nurse’s Station	0.73	1.09	0.75	0.10	0.85	0.30
Healthcare Facility and Hospitals: Operating Room	3.61	3.61	1.90		1.90	
Healthcare Facility and Hospitals: Patient Room	0.80	0.80	0.55	0.25	0.70	0.25
Healthcare Facility and Hospitals: Physical Therapy Room	0.37	0.64	0.85	0.10	0.75	0.10
Healthcare Facility and Hospitals: Recovery Room	0.99	1.12	0.90	0.10	0.90	0.10
Sports Arena – Playing Area: Class I Facility	3.08	3.08	2.25		2.25	
Sports Arena – Playing Area: Class II Facility	1.82	1.82	1.45		1.45	
Sports Arena – Playing Area: Class III Facility	1.14	1.14	1.10		1.10	
Sports Arena – Playing Area: Class IV Facility	0.76	0.76	0.75		0.75	

The table below indicates the proposed Area Category Allowed Lighting Power Densities from this analysis. It is worth noting that in the table below there are two sets of applications where the primary applications have been combined. The first set of applications is offices > 250 sf and open plan offices. There is no consistent definition of open plan office (some people believe that “open” means no partitions and others believe it includes cubicles), the required LPD is close enough between our models of open plan office and offices > 250 sf that it makes sense to combine these two categories into an unambiguous primary function area “offices > 250 sf.” The second set of function areas that have been combined is parking garage parking zone and dedicated ramps. The required LPD for these two areas is approximately the same and would simplify enforcement as it takes some judgement to decide where the parking area ends and where dedicated ramps begin.

As noted earlier in this report, of the 78 primary function areas, 8 increase their LPDs, 34 decrease their LPDs and 36 of the combined general lighting and additional lighting allowances stay the same.

TABLE 140.6-C AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (WATTS/FT²)

<table>
<tr><th colspan="2" rowspan="2">Primary Function Area</th><th rowspan="2">Allowed Lighting Power Density for General Lighting (W/ft²)</th><th colspan="2">Additional Lighting Power[1]</th></tr>
<tr><th>Qualified Lighting Systems</th><th>Additional Allowance (W/ft², unless noted otherwise)</th></tr>
<tr><td colspan="2">Audience Seating Area</td><td>~~0.60~~ 0.50</td><td>Ornamental</td><td>~~0.30~~ 0.25</td></tr>
<tr><td colspan="2" rowspan="2">Auditorium Area</td><td rowspan="2">0.70</td><td>Ornamental</td><td>~~0.30~~ 0.25</td></tr>
<tr><td>Accent, display and feature[3]</td><td>0.20</td></tr>
<tr><td colspan="2">Auto Repair / Maintenance Area</td><td>~~0.55~~ 0.50</td><td>Detailed Task Work[7]</td><td>0.20</td></tr>
<tr><td colspan="2" rowspan="2">Barber, Beauty Salon, Spa Area</td><td rowspan="2">~~0.80~~ 0.65</td><td>Detailed Task Work[7]</td><td>0.20</td></tr>
<tr><td>Ornamental</td><td>~~0.30~~ 0.25</td></tr>
<tr><td colspan="2">Civic Meeting Place Area</td><td>~~1.00~~ 0.90</td><td>Ornamental</td><td>~~0.30~~ 0.25</td></tr>
<tr><td colspan="2">Classroom, Lecture, Training, Vocational Area</td><td>~~0.70~~ 0.60</td><td>White or Chalk Board[1]</td><td>~~4.50~~ 7 W/ft</td></tr>
<tr><td colspan="2">Concourse and Atria Area</td><td>~~0.90~~ 0.60</td><td>Ornamental</td><td>~~0.30~~ 0.25</td></tr>
<tr><td colspan="2">Convention, Conference, Multipurpose and Meeting Area</td><td>~~0.85~~ 0.75</td><td>Ornamental</td><td>~~0.30~~ 0.25</td></tr>
<tr><td colspan="2">Copy Room</td><td>0.50</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Corridor Area</td><td>~~0.60~~ 0.40</td><td>Ornamental</td><td>0.25</td></tr>
<tr><td rowspan="3">Dining Area</td><td>Bar/Lounge and Fine Dining</td><td>~~0.55~~ 0.35</td><td>~~Ornamental~~ Accent, display and feature[3]
Decorative</td><td>~~0.30~~
0.20
0.15</td></tr>
<tr><td>Cafeteria/Fast Food</td><td>~~0.40~~ 0.45</td><td rowspan="2">Ornamental</td><td rowspan="2">~~0.30~~ 0.25</td></tr>
<tr><td>Family and Leisure</td><td>~~0.50~~ 0.40</td></tr>
<tr><td colspan="2">Kitchen/Food Preparation Area</td><td>0.95</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Electrical, Mechanical, Telephone Rooms</td><td>0.40</td><td>Detailed Task Work[7]</td><td>0.20</td></tr>
</table>

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]	
			Qualified Lighting Systems	Additional Allowance (W/ft², unless noted otherwise)
Exercise/Fitness Center and Gymnasium Area		0.50	-	-
Financial Transaction Area		~~0.80~~ 0.70	Ornamental	~~0.30~~ 0.25
Hotel Function Area		0.85	Ornamental	~~0.30~~ 0.25
~~Scientific~~ Laboratory~~,~~ Scientific Area		~~1.00~~ 0.90	Specialized Task Work[8]	0.35
Laundry Area		0.45	-	-
Library	Reading Area	0.80	Ornamental	~~0.30~~ 0.25
	Stacks Area	~~1.10~~ 1.00	-	-
~~Main Entry~~ Lobby, Main Entry		~~0.85~~ 0.70	Ornamental	~~0.30~~ 0.25
Locker Room		0.45	-	-
Lounge, Breakroom, or Waiting Area		~~0.65~~ 0.55	Ornamental	~~0.30~~ 0.25
~~General/~~Manufacturing, Commercial & Industrial Work Area	Low Bay	0.60	Detailed Task Work[7]	0.20
	High Bay	0.65	Detailed Task Work[7]	0.20
	Precision	0.85	Precision Specialized Work[9]	0.70
Museum Area	Exhibition/Display	0.60	Accent, display and feature[3]	~~0.50~~ 0.45
	Restoration Room	~~0.75~~ 0.70	Detailed Task Work[7]	~~0.20~~ 0.35
Office Area	≤ 250 square feet	~~0.70~~ 0.65	Portable lighting for office areas[6]	0.20
	> 250 square feet	~~0.65~~ 0.60		
	~~Open plan office~~	~~0.60~~		
Parking Garage Area	Parking Zone and Ramps	0.10	First ATM or Ticket Machine	100 W
			Additional ATM or Ticket machine	50 W each
	~~Dedicated Ramps~~	~~0.25~~	-	-
	Daylight Adaptation Zones[2]	~~0.50~~ 1.00	-	-

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft^2)	Additional Lighting Power[1]: Qualified Lighting Systems	Additional Lighting Power[1]: Additional Allowance (W/ft^2, unless noted otherwise)
Pharmacy Area		~~1.10~~ 1.00	Specialized Task Work[8]	0.35
Retail Sales Area	Grocery Sales	~~1.05~~ 1.00	Accent, display and feature[3]	0.20
			Decorative	0.15
	Retail Merchandise Sales	~~1.00~~ 0.95	Accent, display and feature[3]	0.20
			Decorative	0.15
	Fitting Room	0.60	External Illuminated Mirror[5]	40 W/ea
			Internal Illuminated Mirror[5]	120 W/ea
Religious Worship Area		0.95	Ornamental	~~0.30~~ 0.25
Restrooms		0.65	Accent, display and feature[3]	0.20
			Decorative[4]	0.15
Stairwell		~~0.5~~ 0.45	Accent, display and feature[3]	0.20
			Decorative[4]	0.15
Storage, Commercial/Industrial ~~Storage~~	Warehouse	~~0.45~~ 0.40	-	-
	Shipping & Handling	0.60	-	-
Theater Area	Motion picture	~~0.60~~ 0.40	Ornamental	~~0.30~~ 0.25
	Performance	~~1.00~~ 0.80		
Transportation Function	Baggage Area	0.40	-	-
	Ticketing Area	0.45	Accent, display and feature[3]	0.20
Videoconferencing Studio[14]		0.90	Videoconferencing	1.00

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft^2)	Additional Lighting Power[1]	
			Qualified Lighting Systems	**Additional Allowance (W/ft^2, unless noted otherwise)**
Aging Eye/Low-vision[11]	Corridor Area	~~0.80~~ 0.70	Ornamental ~~Decorative~~[4]	~~0.15~~ 0.30
	Dining	0.80	Ornamental	0.30
	Lounge/Waiting Area	~~0.75~~ 0.80	Ornamental	0.30
	Main Entry Lobby	0.85	Ornamental	0.30
			Transition Lighting OFF at night[12]	0.95
	Multipurpose Room	~~0.95~~ 0.85	Ornamental	0.30
	Religious Worship Area	1.00	Ornamental	0.30
	Restroom	~~0.80~~ 1.00	Accent, display and feature[3]	0.20
	Stairwell	~~0.80~~ 0.70	Accent, display and feature[3]	0.20
Healthcare Facility and Hospitals	Exam/Treatment Room	1.15	-	-
	Imaging Room	~~1.00~~ 0.60	Accent, display and feature[3]	0.20
			Tunable white or dim-to-warm[10]	0.10
	Medical Supply Room	0.55	-	-
	Nursery	~~0.95~~ 0.80	Tunable white or dim-to-warm[10]	0.10
	Nurse's Station	~~0.75~~ 0.85	Tunable white or dim-to-warm[10]	0.10
			Detailed Task Work[7]	0.20
	Operating Room	1.90	-	-
	Patient Room	~~0.55~~ 0.70	Decorative	0.15

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]	
			Qualified Lighting Systems	Additional Allowance (W/ft², unless noted otherwise)
			Tunable white or dim-to-warm[10]	0.10
	Physical Therapy Room	~~0.85~~ 0.75	Tunable white or dim-to-warm[10]	0.10
	Recovery Room	0.90	Tunable white or dim-to-warm[10]	0.10
Sports Arena – Playing Area	Class I Facility[13]	2.25	-	-
	Class II Facility[13]	1.45	-	-
	Class III Facility[13]	1.10	-	-
	Class IV Facility[13]	0.75	-	-
All other		0.40	-	-

The following is commentary on those primary function areas where this proposal is recommending a change in the allowed lighting power allowance.

- **Auditorium, Hotel Function Area, Library : Reading Area, Museum Area: Exhibition/Display and Religious Worship Area:** for all of these areas the only change is to drop the additional allowed wattage allowance by 0.05 W/sf. This drop reflects the increased efficacy of high CRI sources. In the time period between the development of the 2019 Title 24 proposed LPDs and this proposal for the 2022 LPDs, overall LED efficacies have not increased appreciably, but the efficacies for high CRI sources used in modeling ornamental lighting have increased by, on average, 12%. Thus a 0.883 factor was applied to the 0.30 W/sf allowance and rounded to the closest 0.05 W/sf which is 0.25. A detailed description of how this factor was calculated is contained in Appendix Q.
- **Audience Seating Area:** The lighting model indicates that deep reductions can be made to this application due to a re-evaluation of the recommended light levels for seating areas. Because the theoretical required power is substantially less than the current power limits, the decision was to provide some added leeway but nonetheless proposed limits are a 17 percent reduction as compared to the 2019 power density allowances.
- **Auto Repair / Maintenance Area:** A 10 percent reduction is proposed here primarily based on updating the general lighting requirements and recognizing

that task lighting is not provided by hardwired lighting but cord connected portable task lighting that is not within the scope of this allowance. The 2022 model includes a detailed task area with a design illuminance of 100 fc for 10 percent of the space.

- **Barber, Beauty Salon and Spa Area:** The drop in allowed power for ornamental lighting from 0.30 to 0.25 W/sf is detailed in Appendix Q. Though design illuminance in the model was increased, the allowed general lighting power was decreased as not as much leeway (additional lighting power) was provided between the model and the lighting allowance. This provides the incentive to provide lighting on the task areas.
- **Civic Meeting Place Area:** Besides the drop in allowed power for ornamental lighting from 0.30 to 0.25 W/sf as described for other applications, the 10 percent drop in general lighting reflects that around 30 percent of these areas are for circulation.
- **Classroom, Lecture, Training, Vocational Area:** The 14 percent drop in general lighting power is partially offset by the 75 percent increase in power for teaching surfaces. The general lighting model provides a 40 fc maintained task levels for the entire room.
- **Concourse and Atria Area.** Based on the significant difference between the lighting model and the 2019 lighting power allowances, this application dropped significantly. This more closely matches the configurations of concourses and atria with 80 percent of the floor area being circulation with a maintained illuminance of 10 fc and a 20 percent of the area with kiosks, bank teller stations with maintained illuminances of 30 fc and additional wall washing of 10 fc tor 2/3s of wall areas. It should be noted that transportation concourses need even less light but these spaces are often performing a retail concourse function. Because the theoretical required power is substantially less than the current power limits, the decision was to provide some added leeway but nonetheless proposed limits are a 29 percent reduction as compared to the 2019 power density allowances.
- **Convention, Conference, Multipurpose and Meeting Area.** This reflects more accurate modeling of the application with 30 percent of the space being allocated for circulation and wall washing half of the walls instead of all walls.
- **Corridor Area:** Small increase in allowed lighting however for corridors without any ornamental lighting the allowed lighting would be less. This reflects that circulation in the corridor has a bas allowance that would allow 10 maintained foot-candles and 5 fc of wall washing for about half of the walls.
- **Dining Area: Bar/Lounge and Fine Dining:** These areas have significantly

lower recommended illuminance levels than other types of dining. Using these recommended illuminance targets resulted in the models producing a significantly lower LPD than other dinning types. However, since Bar, Lounge and Fine Dining areas typically employ a higher level of theme and mood lighting than other dining areas for the 2022 code cycle current code Ornamental Lighting adder is replaced by with two new separate adders for this space type.

- **Dining Area:** Cafeteria/Fast Food. Cafeteria/Fast Food remained the same, primarily because higher light levels were applied to the Cafeteria model (per IES recommendation) and this space type does not depend on higher 90+ CRI as do the other dining types.
- **Dining Area:** Family and Leisure Family/Leisure allowed LPD dropping 19 percent. These targets are based on results of the updated (more details and precise) modeling based on current IES Recommended Practice as well as efficiency increases in the higher 90+ CRI LED product used in the modeling.
- **Financial Transaction Area:** Besides the drop in allowed power for ornamental lighting from 0.30 to 0.25 W/sf as described for other applications, the 12 percent drop in general lighting allowances reflects a layered lighting model that has 60 percent of the area being circulation.
- **Laboratory,Scientific:** The allowed lighting power for general lighting for this application dropped by 10 percent to reflect the IES -RP-7 recommended illuminance value of 50 fc for general laboratory applications.
- **Library, Stacks:** This dropped by 9 percent to reflect IES-RP-4 illuminance recommendations as compared to the design illuminances used in 2019.
- **Lounge, Breakroom, or Waiting Area:** Besides the drop in allowed power for ornamental lighting from 0.30 to 0.25 W/sf as described for other applications, the 15 percent drop in general lighting allowances is due to use of improved light sources (basket troffer instead of downlight)
- **Museum Area: Restoration Room:** Allowed wattages were slightly increased to account for higher illuminance levels 50 fc versus 30 fc general and 100 fc versus 75 fc for detailed task areas.
- **Office Area: ≤ 250 square feet:** The allowed wattages dropped by 6 percent to account for more accurate modeling of the space with updated illuminance targets from IES-RP-1.
- **Office Area: > 250 square feet:** This makes use of the detailed AGI-32 modeling conducted in 2019 for open plan offices. In addition the lumen model calculated a LPD for a 600 sf space that was around 0.4 W/sf or 30 percent lower than the proposed allowance.

- **Parking Garage Area: Dedicated Ramps:** The lighting power allowance for this application was reduced by 60 percent. This area was modeled at 4 fc maintained average illuminance as compared to the RP-8 minimum illuminance of 2 fc. The resulting 0.10 W/sf LPD matches that for parking and as noted earlier simplifies compliance for the combined parking and ramp areas.
- **Parking Garage Area: Daylight Adaptation Zones:** The allowed lighting power allowance for this area increased by 100 percent to account for RP-8 recommended design illuminances of 50 fc in the daylight adaptation zone.
- **Pharmacy Area:** The seven percent drop in overall LPD represents a more detailed model of general lighting, filling assembly and compounding tasks from IES-RP-29.
- **Retail Sales Area: Grocery Sales and Retail Merchandise Sales**: These allowed lighting power allowances dropped by 0.05 W/sf to account for the increased efficacy of 90 CRI LED light sources.
- **Warehouse:** Using the design illuminance of 10 fc and an improved lighting model, an 11 percent reduction in general lighting is proposed.
- **Stairwell:** A 10 percent reduction in general lighting is proposed to reflect a simple lighting design for stairwells with general lighting only. The accent, display and ornamental lighting additional wattage is unchanged. This accommodates both basic stairwells for egress versus stairwells with lighting features to encourage greater use.
- **Theater Area: Motion picture:** A 30 percent reduction on the general area for motion picture reflects the low light levels in these spaces. Since the new lumen method model could represent any reflectance combination, the proposal could more closely match the model results. For this model the reflectances were: 30 percent ceiling, 10 percent wall, and 20 percent floor reflectances.
- **Theater Area: Performance:** A 20 percent reduction on the general area for motion picture reflects the low light levels in these spaces. Since the new lumen method model could represent any reflectance combination, the proposal could more closely match the model results. For this model the reflectances were: 50 percent ceiling, 30 percent wall, and 20 percent floor reflectances.
- **Aging Eye/Low-vision: Stairwell:** The overall lighting power allowance is increased to account for different types of stairwells for populations with vison impairment. The general lighting has been reduced by 0.1 W/sf which would match the lighting power to provide 20 maintained fc on the stairs and 20 fc maintained fc provided by wall washing on the landing end walls. An added 0.2 W/sf is provided for accent, feature and display lighting for artwork etc for active

stairways.

- **Aging Eye/Low-vision: Corridor Area:** The allowed lighting power for this application increased by 0.05 W/sf to account for greater amounts of display lighting. Concurrently the general lighting power allowance decreased by 0.1 W/sf. The general lighting power allowance was equivalent to the power simulated in the model to provide both 20 fc maintained average illuminance on the floor and 20 fc vertical on half of the wall area.
- **Aging Eye/Low-vision: Lounge/Waiting Area:** General lighting increased by 20 percent to better reflect the vertical illumination requirements in RP-28.
- **Aging Eye/Low-vision: Multipurpose Room:** Proposed general lighting allowance dropping by 10 percent to better reflect RP-28 illumination requirements for Visually Impaired Common living area.
- **Aging Eye/Low-vision: Restroom:** General lighting increased by 25 percent to account for larger fraction of task areas at 50 fc versus circulation areas at 20 fc.
- **Healthcare Facility and Hospitals: Imaging Room:** General lighting dropped significantly to represent the lighting needed to conduct the tasks but with a significant added accent, display and features wattage as well and color tuning lighting for enhance the visual environment of the space.
- **Healthcare Facility and Hospitals: Nursery:** General lighting power reduced to account for improved efficiency of high CRI sources and improved fixture optics.
- **Healthcare Facility and Hospitals: Nurse's Station:** Overall lighting power increased 35 percent to account for better definitions of tasks at nurses station. Revised model included wall washing behind nurses station and added supplemental lighting for reading small print in the surrounding area.
- **Healthcare Facility and Hospitals: Patient Room:** Proposed general lighting power increases by 27 percent to account for higher task illuminances for a larger fraction of the patient room.
- **Healthcare Facility and Hospitals: Physical Therapy Room:** General lighting allowed power decreases by 12 percent to account for better matching of the illuminances in IES-RP-29 including 20 fc for General/Group therapy and 50 fc for table and individual therapy.

Complete Building Method

The Complete Building Method allowed lighting LPD values are designed for relatively simple lighting designs which do not have many lighting layers and for which documentation can be streamlined. These LPDs are based on an area weighted average of primary function area general lighting power LPDs to each Complete Building Method Type. Of the 17 buildings in the Complete Building Method, this proposal would drop the LPDs for 6 of the building types mostly by 0.05 W/sf and for motion picture theaters by 0.10 W/sf. The area weighting factors are provided in Table 111.

TABLE 140.6-B COMPLETE BUILDING METHOD LIGHTING POWER DENSITY VALUES

TYPE OF BUILDING	ALLOWED LIGHTING POWER DENSITY (WATTS PER SQUARE FOOT)
Assembly Building	~~0.70~~ 0.65
Financial Institution Building	0.65
Industrial/Manufacturing Facility Building	0.60
Grocery Store Building	~~0.95~~ 0.90
Gymnasium Building	~~0.65~~ 0.60
Library Building	0.70
Healthcare Facility	0.90
Office Building	~~0.65~~ 0.60
Parking Garage Building	0.13
Religious Facility Building	0.70
Restaurant Building	~~0.70~~ 0.65
Retail Store Building	0.90
School Building	~~0.65~~ 0.60
Sports Arena Building	0.75
Motion Picture Theater Building	~~0.70~~ 0.60
Performing Arts Theater Building	~~0.80~~ 0.75
All other~~s~~ buildings	0.40

The weighting factors of primary application areas to building types are shown in the table below.

Table 111: Area Weighted Mapping of Primary Function Areas to Complete Building Types

Primary Function Areas ↓ \ Complete Building Types →	Assembly	Financial Institution	Manufacturing Facility	Grocery Store	Gymnasium	Library	Healthcare	Hospital	Office	Parking	Religious	Restaurant (Average)	Retail	School	Sports Arena	Motion Picture	Performing Arts
Audience Seating Area	30.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	27.0%	0.0%	0.0%
Auditorium Area	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	2.0%
Auto Repair / Maintenance Area	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barber, Beauty Salon and Spa Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Civic Meeting Place Area	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Classroom, Lecture, Training, Vocational Area	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	6.0%	0.0%	1.0%	0.0%	10.0%	0.0%	0.0%	40.0%	0.0%	0.0%	1.0%
Commercial/Industrial Storage: Warehouse	0.0%	0.0%	12.0%	20.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	9.0%	9.0%	0.0%	1.0%	1.0%
Commercial/Industrial Storage: Shipping & Handling	0.0%	0.0%	2.0%	5.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	2.0%	1.0%	1.0%
Concourse and Atria Area	4.0%	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.0%	0.0%	4.0%	0.0%	8.0%
Convention, Conference, Multipurpose and Meeting Area	9.0%	0.0%	2.0%	0.0%	2.0%	12.0%	3.0%	1.0%	10.0%	0.0%	1.0%	0.0%	0.0%	4.0%	2.0%	0.0%	5.0%
Copy Room	0.0%	5.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Corridor Area	9.0%	0.0%	3.0%	1.0%	5.0%	10.0%	7.0%	20.0%	15.0%	0.0%	14.0%	1.8%	2.0%	11.0%	5.0%	14.0%	12.0%
Dining Area: Bar/Lounge and Fine Dining	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.2%	0.0%	0.0%	0.0%	0.0%	0.0%
Dining Area: Cafeteria/Fast Food	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	1.0%	2.0%	1.0%	0.0%	0.0%	25.2%	1.0%	2.0%	0.0%	0.0%	0.0%
Dining Area: Family and Leisure	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	17.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Kitchen/Food Preparation Area	1.0%	0.0%	1.0%	0.0%	5.0%	0.0%	0.0%	2.0%	0.0%	0.0%	2.0%	32.0%	1.0%	2.0%	5.0%	8.0%	2.0%
Electrical, Mechanical, Telephone Rooms	2.0%	2.0%	2.0%	5.0%	1.0%	2.0%	2.0%	7.0%	2.0%	1.0%	2.0%	1.3%	1.0%	3.0%	1.0%	4.0%	5.0%
Exercise/Fitness Center and Gymnasium Area	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.0%	0.0%	0.0%	0.0%
Financial Transaction Area	0.0%	30.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
General/Commercial & Industrial Work Area: Low Bay	0.0%	0.0%	30.0%	0.0%	0.0%	1.0%	0.0%	0.0%	2.0%	0.0%	3.0%	0.0%	3.0%	0.0%	0.0%	0.0%	1.0%
General/Commercial & Industrial Work Area: High Bay	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
General/Commercial & Industrial Work Area: Precision	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hotel Function Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Scientific Laboratory Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
Laundry Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Library : Reading Area	0.0%	0.0%	0.0%	0.0%	0.0%	35.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
Library : Stacks Area	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
Main Entry Lobby	12.0%	15.0%	1.0%	0.0%	5.0%	4.0%	6.0%	4.0%	5.0%	0.0%	1.0%	5.3%	1.0%	5.0%	20.0%	5.0%	10.0%
Locker Room	0.0%	0.0%	2.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	5.0%	0.0%	0.0%
Lounge, Breakroom, or Waiting Area	0.0%	0.0%	3.0%	0.0%	0.0%	2.0%	11.0%	1.0%	2.0%	0.0%	1.0%	0.8%	1.0%	1.0%	5.0%	0.0%	2.0%
Museum Area: Exhibition/Display	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
Museum Area: Restoration Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Office Area: ≤ 250 square feet	1.0%	4.0%	3.0%	2.0%	1.0%	6.0%	9.0%	5.0%	16.0%	0.0%	10.0%	2.0%	3.0%	4.0%	1.0%	1.0%	1.0%
Office Area: > 250 square feet and ≤ xxx sf	0.0%	19.0%	1.0%	0.0%	0.0%	0.0%	0.0%	2.0%	16.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Office Area: Open plan office > xxx sf	0.0%	21.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	21.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
Parking Garage Area: Parking Zone	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	87.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Parking Garage Area: Dedicated Ramps	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Parking Garage Area: Daylight Adaptation Zones	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pharmacy Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Retail Sales Area: Grocery Sales	0.0%	0.0%	0.0%	60.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Retail Sales Area: Retail Merchandise Sales	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	65.0%	0.0%	2.0%	10.0%	0.0%
Retail Sales Area: Fitting Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	1.0%	0.0%	0.0%	0.0%	2.0%
Religious Worship Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Restrooms	4.0%	3.0%	2.0%	4.0%	6.0%	4.0%	7.0%	7.0%	3.0%	0.0%	4.0%	7.2%	2.0%	4.0%	5.0%	4.0%	3.0%
Stairwell	2.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	2.0%	1.0%	2.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	3.0%
Theater Area: Motion picture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	51.0%	0.0%
Theater Area: Performance	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40.0%
Transportation Function : Baggage Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Transportation Function : Ticketing Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Videoconferencing Studio	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Main Entry Lobby	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Stairwell	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Corridor Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Lounge/Waiting Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Multipurpose Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Religious Worship Area	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Dining	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aging Eye/Low-vision: Restroom	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Exam/Treatment Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	36.0%	21.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Imaging Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Medical Supply Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Nursery	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Nurse’s Station	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Operating Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Patient Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Physical Therapy Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Healthcare Facility and Hospitals: Recovery Room	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sports Arena – Playing Area: Class I Facility	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.0%	0.0%	0.0%
Sports Arena – Playing Area: Class II Facility	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sports Arena – Playing Area: Class III Facility	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Sports Arena – Playing Area: Class IV Facility	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Appendix S: Model Cost Calculations

Each table calculate the cost of each subsystem (general lighting, task lighting, supplemental lighting and wall washing) for a prototype space for each primary function area. Adding the tables together results in the total costs as shown in the last table. All of the lines that grey in color, the LPD is unchanged and the incremental cost has been greyed out as the cost shouldn't change if the same power is used to light the space.

Table 112: General Lighting System Proposed 2022 and 2019 Base Costs

Primary Function Area	General Luminaire	2022 General fc x % area x Area (lumens)	2022 General System watts	2022 General Luminaire efficacy	2022 Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 General fc x % area x Area (lumens)	2019 General Luminaire Ref No.	2019 Gen Luminaire Description	2019 General System watts	2019 General Luminaire efficacy	2019 Avg Watts/luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base General Cost	2022 Proposed General Cost
Audience Seating Area	Downlight large 6"+ 80CRI Hi Ou	32,000	305	90	57	5.33	$182	48,000	811	PAR downlight flood	648	71	27	24	$158	$3,803	$970
Auditorium Area	#N/A	0	0		#N/A		$0	45,000	801	Downlight open (repl INC)	254	86	46	6	$157	$868	$0
Auto Repair / Maintenance Area	Industrial strip 80CRI	64,800	1,202	135	32	37.68	$81	120,000	838	Linear Industrial (repl FL)	1,965	131	59	33	$71	$2,363	$3,052
Barber, Beauty Salon and Spa Area	Troffer Basket 90CRI	2,880	35	101	41	0.86	$196	28,800	830	Linear Direct Lensed (repl FL)	636	106	48	13	$122	$1,622	$168
Civic Meeting Place Area	Troffer Basket 90CRI	1,620	18	101	41	0.42	$196	2,700	823	Indirect Pendant (repl CF)	91	77	124	1	$514	$378	$83
Classroom, Lecture, Training, Vocational Area	#N/A	0	0		#N/A		$0	37,240	835	Linear Dir/Ind (repl FL)	735	105	42	17	$372	$6,488	$0
Commercial/Industrial Storage: Warehouse	Low bay 70CRI	8,000	260	123	137	1.90	$270	16,000	859-2	High Bay (repl MH)	339	117	168	2	$240	$483	$514
Commercial/Industrial Storage: Shipping & Handling	High Bay 80CRI	7,200	157	128	175	0.90	$0	63,000	838	Linear Industrial (repl FL)	1,032	131	59	17		$0	$0
Concourse and Atria Area	Linear light slot 4" or more 80CR	96,000	1,315	104	33	39.34	$320	120,000	851	PAR downlight flood	1,895	71	27	70	$158	$11,132	$12,590
Convention, Conference, Multipurpose and Meeting Area	Troffer Basket 80CRI	2,700	24	116	38	0.63	$146	27,000	831	Narrow Linear (repl FL)	518	87	25	21	$341	$7,207	$92
Copy Room	Troffer Basket 80CRI	1,200	24	116	38	0.63				No copy room model in 2019							$0
Corridor Area	Linear light slot 4" or more 80CR	6,400	106	104	33	3.17	$320	0	801	Downlight open (repl INC)	0	86	46	0	$157	$0	$1,014
Dining Area: Bar/Lounge and Fine Dining	Downlight 4" and less 90CRI Wa	4,590	84	69	36	2.34	$162	18,000	811	PAR downlight flood	284	71	27	11	$158	$1,670	$379
Dining Area: Cafeteria/Fast Food	Troffer Lensed 80CRI	7,200	108	110	38	2.85		12,000	831	Narrow Linear (repl FL)	186	87	25	8		$0	$0
Dining Area: Family and Leisure	Downlight large 6"+ 90CRI	3,600	59	78	36	1.63	$162	38,400	801	Downlight open (repl INC)	530	86	46	12	$157	$1,812	$263
Kitchen/Food Preparation Area	Troffer Lensed 80CRI	3,600	76	110	38	1.99		18,000	830	Linear Direct Lensed (repl FL)	325	106	48	7		$0	$0
Electrical, Mechanical, Telephone Rooms	Industrial strip 80CRI Lo Output	24,000	427	121	14	30.52		12,000	838	Linear Industrial (repl FL)	261	131	59	4		$0	$0
Exercise/Fitness Center and Gymnasium Area	Low bay 80CRI Lo Output	72,000	862	133	66	13.06		72,000	835	Linear Dir/Ind (repl FL)	1,203	105	42	29		$0	$0
Financial Transaction Area	Troffer Basket 80CRI	4,320	41	116	38	1.07	$146	21,600	831	Narrow Linear (repl FL)	463	87	25	19	$341	$6,440	$157
General/Commercial & Industrial Work Area: Low Bay	Low bay 80CRI	43,200	605	145	112	5.42		204,000	859-1	Lowbay Lensed (Lin Ind - repl M	2,950	120	94	31		$0	$0
General/Commercial & Industrial Work Area: High Bay	High Bay 80CRI	108,000	1,634	128	175	9.34		510,000	859-2	High Bay (repl MH)	7,005	117	168	42		$0	$0
General/Commercial & Industrial Work Area: Precision	High Bay 80CRI	32,400	460	128	175	2.63		240,000	869	Industrial Super High Bay	4,076	118	376	11		$0	$0
Hotel Function Area	Pend bowl direct/indirect 80CRI	1,620	39	81	48	0.80	$514	5,400	823	Indirect Pendant (repl CF)	117	77	124	1	$514	$487	$412
Scientific Laboratory Area	Troffer Lensed 80CRI Hi Output	33,600	501	115	67	7.48	$128	25,805	831	Narrow Linear (repl FL)	567	87	25	23	$341	$7,886	$958
Laundry Area	Troffer Basket 80CRI	36,000	422	116	38	11.19		36,000	830	Linear Direct Lensed (repl FL)	514	106	48	11		$0	$0
Library : Reading Area	Troffer Basket 80CRI	36,000	482	116	38	12.77	$146	21,600	835	Linear Dir/Ind (repl FL)	361	105	42	9	$372	$3,184	$1,864
Library : Stacks Area	Linear light slot 4" or more 80CR	2,880	92	104	33	2.76	$320	10,800	831	Narrow Linear (repl FL)	103	87	25	4	$341	$1,440	$884
Main Entry Lobby	Downlight large 6"+ 90CRI	10,800	177	78	36	4.84	$162	36,000	823	Indirect Pendant (repl CF)	967	77	124	8	$514	$4,009	$785
Locker Room	Troffer Lensed 80CRI	1,600	48	110	38	1.27		4,200	830	Linear Direct Lensed (repl FL)	76	106	48	2		$0	$0
Lounge, Breakroom, or Waiting Area	Troffer Basket 90CRI	4,320	44	101	41	1.07	$196	5,280	801	Downlight open (repl INC)	30	86	46	1	$157	$102	$210
Museum Area: Exhibition/Display	Downlight 4" and less 90CRI Wa	9,828	208	69	16	13.29		21,840	811	PAR downlight flood	491	71	27	18		$0	$0
Museum Area: Restoration Room	Troffer Basket 90CRI	108,000	1,469	101	41	35.46	$196	72,000	800-1	Linear Rec Hi Perf Lensed (repl I	1,350	119	41	33	$114	$3,779	$6,951
Office Area: ≤ 250 square feet	Troffer Basket 80CRI	560	11	116	38	0.30	$146	2,800	800	Linear Rec Hi Perf Lensed (repl I	63	119	41	2	$129	$201	$44
Office Area: > 250 square feet and ≤ xxx sf	Troffer Basket 80CRI	2,400	30	116	38	0.79	$146	12,000	835	Linear Dir/Ind (repl FL)	195	105	42	5	$372	$1,720	$116
Office Area: Open plan office > xxx sf	Pendant direct/indirect 80CRI	7,200	117	97	50	2.36		48,000	835	Linear Dir/Ind (repl FL)	780	105	42	18		$0	$0

Primary Function Area	General Luminaire	2022 General fc x % area x Area (lumens)	2022 General System watts	2022 General Luminaire efficacy	2022 Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 General fc x % area x Area (lumens)	2019 General Luminaire Ref No.	2019 Gen Luminaire Description	2019 General System watts	2019 General Luminaire efficacy	2019 Avg Watts/luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base General Cost	2022 Proposed General Cost
Parking Garage Area: Parking Zone	Parking garage luminaire 70CRI	36,000	680	111	42	16.34		36,000	859-3	Parking structure luminaire	664	112	55	12		$0	$0
Parking Garage Area: Dedicated Ramps	Parking garage luminaire 70CRI	7,680	196	111	42	4.70	$300	9,600	859-3	Parking structure luminaire	480	112	55	9	$300	$2,616	$1,409
Parking Garage Area: Daylight Adaptation Zones	Parking garage luminaire 70CRI H	99,000	1,910	112	111	17.20	$300	9,900	859-3	Parking structure luminaire	990	112	55	18	$300	$5,395	$5,161
Pharmacy Area	Troffer Basket 80CRI	19,200	273	116	38	7.24	$95	28,800	830	Linear Direct Lensed (repl FL)	520	106	48	11	$94	$1,023	$688
Retail Sales Area: Grocery Sales	Linear light slot 4" or more 80CR	19,200	224	104	33	6.71	$320	96,000	800	Linear Rec Hi Perf Lensed (repl I	1,115	119	41	27	$129	$3,532	$2,148
Retail Sales Area: Retail Merchandise Sales	Cove light assymetric 80CRI	14,400	248	91	40	6.25	$380	72,000	831	Narrow Linear (repl FL)	956	87	25	39	$341	$13,304	$2,375
Retail Sales Area: Fitting Room	Downlight 4" and less 90CRI	1,800	20	83	29	0.69		600	830	Linear Direct Lensed (repl FL)	13	106	48	0		$0	$0
Religious Worship Area	#N/A	0	0		#N/A		$0	120,000	811	PAR downlight flood	1,834	71	27	68	$158	$10,770	$0
Restrooms	Cove light assymetric 80CRI	600	20	91	40	0.50		3,000	801	Downlight open (repl INC)	51	86	46	1		$0	$0
Stairwell	Industrial strip 80CRI	3,600	67	135	32	2.11	$81	3,600	831	Narrow Linear (repl FL)	77	87	25	3	$130	$410	$171
Theater Area: Motion picture	#N/A	0	0		#N/A		$0	46,800	811	PAR downlight flood	958	71	27	36	$158	$5,628	$0
Theater Area: Performance	#N/A	0	0		#N/A		$0	80,000	811	PAR downlight flood	1,084	71	27	40	$158	$6,369	$0
Transportation Function : Baggage Area	Troffer Basket 80CRI	37,800	463	116	38	12.27		27,000	830	Linear Direct Lensed (repl FL)	385	106	48	8		$0	$0
Transportation Function : Ticketing Area	Linear light slot 4" or less 80CRI	14,000	197	94	32	6.11		20,000	831	Narrow Linear (repl FL)	194	87	25	8		$0	$0
Videoconferencing Studio	#N/A	0	0		#N/A			#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0			$0
Aging Eye/Low-vision: Main Entry Lobby	Cove light assymetric 80CRI	30,000	535	91	40	13.49		60,000	835	Linear Dir/Ind (repl FL)	971	105	42	23		$0	$0
Aging Eye/Low-vision: Stairwell	Downlight large 6"+ 90CRI Warn	3,200	77	66	38	2.03	$162	1,600	831	Narrow Linear (repl FL)	31	87	25	1	$341	$436	$328
Aging Eye/Low-vision: Corridor Area	Troffer Basket 90CRI	12,800	156	101	41	3.77	$196	12,800	851	PAR downlight flood	245	71	27	9	$158	$1,438	$739
Aging Eye/Low-vision: Lounge/Waiting Area	Troffer Basket 90CRI	13,500	154	101	41	3.71	$196	27,000	823	Indirect Pendant (repl CF)	727	77	124	6	$514	$3,015	$728
Aging Eye/Low-vision: Multipurpose Room	Troffer Basket 90CRI	13,500	179	101	41	4.33	$196	18,000	851	PAR downlight flood	284	71	27	11	$158	$1,667	$848
Aging Eye/Low-vision: Religious Worship Area	Pend bowl direct/indirect 80CRI	2,016	44	81	48	0.92		15,120	851	PAR downlight flood	257	71	27	10		$0	$0
Aging Eye/Low-vision: Dining	Cove light assymetric 80CRI	12,800	214	91	40	5.39		48,000	823	Indirect Pendant (repl CF)	1,813	77	124	15		$0	$0
Aging Eye/Low-vision: Restroom	Cove light assymetric 80CRI	2,592	79	91	40	1.99	$380	7,560	834-1	Linear Wall Cove (repl FL)	330	81	26	13	$360	$4,532	$757
Healthcare Facility and Hospitals: Exam/Treatment Room	Troffer Basket 90CRI	480	10	101	41	0.24		6,000	800-1	Linear Rec Hi Perf Lensed (repl I	139	119	41	3		$0	$0
Healthcare Facility and Hospitals: Imaging Room	Troffer Basket 80CRI	1,568	31	116	38	0.82	$146	8,400	820	Downlight Lensed (repl CF)	193	77	30	6	$162	$1,050	$120
Healthcare Facility and Hospitals: Medical Supply Room	Troffer Basket 90CRI	12,000	180	101	41	4.35		36,000	830	Linear Direct Lensed (repl FL)	650	106	48	14		$0	$0
Healthcare Facility and Hospitals: Nursery	Troffer Basket 80CRI	0	0	116	38	0.00	$146	19,200	800	Linear Rec Hi Perf Lensed (repl I	366	119	41	9	$129	$1,159	$0
Healthcare Facility and Hospitals: Nurse's Station	Troffer Basket 80CRI	4,800	72	116	38	1.90	$146	3,000	835	Linear Dir/Ind (repl FL)	64	105	42	2	$372	$562	$277
Healthcare Facility and Hospitals: Operating Room	#N/A	0	0		#N/A			90,000	800-1	Linear Rec Hi Perf Lensed (repl I	1,687	119	41	41		$0	$0
Healthcare Facility and Hospitals: Patient Room	Troffer Basket 90CRI	576	13	101	41	0.31	$196	1,920	835	Linear Dir/Ind (repl FL)	41	105	42	1	$372	$360	$61
Healthcare Facility and Hospitals: Physical Therapy Room	Troffer Basket 80CRI	19,200	167	116	38	4.41	$146	12,000	835	Linear Dir/Ind (repl FL)	255	105	42	6	$372	$2,249	$644
Healthcare Facility and Hospitals: Recovery Room	#N/A	0	0		#N/A			7,488	800-1	Linear Rec Hi Perf Lensed (repl I	136	119	41	3		$0	$0
Sports Arena – Playing Area: Class I Facility	#N/A	0	0		#N/A			750,000	809-1	High Bay Industrial (repl FL)	11,319	117	168	67	$0	$0	$0
Sports Arena – Playing Area: Class II Facility	#N/A	0	0		#N/A			500,000	859-1	Lowbay Lensed (Lin Ind - repl M	7,230	120	94	77	$0	$0	$0
Sports Arena – Playing Area: Class III Facility	#N/A	0	0		#N/A			375,000	859-1	Lowbay Lensed (Lin Ind - repl M	5,422	120	94	58	$0	$0	$0
Sports Arena – Playing Area: Class IV Facility	#N/A	0	0		#N/A			250,000	859-1	Lowbay Lensed (Lin Ind - repl M	3,615	120	94	38	$0	$0	$0

Table 113: Task Lighting System Proposed 2022 and 2019 Base Costs

Primary Function Area	2022 Task Luminaire	2022 Task fc x % area x Area (lumens)	2022 Task System Watts	2022 Task Luminaire efficacy	Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 Task fc x % area x Area (lumens)	2019 Task Luminaire Ref No.	2019 Task Luminaire Description	2019 Task System watts	2019 Task Luminaire efficacy	2019 Avg Watts/luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base Task Cost	2022 Proposed Task Cost
Audience Seating Area	Downlight large 6"+ 80CRI Hi Output	16,000	330	90	57	5.8	$182	0	811	PAR downlight flood	0	71	27		$158.00		$1,049.67
Auditorium Area	Downlight large 6"+ 80CRI Hi Output	135,000	2,707	90	57	47.3	$182	13,500	823	Indirect Pendant (repl CF)	440	77	124	3.5	$514.00	$1,824.63	$8,603.29
Auto Repair / Maintenance Area	Downlight large 6"+ 80CRI Warm Hi Ou	0	0	85	42	0.0	$182	24,000	839	Task (repl FL)	571	67	7	77.4	$45.00	$3,481.36	$0.00
Barber, Beauty Salon and Spa Area	Downlight 4" and less 90CRI Warm	46,800	863	69	36	24.2	$162	10,800	811	PAR downlight flood	266	71	27	9.9	$158.00	$1,563.41	$3,912.71
Civic Meeting Place Area	Downlight large 6"+ 90CRI	11,340	216	78	36	5.9	$162	13,230	801	Downlight open (repl INC)	254	86	46	5.5	$157.00	$868.21	$958.58
Classroom, Lecture, Training, Vocational Area	Troffer Basket 80CRI Hi Output	42,560	617	112	61	10.1	$128	0	801	Downlight open (repl INC)	0	86	46		$157.00		$1,293.71
Commercial/Industrial Storage: Warehouse	#N/A	0	0		#N/A	0.0	$0	0	0	NA	0	0			$0.00		$0.00
Commercial/Industrial Storage: Shipping & Handling	Linear light slot 4" or more 80CRI	32,400	746	104	33	22.3		0	0	NA	0	0					
Concourse and Atria Area	Downlight large 6"+ 80CRI Hi Output	72,000	1,354	90	57	23.6	$182	0	0	NA	0	0			$0.00		$4,304.25
Convention, Conference, Multipurpose and Meeting Area	Downlight 4" and less 80CRI	18,900	370	76	32	11.5	$162	4,500	811	PAR downlight flood	101	71	27	3.8	$158.00	$594.28	$1,858.76
Copy Room	Linear light slot 4" or more 80CRI	2,400	45	104	33	1.3				No copy room model in 2019							
Corridor Area	#N/A	0	0		#N/A	0.0	$0	0	0	NA	0	0			$0.00		$0.00
Dining Area: Bar/Lounge and Fine Dining	Strip Under cabinet 90CRI	1,350	68	46	9	7.2	$40	4,500	803	Linear WW Open (repl FL	82	84	28	3.0	$318.00	$940.32	$287.58
Dining Area: Cafeteria/Fast Food	Downlight large 6"+ 80CRI	5,400	131	82	33	4.0		7,200	801	Downlight open (repl INC)	122	86	46	2.7			
Dining Area: Family and Leisure	Downlight large 6"+ 90CRI	9,600	181	78	36	5.0	$162	9,600	823	Indirect Pendant (repl CF)	313	77	124	2.5	$514.00	$1,297.52	$804.79
Kitchen/Food Preparation Area	#N/A	0	0		#N/A	0.0		4,050	838	Linear Industrial (repl FL)	88	131	59	1.5			
Electrical, Mechanical, Telephone Rooms	#N/A	0	0		#N/A	0.0		7,200	839	Task (repl FL)	207	67	7	28.0			
Exercise/Fitness Center and Gymnasium Area	#N/A	0	0		#N/A	0.0		0	0	NA	0	0					
Financial Transaction Area	Linear light slot 4" or less 80CRI	6,480	127	94	32	4.0	$300	0	0	NA	0	0			$0.00		$1,187.41
General/Commercial & Industrial Work Area: Low Bay	Industrial strip 80CRI	43,200	657	135	32	20.6		0	0	NA	0	0					
General/Commercial & Industrial Work Area: High Bay	Industrial strip 80CRI	108,000	1,530	135	32	48.0		0	0	NA	0	0					
General/Commercial & Industrial Work Area: Precision	Industrial strip 80CRI	360,000	4,835	135	32	151.6		0	0	NA	0	0					
Hotel Function Area	Downlight 4" and less 90CRI	11,340	201	83	29	7.0	$162	7,560	801	Downlight open (repl INC)	128	86	46	2.8	$157.00	$437.61	$1,126.21
Scientific Laboratory Area	#N/A	0	0		#N/A	0.0	$0	6,720	801	Downlight open (repl INC)	129	86	46	2.8	$157.00	$441.00	$0.00
Laundry Area	#N/A	0	0		#N/A	0.0		0	0	NA	0	0					
Library : Reading Area	#N/A	0	0		#N/A	0.0	$0	10,080	820	Downlight Lensed (repl CI	197	77	30	6.6	$162.00	$1,071.36	$0.00
Library : Stacks Area	Linear light slot 4" or more 80CRI	6,480	168	104	33	5.0	$320	0	803	Linear WW Open (repl FL	0	84	28		$318.00		$1,609.14
Main Entry Lobby	Downlight large 6"+ 90CRI	6,750	124	78	36	3.4	$162	7,200	801	Downlight open (repl INC)	122	86	46	2.7	$157.00	$416.77	$549.81
Locker Room	#N/A	0	0		#N/A	0.0		600	822	Downlight open	15	77	30	0.5			
Lounge, Breakroom, or Waiting Area	Downlight large 6"+ 90CRI	1,440	27	78	36	0.7	$162	0	0	NA	0	0			$0.00		$120.15
Museum Area: Exhibition/Display	#N/A	0	0		#N/A	0.0		0	0	NA	0	0					
Museum Area: Restoration Room	#N/A	0	0		#N/A	0.0	$0	27,000	830	Linear Direct Lensed (repl	488	106	48	10.2	$122.00	$1,244.82	$0.00
Office Area: ≤ 250 square feet	Downlight large 6"+ 80CRI	2,520	50	82	33	1.5	$162	1,050	839	Task (repl FL)	35	67	7	4.8	$45.00	$214.51	$247.48
Office Area: > 250 square feet and ≤ xxx sf	Troffer Basket 80CRI	10,800	138	116	38	3.7	$146	5,400	839	Task (repl FL)	129	67	7	17.4	$45.00	$783.31	$534.57
Office Area: Open plan office > xxx sf	Pendant direct/indirect 80CRI	50,400	828	97	50	16.7		21,600	839	Task (repl FL)	514	67	7	69.6			

Primary Function Area	2022 Task Luminaire	2022 Task fc x % area x Area (lumens)	2022 Task System Watts	2022 Task Luminaire efficacy	Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 Task fc x % area x Area (lumens)	2019 Task Luminaire Ref No.	2019 Task Luminaire Description	2019 Task System watts	2019 Task Luminaire efficacy	2019 Avg Watts/luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base Task Cost	2022 Proposed Task Cost
Parking Garage Area: Parking Zone	Parking garage luminaire 70CRI	0	0	111	42	0.0		0	0	NA	0	0					
Parking Garage Area: Dedicated Ramps	Parking garage luminaire 70CRI	0	0	111	42	0.0	$300	0	0	NA	0	0			$0		$0.00
Parking Garage Area: Daylight Adaptation Zones	Parking garage luminaire 70CRI Hi Outpu	0	0	112	70	0.0	$300	0	0	NA	0	0			$0		$0.00
Pharmacy Area	Downlight large 6"+ 80CRI Hi Output	7,200	139	90	57	2.4	$182	3,840	830	Linear Direct Lensed (repl	69	106	48	1.5	$122	$177.04	$442.99
Retail Sales Area: Grocery Sales	Downlight large 6"+ 90CRI	218,880	3,524	78	36	96.7	$162	145,920	841	Downlight open (repl MH)	2,550	86	46	55.5	$157	$8,708.92	$15,664.32
Retail Sales Area: Retail Merchandise Sales	Downlight 4" and less 90CRI	134,400	2,064	83	29	71.2	$162	134,400	811	PAR downlight flood	2,752	71	27	102.3	$158	$16,161.35	$11,541.89
Retail Sales Area: Fitting Room	#N/A	0	0		#N/A	0.0		720	830	Linear Direct Lensed (repl	16	106	48	0.3			
Religious Worship Area	Downlight large 6"+ 90CRI Warm Hi Ou	256,000	4,965	70	72	69.2	$182	32,000	834-1	Linear Wall Cove (repl FL	953	81	26	36.3	$360	$13,075.49	$12,589.00
Restrooms	Downlight 4" and less 90CRI	1,200	24	83	29	0.8		1,000	820	Downlight Lensed (repl CI	27	77	30	0.9			
Stairwell	#N/A	0	0	#N/A	#N/A	0.0		0	0	NA	0	0			$0		$0.00
Theater Area: Motion picture	Downlight 4" and less 80CRI	23,400	581	76	32	18.0	$162	0	0	NA	0	0			$0		$2,917.54
Theater Area: Performance	Downlight 4" and less 90CRI Warm	240,000	4,921	69	36	137.7	$162	280,000	811	PAR downlight flood	6,901	71	27	256.5	$158	$40,532.88	$22,308.68
Transportation Function : Baggage Area	Downlight large 6"+ 80CRI	32,400	643	82	33	19.6		27,000	835	Linear Dir/Ind (repl FL)	451	105	42	10.7			
Transportation Function : Ticketing Area	Downlight 4" and less 90CRI	18,000	286	83	29	9.9		20,000	801	Downlight open (repl INC)	339	86	46	7.4			
Videoconferencing Studio	Troffer Basket 90CRI	33,120	567	101	41	13.7		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A			
Aging Eye/Low-vision: Main Entry Lobby	#N/A	0	0		#N/A	0.0		0	801	Downlight open (repl INC)	0	86	46				
Aging Eye/Low-vision: Stairwell	#N/A	0	0		#N/A	0.0	$0	1,600	801	Downlight open (repl INC)	39	86	46	0.8	$157	$132.50	$0.00
Aging Eye/Low-vision: Corridor Area	#N/A	0	0		#N/A	0.0	$0	0	0	NA	0	0			$0		$0.00
Aging Eye/Low-vision: Lounge/Waiting Area	Downlight large 6"+ 90CRI	22,500	364	78	36	10.0	$162	7,200	851	PAR downlight flood	148	71	27	5.5	$158	$871.16	$1,619.02
Aging Eye/Low-vision: Multipurpose Room	Downlight 4" and less 90CRI	22,500	347	83	29	12.0	$162	8,100	851	PAR downlight flood	167	71	27	6.2	$158	$980.06	$1,940.81
Aging Eye/Low-vision: Religious Worship Area	Downlight 4" and less 90CRI	9,072	167	83	29	5.8		0	0	NA	0	0					
Aging Eye/Low-vision: Dining	Downlight 4" and less 90CRI	48,000	833	83	29	28.7		12,800	823	Indirect Pendant (repl CF)	540	77	124	4.4			
Aging Eye/Low-vision: Restroom	Downlight 4" and less 90CRI	4,320	89	83	29	3.1	$162	0	820	Downlight Lensed (repl CI	0	77	30		$162		$500.23
Healthcare Facility and Hospitals: Exam/Treatment Roc	Troffer Basket 90CRI	1,800	55	101	41	1.3		0	0	NA	0	0					
Healthcare Facility and Hospitals: Imaging Room	Downlight large 6"+ 80CRI	3,360	69	82	33	2.1	$162	1,120	820	Downlight Lensed (repl CI	26	77	30	0.9	$162	$139.99	$338.60
Healthcare Facility and Hospitals: Medical Supply Roo	Troffer Basket 90CRI	10,800	181	101	41	4.4		0	0	NA	0	0					
Healthcare Facility and Hospitals: Nursery	Troffer Basket 80CRI	19,200	240	116	38	6.4	$146	4,800	800	Linear Rec Hi Perf Lensed	91	119	41	2.2	$129	$289.80	$928.17
Healthcare Facility and Hospitals: Nurse's Station	Downlight 4" and less 90CRI	2,000	44	83	29	1.5	$162	3,000	839	Task (repl FL)	86	67	7	11.7	$45.00	$524.60	$245.91
Healthcare Facility and Hospitals: Operating Room	Troffer Basket 90CRI	180,000	3,246	101	41	78.4		0	0	NA	0	0					
Healthcare Facility and Hospitals: Patient Room	Troffer Basket 90CRI	4,608	117	101	41	2.8	$196	2,400	830	Linear Direct Lensed (repl	43	106	48	0.9	$122	$110.65	$555.56
Healthcare Facility and Hospitals: Physical Therapy Rc	Downlight large 6"+ 80CRI	12,000	193	82	33	5.9	$162	30,000	835	Linear Dir/Ind (repl FL)	637	105	42	15.1	$372	$5,622.64	$953.15
Healthcare Facility and Hospitals: Recovery Room	Troffer Basket 90CRI	4,608	117	101	41	2.8		0	0	NA	0	0					
Sports Arena – Playing Area: Class I Facility	High Bay 80CRI Hi Output	750,000	15,407	126	517	29.8		0	0	NA	0	0					
Sports Arena – Playing Area: Class II Facility	High Bay 80CRI	500,000	9,119	128	175	52.1		0	0	NA	0	0					
Sports Arena – Playing Area: Class III Facility	Low bay 80CRI	375,000	5,702	145	112	51.1		0	0	NA	0	0					
Sports Arena – Playing Area: Class IV Facility	Low bay 80CRI	250,000	3,801	145	112	34.0		0	0	NA	0	0					

Table 114: Supplemental Lighting System Proposed 2022 and 2019 Base Costs

Primary Function Area	Supplemental Luminaire	2022 Supple-mental fc x % area x Area (lumens)	2022 Supple-mental System Watts	2022 Supple-mental Luminaire efficacy	Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 Supple-mental fc x % area x Area (lumens)	2019 Supple-mental Luminaire Ref No.	2019 Supple-mental Luminaire Description	2019 Supple-mental System watts	2019 Supple-mental Luminaire efficacy	2019 Avg Watts/luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base Supple-mental Cost	2022 Proposed Supple-mental Cost
Audience Seating Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Auditorium Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Auto Repair / Maintenance Area	Industrial strip 80CRI Hi Output	48,000	779	122	59	13	$95.00	0	0	NA	0.00	0		0.00	$0	$0.00	$1,252.52
Barber, Beauty Salon and Spa Area	Downlight 4" and less 90CRI Warm	21,600	392	69	36	11	$162.00	0	0	NA	0.00	0		0.00	$0	$0.00	$1,776.11
Civic Meeting Place Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Classroom, Lecture, Training, Vocational Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Commercial/Industrial Storage: Warehouse	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Commercial/Industrial Storage: Shipping & Handling	#N/A	0	0	0	#N/A			0	0	NA	0.00	0		0.00	$0		
Concourse and Atria Area	#N/A	0	0	0	#N/A		$0.00	108,000	851	PAR downlight flood	2224.78	71	27	82.71	$158	$13,067.46	$0.00
Convention, Conference, Multipurpose and Meeting Are	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Copy Room	#N/A	0	0	0	#N/A			#N/A	#N/A	No copy room model in 2019							
Corridor Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Dining Area: Bar/Lounge and Fine Dining	Downlight 4" and less 90CRI	2,700	51	83	29	2	$162.00	4,500	819	Task (repl MR)	107.09	67	7	14.51	$45	$652.75	$285.73
Dining Area: Cafeteria/Fast Food	Strip Under cabinet 80CRI	3,600	106	63	9	12		0	0	NA	0.00	0		0.00			
Dining Area: Family and Leisure	Downlight 4" and less 90CRI	12,000	217	83	29	7	$162.00	0	0	NA	0.00	0		0.00	$0	$0.00	$1,211.50
Kitchen/Food Preparation Area	Troffer Lensed 80CRI Hi Output	13,500	361	115	67	5		0	0	NA	0.00	0		0.00	$0		
Electrical, Mechanical, Telephone Rooms	#N/A	0	0	0	#N/A			0	0	NA	0.00	0		0.00	$0		
Exercise/Fitness Center and Gymnasium Area	#N/A	0	0	0	#N/A			0	0	NA	0.00	0		0.00	$0		
Financial Transaction Area	Strip Under cabinet 80CRI	3,600	88	63	9	10	$40.00	0	0	NA	0.00	0		0.00	$0	$0.00	$399.42
General/Commercial & Industrial Work Area: Low Bay	Strip Under cabinet 80CRI Hi Output	48,000	1,223	76	15	82		0	0	NA	0.00	0		0.00	$0		
General/Commercial & Industrial Work Area: High Bay	Strip Under cabinet 80CRI Hi Output	120,000	2,978	76	15	199		0	0	NA	0.00	0		0.00	$0		
General/Commercial & Industrial Work Area: Precision	Industrial strip 80CRI Hi Output	72,000	855	122	59	14		0	0	NA	0.00	0		0.00	$0		
Hotel Function Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Scientific Laboratory Area	Strip Under cabinet 80CRI Hi Output	0	0	76	15		$40.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Laundry Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0		
Library : Reading Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Library : Stacks Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Main Entry Lobby	Downlight 4" and less 90CRI Warm	13,500	260	69	36	7	$162.00	0	0	NA	0.00	0		0.00	$0	$0.00	$1,178.38
Locker Room	Troffer Lensed 80CRI	800	24	110	38	1		0	0	NA	0.00	0		0.00	$0		
Lounge, Breakroom, or Waiting Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Museum Area: Exhibition/Display	Downlight 4" and less 90CRI	4,368	80	83	29	3		0	0	NA	0.00	0		0.00	$0		
Museum Area: Restoration Room	Downlight 4" and less 90CRI	24,000	365	83	29	13	$162.00	0	0	NA	0.00	0		0.00	$0	$0.00	$2,043.81
Office Area: ≤ 250 square feet	Desk light task 90CRI	0	0	77	6		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Office Area: > 250 square feet and ≤ xxx sf	Strip Under cabinet 80CRI	0	0	63	9		$40.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Office Area: Open plan office > xxx sf	Strip Under cabinet 80CRI	0	0	63	9			0	0	NA	0.00	0		0.00	$0		

Primary Function Area	Supplemental Luminaire	2022 Supple-mental fc x % area x Area (lumens)	2022 Supple-mental System Watts	2022 Supple-mental Luminaire efficacy	Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 Supple-mental fc x % area x Area (lumens)	2019 Supple-mental Luminaire Ref No.	2019 Supple-mental Luminaire Description	2019 Supple-mental System watts	2019 Supple-mental Luminaire efficacy	2019 Avg Watts/luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base Supple-mental Cost	2022 Proposed Supple-mental Cost
Parking Garage Area: Parking Zone	#N/A	0	0	0	#N/A			0	0	NA	0.00	0		0.00	$0		
Parking Garage Area: Dedicated Ramps	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Parking Garage Area: Daylight Adaptation Zones	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Pharmacy Area	Downlight large 6"+ 80CRI Hi Output	3,600	70	90	57	1	$182.00	0	0	NA	0.00	0		0.00	$0	$0.00	$221.50
Retail Sales Area: Grocery Sales	Downlight large 6"+ 90CRI	57,600	923	78	36	25	$162.00	57,600	851	PAR downlight flood	1186.55	71		#DIV/0!	$158	$0.00	$4,101.59
Retail Sales Area: Retail Merchandise Sales	Downlight large 6"+ 90CRI	96,000	1,516	78	36	42	$162.00	0	0	NA	0.00	0		0.00	$0	$0.00	$6,739.91
Retail Sales Area: Fitting Room	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0			$0		
Religious Worship Area	Downlight 4" and less 90CRI	120,000	2,023	83	29	70	$162.00	84,000	811	PAR downlight flood	1719.70	71	27	63.93	$158	$10,100.84	$11,315.18
Restrooms	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0			$0		
Stairwell	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Theater Area: Motion picture	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Theater Area: Performance	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Transportation Function : Baggage Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0					
Transportation Function : Ticketing Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0					
Videoconferencing Studio	#N/A	0	0	0	#N/A		$0.00	#N/A	#N/A	#N/A	#N/A	#N/A					
Aging Eye/Low-vision: Main Entry Lobby	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0					
Aging Eye/Low-vision: Stairwell	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Aging Eye/Low-vision: Corridor Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Aging Eye/Low-vision: Lounge/Waiting Area	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Aging Eye/Low-vision: Multipurpose Room	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Aging Eye/Low-vision: Religious Worship Area	#N/A	0	0	0	#N/A		$0.00	12,096	801	Downlight open (repl INC)	205.00	86	46				
Aging Eye/Low-vision: Dining	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0					
Aging Eye/Low-vision: Restroom	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Healthcare Facility and Hospitals: Exam/Treatment Roc	Downlight large 6"+ 90CRI	3,600	68	78	36	2		0	0	NA	0.00	0					
Healthcare Facility and Hospitals: Imaging Room	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Healthcare Facility and Hospitals: Medical Supply Roo	Troffer Basket 90CRI	12,000	202	101	41	5		0	0	NA	0.00	0					
Healthcare Facility and Hospitals: Nursery	Downlight large 6"+ 90CRI	8,000	138	78	36	4	$162.00	1,600	800	Linear Rec Hi Perf Lensed (	30.50	119	41	0.75	$129	$96.60	$611.44
Healthcare Facility and Hospitals: Nurse's Station	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Healthcare Facility and Hospitals: Operating Room	#N/A	#VALUE!	0	0	#N/A		$0.00	0	0	NA	0.00	0					
Healthcare Facility and Hospitals: Patient Room	Downlight 4" and less 90CRI	1,440	24	83	29	1	$162.00	96	839	Task (repl FL)	2.75	67	7	0.37	$45	$16.79	$134.28
Healthcare Facility and Hospitals: Physical Therapy Rc	#N/A	0	0	0	#N/A		$0.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
Healthcare Facility and Hospitals: Recovery Room	Downlight 4" and less 90CRI Warm	3,840	72	69	36	2		0	0	NA	0.00	0	0	0.00			
Sports Arena – Playing Area: Class I Facility	#N/A	0	0	0	#N/A			0	0	NA	0.00	0	0	0.00			
Sports Arena – Playing Area: Class II Facility	#N/A	0	0	0	#N/A			0	0	NA	0.00	0	0	0.00			
Sports Arena – Playing Area: Class III Facility	#N/A	0	0	0	#N/A			0	0	NA	0.00	0	0	0.00			
Sports Arena – Playing Area: Class IV Facility	#N/A	0	0	0	#N/A			0	0	NA	0.00	0	0	0.00			

Table 115: Wall Washing Lighting System Proposed 2022 and 2019 Base Costs

Primary Function Area	2022 Wall Washer Description	2022 Wall Washer System Watts	2022 Vertical Delivered Efficacy	2022 Avg Watts/luminaire	Avg Lumens Per WW Luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 WW Luminaire Ref No.	2019 WWl Luminaire Description	2019 Wall Washer System Watts	2019 Vertical delivered efficacy	2019 Avg Watts/luminaire	2019 Avg Lumens per Luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base Wall Wash Cost	2022 Proposed Wall Wash Cost	2019 Base Total Cost	2022 Proposed Total Cost
Audience Seating Area	Linear WW HO 70/30/20	828	38.8	47.0	4,289	17.6	$380.00	901	Forward WW - Linear	935.32	21.90	18.0	926.3	52.0	$320.00	$16,627.87	$6,696.33	$20,431	$8,716
Auditorium Area	Hi CRI Linear WW HO 70/50/20	2,281	35.4	37.0	4,009	61.7	$410.00	902	Wall Graze - Aperture	2,048	29	24	2,155	85.4	$282.00	$24,069.14	$25,277.06	$26,762	$33,880
Auto Repair / Maintenance Area	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$5,845	$4,304
Barber, Beauty Salon and Spa Area	Hi CRI Aperture WW 70/50/20	177	37.5	23.4	1,886	7.6	$228.00	902	Aperture Wall Wash	117.76	44	23	2,176	5.1	$282.00	$1,443.82	$1,728.59	$4,630	$7,585
Civic Meeting Place Area	Hi CRI Aperture WW 70/50/20	141	37.5	23.4	1,886	6.0	$228.00	952	CRI-Wall Graze - Aperture	92	23	34	1,712	2.7	$282.00	$764.55	$1,371.90	$2,010	$2,414
Classroom, Lecture, Training, Vocational Area	Linear WW 70/50/20	111	43.0	27.0	2,713	4.1	$356.00	905	Wall Wash - Linear	103	34	18	1,445	5.7	$320.00	$1,837.45	$1,458.37	$8,325	$2,752
Commercial/Industrial Storage: Warehouse	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$483	$514
Commercial/Industrial Storage: Shipping & Handling	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Concourse and Atria Area	Linear Wall Grazer HO 70/30/20	3,355	30.7	47.0	2,905	71.4	$380.00	956	WW - Aperture HC	2,243	25	72	3,620	31.2	$282.00	$8,785.40	$27,122.99	$32,984	$44,017
Convention, Conference, Multipurpose and Meeting Are	Hi CRI Linear WW 70/50/20	171	38.7	27.0	2,713	6.3	$228.00	954	CRI-Wall Wash - Aperture	170	35	34	3,109	5.0	$282.00	$1,413.05	$1,440.00	$9,214	$3,390
Copy Room	0	0	38.7	27.0	2,713	0.0		#N/A	No copy room model in 2019									$0	$0
Corridor Area	Forward throw WW corridor 70/50/20	59	69.8	27.0	2,713	2.2	$360.00	904	Wall Wash - Aperture	291	44	24	1,521	12.1	$228.00	$2,762.23	$790.32	$2,762	$1,804
Dining Area: Bar/Lounge and Fine Dining	Hi CRI Linear Wall Grazer HO 70/50/20	201	28.3	36.8	2,616	5.5	$444.00	952	CRI-Wall Graze - Aperture	307	23	34	2,004	9.0	$282.00	$2,548.50	$2,420.65	$5,812	$3,373
Dining Area: Cafeteria/Fast Food	Linear WW 70/50/20	129	43.0	27.0	2,713	4.8		905	Wall Wash - Linear	52	34	18	1,445	2.9				$0	$0
Dining Area: Family and Leisure	Linear WW 70/50/20	90	43.0	27.0	2,713	3.3	$356.00	905	Wall Wash - Linear	280	34	18	1,445	15.5	$320.00	$4,973.56	$1,181.55	$8,083	$3,461
Kitchen/Food Preparation Area	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Electrical, Mechanical, Telephone Rooms	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Exercise/Fitness Center and Gymnasium Area	0	0	#N/A	#N/A	#N/A	#N/A		901	Forward WW - Linear	0	22	18	#N/A	0.0				$0	$0
Financial Transaction Area	Linear Wall Grazer 70/50/20	177	37.5	27.0	2,183	6.6	$356.00	903	Wall Graze - Linear	22	31	18	1,202	1.2	$360.00	$434.05	$2,340.31	$6,874	$4,084
General/Commercial & Industrial Work Area: Low Bay	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
General/Commercial & Industrial Work Area: High Bay	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
General/Commercial & Industrial Work Area: Precision	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Hotel Function Area	Hi CRI Aperture WW 70/50/20	141	37.5	23.4	1,886	6.0	$228.00	904	Wall Wash - Aperture	82	44	24	2,271	3.4	$228.00	$776.88	$1,371.90	$1,701	$2,910
Scientific Laboratory Area	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$8,327	$958
Laundry Area	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Library : Reading Area	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$4,255	$1,864
Library : Stacks Area	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	901	Forward WW - Linear	164	22	18	#N/A	9.1	$320.00	$2,922.87	$0.00	$4,362	$2,493
Main Entry Lobby	Hi CRI Aperture WW HO 70/40/20	497	36.3	50.0	4,018	9.9	$282.00	906	WW - Aperture HC	385	31	52	3,597	7.4	$282.00	$2,085.32	$2,800.55	$6,512	$5,313
Locker Room	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Lounge, Breakroom, or Waiting Area	Hi CRI Linear Wall Grazer 70/50/20	150	22.1	18.3	1,330	8.2	$406.00	953	CRI-Wall Graze - Linear	258	25	28	2,283	9.2	$410.00	$3,783.18	$3,328.40	$3,885	$3,658
Museum Area: Exhibition/Display	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A			$0	$0
Museum Area: Restoration Room	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$5,024	$8,995
Office Area: ≤ 250 square feet	Linear WW 70/50/20	0	43.0	27.0	2,713	0.0	$356.00	0	N/A	0	N/A	0	#VALUE!	#DIV/0!	#N/A	$0.00	$0.00	$415	$292
Office Area: > 250 square feet and ≤ xxx sf	Forward throw WW 70/50/20	68	51.6	28.0	2,713	2.4	$360.00	905	Wall Wash - Linear	13	34	18	1,160	0.7	$320.00	$233.14	$872.58	$2,736	$1,523
Office Area: Open plan office > xxx sf	Forward throw WW 70/50/20	136	51.6	28.0	2,713	4.8		905	Wall Wash - Linear	52	34	18	1,160	2.9				$0	$0

Primary Function Area	2022 Wall Washer Description	2022 Wall Washer System Watts	2022 Vertical Delivered Efficacy	2022 Avg Watts/luminaire	Avg Lumens Per WW Luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 WW Luminaire Ref No.	2019 WWl Luminaire Description	2019 Wall Washer System Watts	2019 Vertical delivered efficacy	2019 Avg Watts/luminaire	2019 Avg Lumens per Luminaire	2019 Number of Luminaires	2019 Cost Per Luminaire	2019 Base Wall Wash Cost	2022 Proposed Wall Wash Cost	2019 Base Total Cost	2022 Proposed Total Cost
Parking Garage Area: Parking Zone	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Parking Garage Area: Dedicated Ramps	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$2,616	$1,409
Parking Garage Area: Daylight Adaptation Zones	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$5,395	$5,161
Pharmacy Area	0	0	#N/A	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$1,200	$1,352
Retail Sales Area: Grocery Sales	Hi CRI Linear WW 70/50/20	286	38.7	27.0	2,713	10.6	$228.00	905	Wall Wash - Linear	671	34	18	1,604	37.3	$320.00	$11,936.54	$2,419.20	$24,178	$24,333
Retail Sales Area: Retail Merchandise Sales	Hi CRI Aperture WW 70/50/20	887	37.5	23.4	1,886	37.9	$228.00	904	Wall Wash - Aperture	1,570	44	24	2,271	65.4	$228.00	$14,916.04	$8,642.95	$44,381	$29,300
Retail Sales Area: Fitting Room	Hi CRI Aperture WW 70/50/20	71	37.5	23.4	1,886	3.1		0	N/A	0	N/A	0	#VALUE!	#DIV/0!				$0	$0
Religious Worship Area	Hi CRI Linear Wall Grazer HO 70/30/20	758	25.7	36.8	2,616	20.6	$444.00	952	CRI-Wall Graze - Aperture	2,276	23	34	2,208	66.9	$282.00	$18,877.76	$9,143.39	$52,825	$33,048
Restrooms	Forward throw WW 70/50/20	22	51.6	28.0	2,713	0.8		903	Wall Graze - Linear	26	31	18	1,047	1.4				$0	$0
Stairwell	Linear WW 70/50/20	16	43.0	27.0	2,713	0.6	$356.00	901	Forward WW - Linear	55	22	18	922	3.0	$320.00	$974.29	$214.83	$1,384	$386
Theater Area: Motion picture	Linear Wall Grazer 70/30/20	268	36.0	27.0	2,183	9.9	$356.00	903	Wall Graze - Linear	0	31	18	1,252	0.0	$360.00	$0.00	$3,527.77	$5,628	$6,445
Theater Area: Performance	Hi CRI Linear Wall Grazer HO 70/30/20	5,027	25.7	36.8	2,616	136.6	$444.00	952	CRI-Wall Graze - Aperture	6,145	23	34	2,208	180.7	$282.00	$50,969.94	$60,654.92	$97,872	$82,964
Transportation Function : Baggage Area	Forward throw WW 70/50/20	244	51.6	28.0	2,713	8.7		902	Wall Graze - Aperture	0	29	24	1,321	0.0				$0	$0
Transportation Function : Ticketing Area	Linear WW 70/50/20	235	43.0	27.0	2,713	8.7		905	Wall Wash - Linear	350	34	18	1,445	19.4				$0	$0
Videoconferencing Studio	Hi CRI Linear Wall Grazer 70/50/20	1,122	22.1	18.3	1,330	61.3		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A				$0	$0
Aging Eye/Low-vision: Main Entry Lobby	Linear Wall Grazer 70/50/20	560	37.5	27.0	2,183	20.8		903	Wall Graze - Linear	78	31	18	1,202	4.3				$0	$0
Aging Eye/Low-vision: Stairwell	Forward throw WW 70/50/20	37	51.6	28.0	2,713	1.3	$360.00	903	Wall Graze - Linear	26	31	18	1,047	1.4	$360.00	$516.73	$474.68	$1,086	$803
Aging Eye/Low-vision: Corridor Area	Hi CRI Forward throw WW corridor 70/!	287	55.1	27.0	2,713	10.6	$410.00	902	Wall Graze - Aperture	437	29	24	1,282	18.2	$282.00	$5,134.75	$4,364.52	$6,572	$5,104
Aging Eye/Low-vision: Lounge/Waiting Area	Hi CRI Aperture WW 70/50/20	401	37.5	23.4	1,886	17.1	$228.00	903	Wall Graze - Linear	194	31	18	1,198	10.8	$360.00	$3,875.45	$3,909.91	$7,762	$6,257
Aging Eye/Low-vision: Multipurpose Room	Hi CRI Aperture WW 70/50/20	176	37.5	23.4	1,886	7.5	$228.00	903	Wall Graze - Linear	174	31	18	1,198	9.7	$360.00	$3,487.91	$1,714.87	$6,135	$4,504
Aging Eye/Low-vision: Religious Worship Area	Hi CRI Linear Wall Grazer 70/50/20	450	22.1	18.3	1,330	24.6		903	Wall Graze - Linear	109	31	18	1,835	6.0				$0	$0
Aging Eye/Low-vision: Dining	Hi CRI Linear Wall Grazer 70/50/20	606	22.1	18.3	1,330	33.1		903	Wall Graze - Linear	207	31	18	1,835	11.5				$0	$0
Aging Eye/Low-vision: Restroom	Forward throw WW 70/50/20	81	51.6	28.0	2,713	2.9	$360.00	903	Wall Graze - Linear	33	31	18	1,047	1.8	$360.00	$651.08	$1,047.09	$5,183	$2,304
Healthcare Facility and Hospitals: Exam/Treatment Roo	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A			$0	$0
Healthcare Facility and Hospitals: Imaging Room	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!	#N/A	$0.00	$0.00	$1,190	$458
Healthcare Facility and Hospitals: Medical Supply Roo	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Healthcare Facility and Hospitals: Nursery	0	0	#N/A	#N/A	#N/A	#N/A		905	Wall Wash - Linear	0	34	18	#N/A	0.0	$320.00	$0.00	$0.00	$1,546	$1,540
Healthcare Facility and Hospitals: Nurse’s Station	Hi CRI Linear Wall Grazer 70/50/20	102	22.1	18.3	1,330	5.6	$406.00	0	N/A	0	N/A	0	#VALUE!	#DIV/0!	#N/A	$0.00	$2,255.11	$1,087	$2,778
Healthcare Facility and Hospitals: Operating Room	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Healthcare Facility and Hospitals: Patient Room	Hi CRI Aperture WW 70/50/20	0	37.5	23.4	1,886	0.0	$228.00	0	N/A	0	N/A	0	#VALUE!	#DIV/0!	#N/A	$0.00	$0.00	$487	$751
Healthcare Facility and Hospitals: Physical Therapy Rc	Linear Wall Grazer 70/50/20	411	37.5	27.0	2,183	15.2	$356.00	0	N/A	0	N/A	0	#VALUE!	#DIV/0!	#N/A	$0.00	$5,417.39	$7,872	$7,014
Healthcare Facility and Hospitals: Recovery Room	Hi CRI Linear WW 70/50/20	26	38.7	955S-nr	0	#VALUE!		955	CRI-Wall Wash - Linear	12	27	28	#VALUE!	0.4				$0	$0
Sports Arena – Playing Area: Class I Facility	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Sports Arena – Playing Area: Class II Facility	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Sports Arena – Playing Area: Class III Facility	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0
Sports Arena – Playing Area: Class IV Facility	0	0	#N/A	#N/A	#N/A	#N/A		0	N/A	0	N/A	0	#N/A	#DIV/0!				$0	$0

Rows that are salmon colored are spaces where the allowed lighting power has increased. In many cases both the first cost and energy costs would increase, but the designer has more LPD to achieve lighting goals.

The following table contains the incremental cost, energy cost savings and then calculates the present valued benefits (positive energy cost savings and negative incremental first costs) and the present valued costs (negative energy savings and positive incremental costs). The ratios of these two values is the Benefit to Cost Ratio.

Table 116: Total First Costs and Life Cycle Energy Cost Savings and Benefit-to-Cost Ratios

Primary Function Area	Prototype Area (sf)	Incremental Cost 2022 Systems	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Audience Seating Area	3,200	-$11,715	$4,073	$15,788	$0	Infinite
Auditorium Area	4,500	$7,118	$1,909	$1,909	$7,118	0.27
Auto Repair / Maintenance Area	4,800	-$1,540	$1,481	$3,021	$0	Infinite
Barber, Beauty Salon and Spa Area	1,440	$2,956	$2,321	$2,321	$2,956	0.79
Civic Meeting Place Area	540	$403	$687	$687	$403	1.70
Classroom, Lecture, Training, Vocational Area	1,064	-$5,573	$326	$5,899	$0	Infinite
Commercial/Industrial Storage: Warehouse	800	$31	$144	$144	$31	4.66
Commercial/Industrial Storage: Shipping & Handling	1,800	$0	$0	$0	$0	NC
Concourse and Atria Area	12,000	$11,032	$33,849	$33,849	$11,032	3.07
Convention, Conference, Multipurpose and Meeting Area	900	-$5,824	$1,146	$6,969	$0	Infinite
Copy Room	200	$0	$0	$0	$0	NC
Corridor Area	640	-$958	-$166	$958	$166	EC up 5.77
Dining Area: Bar/Lounge and Fine Dining	1,800	-$2,439	$3,267	$5,705	$0	Infinite
Dining Area: Cafeteria/Fast Food	1,200	$0	$0	$0	$0	NC
Dining Area: Family and Leisure	2,400	-$4,622	$4,356	$8,977	$0	Infinite
Kitchen/Food Preparation Area	450	$0	$0	$0	$0	NC
Electrical, Mechanical, Telephone Rooms	1,200	$0	$0	$0	$0	NC
Exercise/Fitness Center and Gymnasium Area	2,400	$0	$0	$0	$0	NC
Financial Transaction Area	720	-$2,790	$560	$3,351	$0	Infinite
General/Commercial & Industrial Work Area: Low Bay	4,800	$0	$0	$0	$0	NC
General/Commercial & Industrial Work Area: High Bay	12,000	$0	$0	$0	$0	NC
General/Commercial & Industrial Work Area: Precision	4,800	$0	$0	$0	$0	NC

Primary Function Area	Prototype Area (sf)	Incremental Cost 2022 Systems	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Hotel Function Area	540	$1,209	$229	$229	$1,209	0.19
Scientific Laboratory Area	672	-$7,369	$589	$7,958	$0	Infinite
Laundry Area	1,200	$0	$0	$0	$0	NC
Library: Reading Area	720	-$2,392	$187	$2,578	$0	Infinite
Library: Stacks Area	360	-$1,870	$187	$2,056	$0	Infinite
Main Entry Lobby	1,800	-$1,198	$3,055	$4,253	$0	Infinite
Locker Room	200	$0	$0	$0	$0	NC
Lounge, Breakroom, or Waiting Area	480	-$227	$611	$838	$0	Infinite
Museum Area: Exhibition/Display	2,184	$0	$0	$0	$0	NC
Museum Area: Restoration Room	2,400	$3,971	-$2,037	$0	$6,008	EC up 0.00
Office Area: ≤ 250 square feet	140	-$123	$36	$160	$0	Infinite
Office Area: > 250 square feet and ≤ xxx sf	600	-$1,214	$156	$1,369	$0	Infinite
Office Area: Open plan office > xxx sf	2,400	$0	$0	$0	$0	NC
Parking Garage Area: Parking Zone	7,200	$0	$0	$0	$0	NC
Parking Garage Area: Dedicated Ramps	1,920	-$1,206	$4,853	$6,060	$0	Infinite
Parking Garage Area: Daylight Adaptation Zones	1,980	-$234	-$16,684	$234	$16,684	EC up 0.01
Pharmacy Area	480	$152	$387	$387	$152	2.54
Retail Sales Area: Grocery Sales	4,800	$155	$1,934	$1,934	$155	12.46
Retail Sales Area: Retail Merchandise Sales	4,800	-$15,081	$1,934	$17,016	$0	Infinite
Retail Sales Area: Fitting Room	60	$0	$0	$0	$0	NC
Religious Worship Area	8,000	-$19,777	$3,394	$23,171	$0	Infinite
Restrooms	200	$0	$0	$0	$0	NC
Stairwell	360	-$998	$93	$1,092	$0	Infinite
Theater Area: Motion picture	1,560	$818	$3,309	$3,309	$818	4.05

Primary Function Area	Prototype Area (sf)	Incremental Cost 2022 Systems	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Theater Area: Performance	16,000	-$14,909	$33,943	$48,852	$0	Infinite
Transportation Function: Baggage Area	5,400	$0	$0	$0	$0	NC
Transportation Function: Ticketing Area	2,000	$0	$0	$0	$0	NC
Videoconferencing Studio	828	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Main Entry Lobby	600	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Stairwell	160	-$282	-$83	$282	$83	EC up 3.40
Aging Eye/Low-vision: Corridor Area	640	-$1,468	-$166	$1,468	$166	EC up 8.84
Aging Eye/Low-vision: Lounge/Waiting Area	900	-$1,505	-$410	$1,505	$410	EC up 3.67
Aging Eye/Low-vision: Multipurpose Room	900	-$1,631	$821	$2,452	$0	Infinite
Aging Eye/Low-vision: Religious Worship Area	504	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Dining	1,600	$0	$0	$0	$0	NC
Aging Eye/Low-vision: Restroom	216	-$2,879	-$224	$2,879	$224	EC up 12.84
Healthcare Facility and Hospitals: Exam/Treatment Room	120	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Imaging Room	224	-$732	$144	$876	$0	Infinite
Healthcare Facility and Hospitals: Medical Supply Room	1,200	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Nursery	800	-$6	$770	$776	$0	Infinite
Healthcare Facility and Hospitals: Nurse's Station	200	$1,691	-$385	$0	$2,076	EC up 0.00
Healthcare Facility and Hospitals: Operating Room	900	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Patient Room	192	$264	-$185	$0	$449	EC up 0.00
Healthcare Facility and Hospitals: Physical Therapy Room	1,200	-$858	$770	$1,627	$0	Infinite
Healthcare Facility and Hospitals: Recovery Room	192	$0	$0	$0	$0	NC

Primary Function Area	Prototype Area (sf)	Incremental Cost 2022 Systems	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Sports Arena – Playing Area: Class I Facility	5,000	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class II Facility	5,000	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class III Facility	5,000	$0	$0	$0	$0	NC
Sports Arena – Playing Area: Class IV Facility	5,000	$0	$0	$0	$0	NC

Key to B/C ratios:

NC: No change to the required LPD, thus both benefits and costs are 0.

Infinite: Energy costs savings with no incremental first costs or a decrease in incremental first costs.

EC up: Energy costs have increased (negative energy savings), followed by benefit cost ratio.