DOCKETED

Docket Number:	21-BSTD-01
Project Title:	2022 Energy Code Update Rulemaking
TN #:	237704
Document Title:	Nonresidential Indoor Lighting CASE Report
Description:	Document Relied Upon. CASE Report #2022-NR-LIGHT2-F. Authors: Marissa Lerner, Jasmine Shepard, Christopher Uraine, Yao-Jung Wen, Bernard Bauer, and Jonathan McHugh. March 2021.
Filer:	Adrian Ownby
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	5/6/2021 10:15:54 AM
Docketed Date:	5/6/2021

Nonresidential Indoor Lighting March 2021 Addendum

2022-NR-LIGHT2-F | Nonresidential Lighting | March 2021 ADDENDUM

Prepared by Energy Solutions

Please submit comments to info@title24stakeholders.com.

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

This report was prepared by the California Statewide Codes and Standards Enhancement (CASE) Program that is funded, in part, by California utility customers under the auspices of the California Public Utilities Commission.

Pacific Gas and Electric Company | Southern California Edison — Energy for What's Ahead | SDGE — A Sempra Energy utility | Los Angeles Department of Water & Power | SMUD

Document Information

Category:	Codes and Standards
Keywords:	Statewide Codes and Standards Enhancement (CASE) Initiative; California Statewide Utility Codes and Standards Team; Codes and Standards Enhancements; 2022 California Energy Code; 2022 Title 24, Part 6; efficiency; occupancy sensors, LPD; lighting power density; lighting controls.
Authors:	Marissa Lerner, Jasmine Shepard, Christopher Uraine, Yao-Jung Wen (Energy Solutions); Bernard Bauer (Integrated Lighting Concepts); Jonathan McHugh (McHugh Energy)
Prime Contractor	Energy Solutions
Project Management:	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District.

Table of Contents

List of Tables

Addendum to Nonresidential Indoor Lighting – Final CASE Report

The Statewide CASE Team docketed the Indoor Lighting Final CASE Report in September 2020. Shortly after this report was made publicly available, the Energy Commission reached out to the Statewide CASE Team to request additional details on the cost effectiveness of the proposed measure titled “multi-zone occupancy sensing in large offices.” The Energy Commission requested investigation into smaller office scenarios than what was originally analyzed for the Final CASE Report. At the request of the Energy Commission, the Statewide CASE Team developed a supplementary cost effectiveness analysis for additional office sizes to show the proposed requirement would be cost effective for small offices. The additional analysis was needed to mitigate concerns that the proposed requirement would only be cost effective for very large office spaces. The Statewide CASE Team modeled 400, 601, and 900 square foot offices as a supplementary analysis.[1]

In October 2020, the Statewide CASE Team presented the additional analysis to the Energy Commission showing these smaller sizes were cost effective. As a result, the Statewide CASE Team did not make any updates to the proposed requirement.

The Statewide CASE Team also conducted an additional energy analysis to better capture the non-lighting savings associated with the heating, ventilation, and air conditioning (HVAC) occupied standby requirements that are triggered by the new multi-zone occupancy sensing requirements in large offices. The original analysis underestimated HVAC savings, so the Statewide CASE Team updated the analysis to ensure HVAC savings were accounted for properly.

This addendum presents the additional analysis on the supplementary cost-effectiveness calculations and the updated energy savings analysis to capture HVAC savings.

Model Offices D, E, and F

Overview of Model Offices D, E, and F

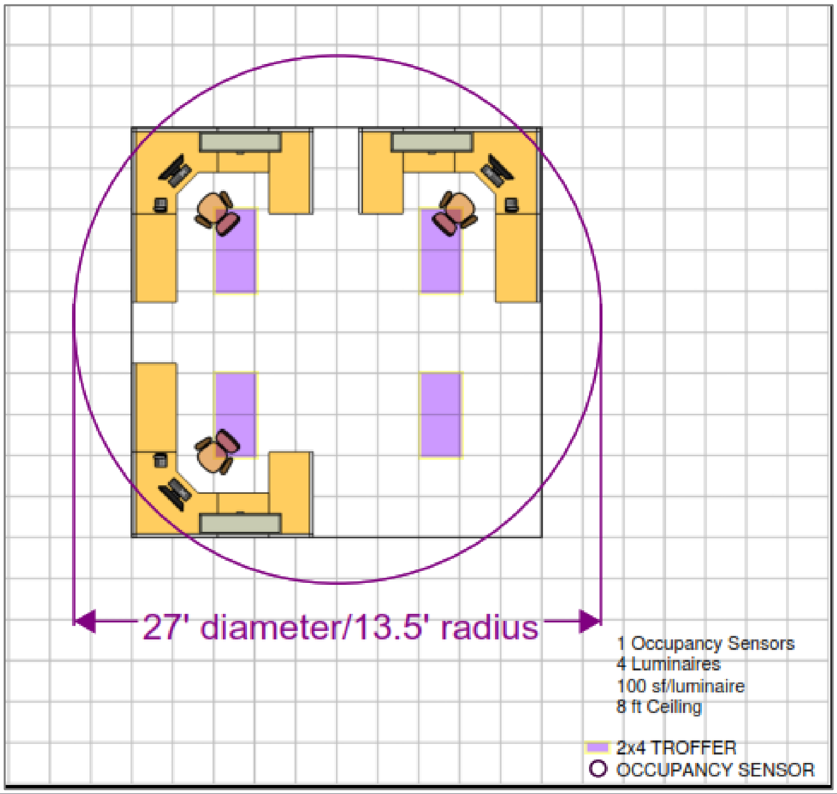
The Statewide CASE Team modeled three additional office spaces to show cost effectiveness at the request of the Energy Commission. The purpose of this investigation was to verify that the proposed code change would still be cost effective in

---

[1] The Statewide CASE Team had already modeled three office sizes for the Draft and Final CASE Reports. The original office sizes are 2,584, 4,000, and 7,540 square feet.

office spaces larger than 250 square feet but smaller than the original model office A, which was 2,584 ft^2. Table 1, Table 2, and Table 3 provide an overview of the three models, including size, number of control zones, and expected occupants.

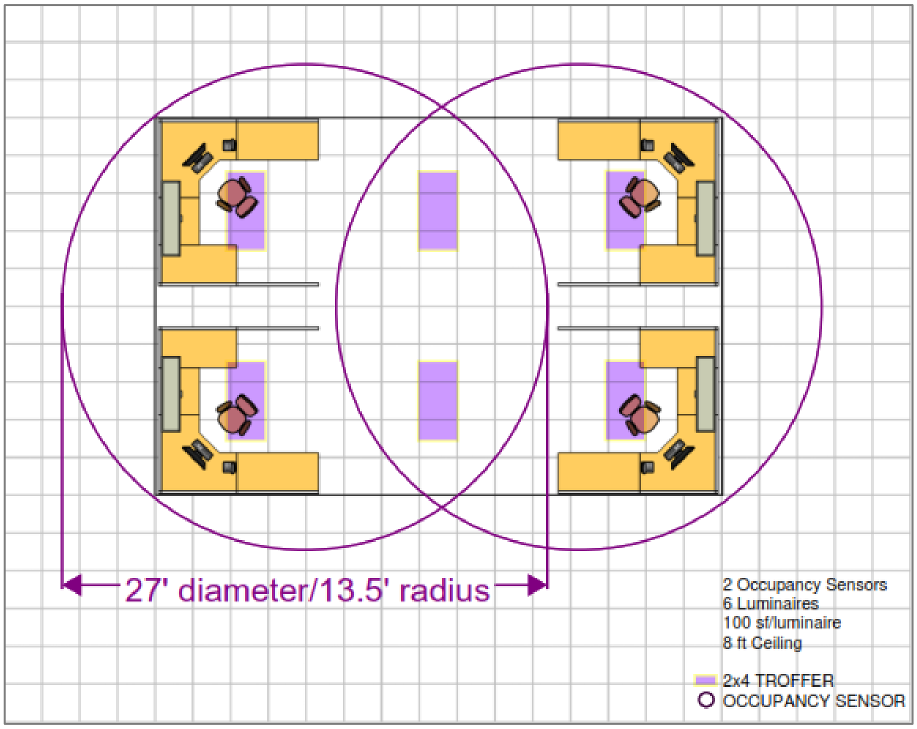
Table 1: Model D Floor Plan Details

Office Floor Plan Model	Model Office D
	
Square footage	400 ft^2
Number of occupants	3
Average area per workstation/cubicle (a)	133 ft^2
Number of luminaires	4
General lighting layout	100 ft^2/luminaire
Total lighting load(b)	160 W
Lighting power density(b)	0.40 W/ft^2

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

(b) The total lighting load and LPDs shown here consider only general lighting in the space.

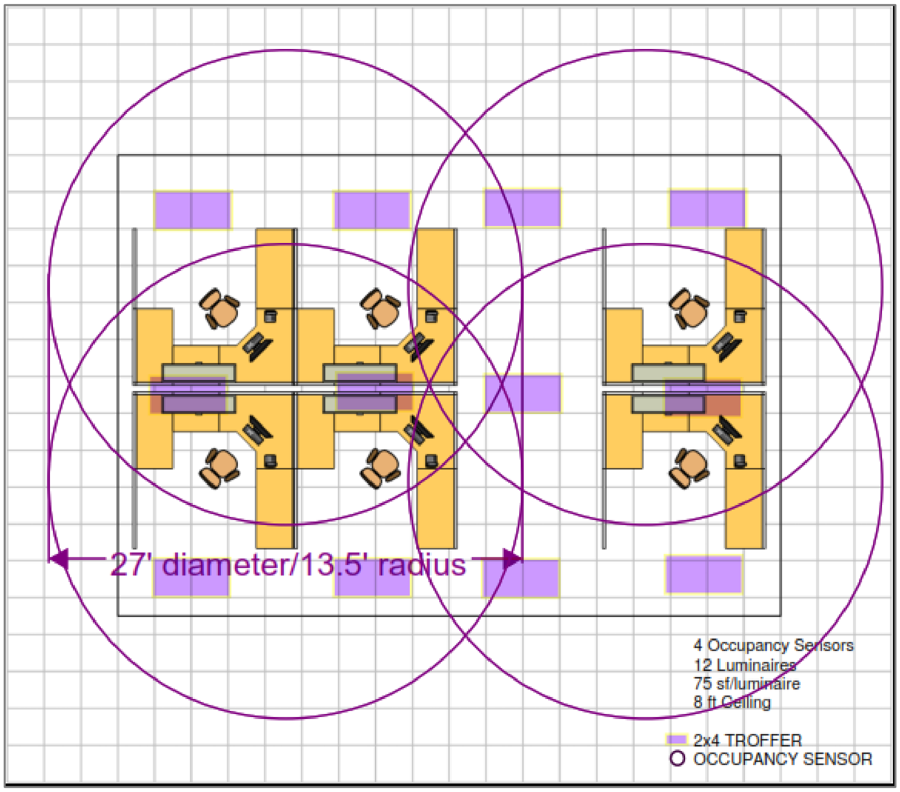
Table 2: Model E Floor Plan Details

Office Floor Plan Model	Model Office E
	
Square footage	601 ft^2
Number of occupants	4
Average area per workstation/cubicle (a)	150 ft^2
Number of luminaires	6
General lighting layout	120 ft^2/luminaire
Total lighting load(b)	240 W
Lighting power density(b)	0.40 W/ft^2

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

(b) The total lighting load and LPDs shown here consider only general lighting in the space.

Table 3: Model F Floor Plan Details

Office Floor Plan Model	Model Office F
	
Square footage	900 ft^2
Number of occupants	6
Average area per workstation/cubicle (a)	150 ft^2
Number of luminaires	12
General lighting layout	80 ft^2/luminaire
Total lighting load(b)	480 W
Lighting power density(b)	0.53 W/ft^2

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

(b) The total lighting load and LPDs shown here consider only general lighting in the space.

Updated Energy Savings

The Statewide CASE Team calculated the energy savings for model offices D, E, and F using the same method as described in Section 2.3 and Section 2.4 of the Final CASE Report. The Statewide CASE Team assumed the same fraction of baseline shut-off technologies as used in model office A: time-switch 40 percent of the time and occupancy sensor 60 percent of the time. Original fractions for model offices A, B, and C can be found in Table 12 of the Final CASE Report. As stated in the Final CASE Report, these fractions were determined based on data collected during outreach. Table 4 shows the final per-unit energy impacts and energy cost savings.

Table 4: Energy Savings for Model Offices D, E, and F

Model Office	Annual Savings kWh/ft^2	Peak Demand Reduction Peak W/ft^2	Average Statewide TDV $kBtu/ft^2$	Average Statewide PV$ 15 yr PV $\$/ft^2$	Average Statewide Nominal 15 yr Nom $\$/ft^2$
Model Office D ($400\ ft^2$)	0.020	0.001	0.557	$0.05	$0.07
Model Office E ($601\ ft^2$)	0.381	0.079	13.034	$1.16	$1.64
Model Office F ($900\ ft^2$)	0.828	0.163	27.732	$2.47	$3.48

Cost and Cost Effectiveness

Incremental First Cost

The Statewide CASE Team used the same cost-effectiveness calculation methodology and assumptions as described in Section 2.4 of the Final CASE Report. The following tables show the cost estimates for model offices D, E, and F.

Table 5: Base Case First Cost for Time-Switch Implementation (Minimal Compliance) – Model Office D

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.1	$11.84
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.56
Design Labor ($/hour)	$120.58	1	$120.58
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	6.389	$655.70
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	1	$25.31
Total Project Cost	N/A	N/A	**$1,613.43**

Table 6: Base Case First Cost for Time-Switch Implementation (Minimal Compliance) – Model Office E

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.1	$11.84
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.56
Design Labor ($/hour)	$120.58	1.5025	$181.17
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	7.669	$787.07
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	2	$50.62
Total Project Cost	N/A	N/A	**$1,830.69**

Table 7: Base Case First Cost for Time-Switch Implementation (Minimal Compliance) – Model Office F

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.1	$11.84
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.56
Design Labor ($/hour)	$120.58	2.25	$271.30
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	8.949	$918.44
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	3	$75.93
Total Project Cost	N/A	N/A	**$2,077.50**

Table 8: Base Case First Cost for Occupancy Sensor Implementation (Above Minimal Compliance) – Model Office D

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.2	$23.68
Cable Connector ($/item)	$5.34	2	$10.68
Commissioning Labor ($/hour)	$118.41	0.969	$114.74
Design Labor ($/hour)	$120.58	1	$120.58
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	5.053	$518.59
Junction Box	$3.35	1	$3.35
Occupancy Sensors ($/item)	$55.63	1	$55.63
Power Cable ($/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	1	$25.31
Total Project Cost	N/A	N/A	**$998.96**

Table 9: Base Case First Cost for Occupancy Sensor Implementation (Above Minimal Compliance) – Model Office E

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.2	$23.68
Cable Connector ($/item)	$5.34	2	$10.68
Commissioning Labor ($/hour)	$118.41	0.969	$114.74
Design Labor ($/hour)	$120.58	1.5025	$181.17
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	6.333	$649.96
Junction Box	$3.35	1	$3.35
Occupancy Sensors ($/item)	$55.63	1	$55.63
Power Cable ($/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	2	$50.62
Total Project Cost	N/A	N/A	**$1,216.22**

Table 10: Base Case First Cost for Occupancy Sensor Implementation (Above Minimal Compliance) – Model Office F

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.2	$23.68
Cable Connector ($/item)	$5.34	2	$10.68
Commissioning Labor ($/hour)	$118.41	0.969	$114.74
Design Labor ($/hour)	$120.58	2.25	$271.30
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	7.613	$781.32
Junction Box	$3.35	1	$3.35
Occupancy Sensors ($/item)	$55.63	1	$55.63
Power Cable ($/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	3	$75.93
Total Project Cost	N/A	N/A	**$1,463.03**

Table 11: Proposed Measure First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office D

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.2	$23.68
Cable Connector ($/item)	$5.34	2	$10.68
Commissioning Labor ($/hour)	$118.41	0.969	$114.74
Design Labor ($/hour)	$120.58	N/A	N/A
HVAC Occupied Standby Integration ($/ft^2)	$0.13	400	$52.00
Installation and Startup Labor ($/hour)	$102.63	5.236	$537.37
Junction Box	$3.35	1	$3.35
Occupancy Sensors ($/item)	$55.63	1	$55.63
Power Cable ($/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	1	$25.31
Total Project Cost	N/A	N/A	**$949.16**

Table 12: Proposed Measure First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office E

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.4	$47.36
Cable Connector ($/item)	$5.34	4	$21.36
Commissioning Labor ($/hour)	$118.41	1.938	$229.48
Design Labor ($/hour)	$120.58	0.25	$30.14
HVAC Occupied Standby Integration ($/ft^2)	$0.13	601	$78.13
Installation and Startup Labor ($/hour)	$102.63	10.472	$1,074.74
Junction Box	$3.35	2	$6.70
Occupancy Sensors ($/item)	$55.63	2	$111.26
Power Cable ($/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	2	$50.62
Total Project Cost	N/A	N/A	**$1,902.60**

Table 13: Proposed Measure First Cost for Multi-Zone Occupancy Sensing in Large Offices – Model Office F

Cost Component	Cost Per Unit	Number of Units	Cost Component Total
ATT Labor ($/hour)	$118.41	0.8	$94.73
Cable Connector ($/item)	$5.34	8	$42.72
Commissioning Labor ($/hour)	$118.41	3.876	$458.96
Design Labor ($/hour)	$120.58	1	$120.58
HVAC Occupied Standby Integration ($/ft^2)	$0.13	900	$117.00
Installation and Startup Labor ($/hour)	$102.63	19.664	$2,018.12
Junction Box	$3.35	4	$13.40
Occupancy Sensors ($/item)	$55.63	4	$222.52
Power Cable ($/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	3	$75.93
Total Project Cost	N/A	N/A	**$3,669.55**

Table 14: 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 D (400 ft^2)	($1.66)	($0.12)	**($0.75)**
Model Office E (601 ft^2)	$0.12	$1.14	**$0.73**
Model Office F (900 ft^2)	$1.77	$2.45	**$2.18**
Average	$0.08	$1.16	**$0.72**

The Statewide CASE Team found the model offices D, E, and F to be cost effective when using the methodology from the Final CASE Report. The incremental first costs for additions and alterations would be the same as that of new construction. The Statewide CASE Team assumed the same fraction of baseline shut-off technologies as used in model office A: time-switch 40 percent of the time and occupancy sensor 60 percent of the time. The two base case incremental first costs were averaged, using the same weighted average used in per model office to determine the overall measure incremental first cost, $0.72/ft^2.

Incremental Maintenance Cost

The Statewide CASE Team used the same methodology as that published in Section 2.4 of the Final CASE Report. In summary, the Statewide CASE Team used the previously calculated present value maintenance cost of $0.01110/ft^2.

Cost Effectiveness

All the same assumptions listed in Section 2.4.5 of the Final CASE Report still apply to the cost-effectiveness estimate for model offices D, E, and F.

Model office D had a negative cost, as the proposed case was less expensive than the weighted average of the base cases. The B/C ratio of model office D was therefore listed as “infinite.” In order to provide the most accurate estimate, model office D was not included in the average B/C ratio calculation.

Table 15: 15-Year Cost Effectiveness Summary Per Square Foot – New Construction, Additions, and Alterations (Model Offices D, E, and F)

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 D (400 ft^2)	$0.05	($0.73)	Infinite
Model Office E (601 ft^2)	$1.16	$0.74	1.57
Model Office F (900 ft^2)	$2.47	$2.19	1.13
		Average B/C Ratio	**1.35**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). Other savings are discounted at a real (inflation-adjusted) 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. **Note**: these energy cost savings do not include the occupied standby savings from the analysis presented in this addendum.

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.

HVAC Occupied Standby

HVAC occupied standby and its relationship to the proposed multi-zone occupancy sensor requirement for large offices is described in Section 2.1.1 of the Final CASE Report, but additional details are provided below for context of this supplemental analysis.

The proposed code change to Section 130.1(c) of Title 24, Part 6 requires occupancy sensor controls of lighting in offices larger than 250 ft^2. Section 120.2(e)3 requires occupied standby HVAC controls for HVAC zones where:

- All spaces within the HVAC zone are required to control their lights with occupancy sensors; and
- Where the Table 120.1-A occupancy category permits ventilation air to be reduced to zero when the space is in occupied-standby mode.

In office spaces, ventilation air is allowed to be reduced to zero, thus occupied standby would be newly required for large offices. Additionally, since occupied standby is required when the entire HVAC zone is serving qualifying spaces, zones serving both small offices and large offices on the same zone would also be required to have occupied standby HVAC controls for the first time. 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 for this measure.

Since HVAC occupied standby is a mandatory measure and thus cannot be traded off by other efficiency measures, the Alternative Compliance Method (ACM) Manual does not provide a standard ruleset for simulating these controls. If the standard HVAC schedules and standard occupancy schedules for occupied standby are used, the actual energy savings from these controls are not captured. The reason for this is that early in the morning and late in the evening, the occupancy profiles show low levels of occupancy that are not zero. Therefore, without some changes, the spaces are not considered to be fully unoccupied and the occupied standby control is never triggered. The low occupancy fractions need to be re-evaluated; not because all spaces have a small fraction of occupancies, but because there is a small fraction of rooms that are partially occupied. The facility operator setting the timeclock control in general would not know on what day and time the spaces are occupied. Therefore, the scheduled HVAC control (scheduled occupancy) would be on for more hours as compared to an occupancy control that is responsive to the actual occupancy patterns of HVAC controls zones and turns off ventilation air when these zones are unoccupied (sensed occupancy).

As noted in more detail below, for the purposes of modeling the difference between scheduled occupancy and sensed occupancy, the Statewide CASE Team used four occupancy schedules over the course of the week to represent the changing occupancy schedules that would be used. On some days, occupancy sensing would turn on ventilation later in the day than the scheduled time, but in most cases would be turning off ventilation air before the HVAC schedule would turn off ventilation air. These updated HVAC schedules captured the fan energy benefit and thermal benefit of reduced ventilation, which were not present in the energy analysis in the Final CASE Report. Lighting profile values were modified to match the full load hours (FLHs)[2] of operation that were originally calculated for the multiple small zone occupancy sensing controls in the Final CASE Report.

Updated Energy Savings

Energy Savings Methodology

The original energy savings methodology for the HVAC occupied standby portion of this measure is described in Section 2.3.2.5 of the Final CASE Report. This methodology focused on the lighting energy savings using a custom spreadsheet model with a separate modeling effort to estimate the HVAC savings using EnergyPlus. However, this approach did not sufficiently account for the HVAC savings associated with the occupied standby portion of this measure as the final results showed limited fan savings. As part of this addendum, the Statewide CASE Team created an updated analysis in EnergyPlus to address the lack of HVAC savings. The main changes to the methodology are:

- Updated occupancy schedules;
- New approach for addressing different occupancy schedules;
- Utilized multiple “Office” prototype models to capture impacts across different HVAC Systems.

The updated methodology for each is described below.

Occupancy schedules

The Statewide CASE Team created a new occupancy schedule to better simulate how the HVAC system interacts with the proposed multi-zone occupancy sensing requirement. In order to model the effects of different occupancy patterns for different areas of a building throughout a day, the Statewide CASE Team utilized a different workday schedule for each workday of the week in order to capture these effects.

[2] Full load hours are the total hours in a year that lights in a space are on at full capacity.

Conceptually, these schedule variations account for normal professional activities that explain lower office occupancy rates such as field visits, flexible working schedules, partial remote working, employee time off, etc.

The occupancy modeling approach was derived from multiple sources:

- The Stochastic Occupancy Patterns found in Section 2.3.2.3 of the Final CASE Report;
- Energy modeling based on field-data studies by Taylor Engineering;[3] and
- Research conducted by Pacific Northwest National Laboratory.[4]

Table 16 through Table 18 below show the baseline and proposed schedules which were used for the updated EnergyPlus model runs.

[3] Taylor Engineering was the primary author of the 2019 Proposals Based on ASHRAE 90.1-2016 CASE Report. One measure within the CASE Report dealt with HVAC occupied standby.

[4] The PNNL research can be found online: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22072.pdf

Table 16: Baseline and Proposed Occupancy Schedule (fraction of full occupancy)

Hour	Baseline			Proposed Case						
	M-F	**Sat**	**Sun**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
7	0.1	0.1	0.05	0	0	0	0	0	0	0
8	0.2	0.1	0.05	0.2	0.2	0	0	0.2	0	0
9	0.95	0.1	0.05	0.9	0.7	0	0	0.9	0.3	0.3
10	0.95	0.3	0.05	1	0.8	0	0	1	0.5	0.3
11	0.95	0.3	0.05	1	0.9	0	0	1	0.5	0.3
12	0.95	0.3	0.05	1	0.7	0.2	0	1	0.3	0.3
13	0.5	0.1	0.05	0.5	0.2	0.5	0	0.5	0	0
14	0.95	0.1	0.05	1	0.2	0.9	0	1	0	0
15	0.95	0.1	0.05	1	0.2	0.9	0	1	0	0
16	0.95	0.1	0.05	1	0	0.8	0	1	0	0
17	0.95	0.1	0.05	0.95	0	0.7	0	0.95	0	0
18	0.3	0.05	0.05	0.3	0	0.3	0	0.3	0	0
19	0.1	0.05	0	0	0	0.1	0	0	0	0
20	0.1	0	0	0	0	0.1	0	0	0	0
21	0.1	0	0	0	0	0.1	0	0	0	0
22	0.1	0	0	0	0	0.08	0	0	0	0
23	0.05	0	0	0	0	0	0	0	0	0
24	0.05	0	0	0	0	0	0	0	0	0

Table 17: Baseline and Proposed Lighting Schedule (fraction of full lighting load)

Hour	Baseline			Proposed						
	M-F	Sat	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
3	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
6	0.17	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
7	0.17	1.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
8	0.53	1.00	0.05	0.20	0.20	0.05	0.05	0.20	0.05	0.05
9	0.98	0.30	0.05	0.65	0.65	0.05	0.05	0.65	0.30	0.05
10	0.98	0.30	0.05	0.65	0.65	0.05	0.05	0.65	0.30	0.05
11	0.98	0.30	0.05	0.65	0.65	0.05	0.05	0.65	0.30	0.05
12	0.93	0.30	0.05	0.65	0.65	0.20	0.05	0.65	0.30	0.05
13	1.00	0.28	0.05	0.50	0.20	0.50	0.05	0.50	0.05	0.05
14	0.93	0.28	0.05	0.65	0.20	0.65	0.05	0.65	0.05	0.05
15	0.93	0.28	0.05	0.65	0.20	0.65	0.05	0.65	0.05	0.05
16	0.97	0.28	0.05	0.65	0.05	0.65	0.05	0.65	0.05	0.05
17	0.97	0.28	0.05	0.65	0.05	0.65	0.05	0.65	0.05	0.05
18	0.55	0.05	0.05	0.30	0.05	0.30	0.05	0.30	0.05	0.05
19	0.62	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.05	0.05
20	0.62	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.05	0.05
21	0.39	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.05	0.05
22	0.39	0.05	0.05	0.05	0.05	0.08	0.05	0.05	0.05	0.05
23	0.41	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
24	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table 18: Baseline and Proposed HVAC Schedule (HVAC operational status, on/off)

Hour	Baseline			Proposed						
	M-F	**Sat**	**Sun**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**
1	0	0	0	0	0	0	1	0	0	0
2	0	0	0	0	0	0	1	0	0	0
3	0	0	0	0	0	0	1	0	0	0
4	0	0	0	0	0	0	1	0	0	0
5	0	0	0	0	0	0	1	0	0	0
6	1	1	1	0	0	0	1	0	0	0
7	1	1	1	1	1	0	0	1	0	0
8	1	1	1	1	1	0	0	1	1	1
9	1	1	1	1	1	0	0	1	1	1
10	1	1	1	1	1	0	0	1	1	1
11	1	1	1	1	1	1	0	1	1	1
12	1	1	1	1	1	1	0	1	1	1
13	1	1	1	1	1	1	0	1	0	0
14	1	1	1	1	1	1	0	1	0	0
15	1	1	1	1	1	1	0	1	0	0
16	1	1	1	1	0	1	0	1	0	0
17	1	1	1	1	0	1	0	1	0	0
18	1	1	1	1	0	1	1	1	0	0
19	1	1	0	0	0	1	1	0	0	0
20	1	0	0	0	0	1	1	0	0	0
21	1	0	0	0	0	1	1	0	0	0
22	1	0	0	0	0	1	1	0	0	0
23	1	0	0	0	0	0	1	0	0	0
24	1	0	0	0	0	0	1	0	0	0

The new analysis using the updated occupancy schedules increased HVAC savings, but ended up underestimating lighting savings (opposite of the original analysis in the Final CASE Report which underestimated HVAC savings). To rectify this, the Statewide CASE Team used the FLHs from the original analysis in the Final CASE Report to develop a ratio to modify the lighting scenarios to better account for lighting savings:

- FLH from Model B from the original analysis are 2,433.
- The updated occupancy schedule yielded FLHs of 1,041.

- The ratio of the FLH from the original to the updated is 2.33.[5]
- The baseline scenario was then increased using the FLH ratio to yield a new FLH for the updated occupancy schedule: 2,287.
- LPDs were also increased to 0.6 W/ft^2, which represents the highest allowable LPD for a minimally compliance office.

These updates have resulted in lighting savings that more closely resemble the original lighting savings analysis.

EnergyPlus Methodology

The Statewide CASE Team originally did not use a specific building prototype to calculate lighting energy savings, instead developing an analysis using three model floor plan configurations (model offices A, B, and C). 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 building models. However, the energy savings due to interactive HVAC effects were not calculated in the original approach, meaning the energy savings were underestimated in the Final CASE Report.

After the Final CASE Report was posted, the Statewide CASE Team conducted an additional analysis using the Medium Office and Large Office prototype building models in EnergyPlus to better account for the HVAC energy savings across the 16 California climate zones. While office spaces can be present in every building type, the Statewide CASE Team chose only the Medium Office and Large Office building prototypes because these buildings represent the vast majority of impacted square-footage, accounting for roughly 82 percent of the new construction and alterations square footage. Additionally, the two prototypes capture a range of HVAC configurations commonly found in office buildings. In order to capture the remaining 18% of floor area, the Statewide CASE Team then averaged the resulting energy savings from the Medium Office and Large Office prototypes to develop an average savings per square foot based on climate zone and apply this savings estimate to the remaining building types. The statewide savings calculations assumed the same building type distribution that was assumed as was listed in Appendix A of the Final CASE Report.

EnergyPlus was run for two prototypes across all 16 climate zones for both the base case and the proposed case scenarios. The incremental energy savings were calculated by subtracting the base case from the proposed case scenario. The savings were then applied to a weighted averaged across the two prototypes to determine an

[5] The base scenario has 4,627 FLH plus the updated occupancy schedule FLHs of 1,041 divided by the target FLHs (2,433 - from the original scenario) equals 2.33.

average energy savings per square foot for each climate zone, and were distributed accordingly to the various building types based on their projected square footage for each climate zone.

Mechanical System Assumptions

When reexamining the savings associated with HVAC occupied standby, the Statewide CASE Team noted a few missing assumptions from the original analysis, such as no savings associated with fan power and very low savings for heating and cooling, which was the main driver for further investigation. The original analysis used the Small Office prototype model,[6] however the Standard Design for the Small Office prototype only utilizes a single zone variable air volume (VAV) system making it unable to capture many of the interactive HVAC savings impacts, such as lower fan speed, that would be present for a packaged VAV unit or Built-up VAV unit without more sophisticated modifications. The Statewide CASE Team updated lighting, occupancy, and HVAC operation schedules for the baseline and proposed designs using the tables noted above. While the original analysis had utilized a mix of two base case scenarios (one for time-clocks and one for occupancy sensors), for modeling simplicity in EnergyPlus, the updated methodology consolidated these into one base case. This base case simply utilized the default occupancy tables from the standard design.

Per-unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 19. 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 0.741 kWh/yr, followed by 0.574 kWh/yr for small office buildings. Demand reductions are expected to be 0.086 W and 0.066 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. Note these savings include HVAC occupied standby, lighting, and all associated interactive effects.

[6] The original analysis used the Small Office prototype for HVAC savings only; lighting savings were calculated separately.

Table 19: First-Year Energy Impacts Per Square Foot

Impacted Building Types	Climate Zone	Electricity Savings (kWh/ft²)	Peak Electricity Demand Reductions (W/ft²)	Natural Gas Savings (therms/ft²)	TDV Energy Savings (TDV kBtu/ft²)
Small Office	All	0.574	0.066	0.010	20.033
Large Office	All	0.741	0.086	0.013	25.852
Retail	All	0.057	0.007	0.001	1.995
Non-Refrigerated Warehouse	All	0.056	0.006	0.001	1.951
Refrigerated Warehouse	All	0.041	0.005	0.001	1.429
Schools	All	0.088	0.010	0.002	3.061
Colleges	All	0.071	0.008	0.001	2.488
Hospitals	All	0.044	0.005	0.001	1.536

Cost and Cost Effectiveness

Energy Cost Savings Results

Energy cost savings were calculated by applying the time dependent valuation (TDV) energy cost factors to the energy savings estimates that were derived using the methodology described in Section 2.3.1 of the Final CASE Report. 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.[7] For both additions and alterations, 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. The TDV methodology as explained in the Final CASE Report allows peak electricity savings to be valued more than electricity savings during non-peak periods.

[7] The proposed code change exempts alterations projects complying with Sections 141.0(b)2Iii and 141.0(b)2Iiii.

Table 20: 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 PV TDV Electricity Cost Savings (2023 PV$)	15-Year PV TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year PV TDV Energy Cost Savings (2023 PV$)
Small Office	All	$1.53	$0.25	$1.78
Large Office	All	$1.97	$0.33	$2.30
Retail	All	$0.15	$0.03	$0.18
Non-Refrigerated Warehouse	All	$0.15	$0.02	$0.17
Refrigerated Warehouse	All	$0.11	$0.02	$0.13
Schools	All	$0.23	$0.04	$0.27
Colleges	All	$0.19	$0.03	$0.22
Hospitals	All	$0.12	$0.02	$0.14

Table 21 below shows the per square foot nominal energy cost savings over the 15-year period of analysis.

Table 21: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction, Alterations, and Additions (Occupied Standby Only)

Impacted Prototypical Building Types	Climate Zone	15-Year Nominal TDV Electricity Cost Savings (Nominal $)	15-Year Nominal TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year Nominal TDV Energy Cost Savings (Nominal $)
Small Office	All	$2.15	$0.36	$2.52
Large Office	All	$2.78	$0.47	$3.25
Retail	All	$0.21	$0.04	$0.25
Non-Refrigerated Warehouse	All	$0.21	$0.04	$0.25
Refrigerated Warehouse	All	$0.15	$0.03	$0.18
Schools	All	$0.33	$0.06	$0.38
Colleges	All	$0.27	$0.04	$0.31
Hospitals	All	$0.17	$0.03	$0.19

Cost Effectiveness

The original cost and cost effectiveness calculations presented in the Final CASE Report underestimated energy savings from HVAC occupied standby, as previously described. The Final CASE Report and the analysis in the Model Offices D, E, and F Section proves that the proposed measure is cost effective for model offices A, B, C, D, E, and F regardless of any additional energy savings captured by the additional HVAC savings.

The Statewide CASE Team also calculated an updated B/C ratio that included the HVAC occupied standby energy savings presented in this addendum.

The costs were calculated by averaging the total incremental PV costs across all model offices, since model offices would be assumed to be evenly distributed across climate zones. This provided an average cost of $1.51/ft^2. The non-occupied standby energy savings were calculated using the same method since model offices would be assumed to be evenly distributed across climate zones. This benefit was then added to the new construction, alterations, and additions energy cost savings presented in this addendum to fill in the total TDV energy cost savings presented in Table 22.

Table 22 presents the updated B/C ratio, which includes the HVAC occupied standby energy savings presented in this addendum.

Table 22: 15-Year Cost Effectiveness Summary Per Square Foot – New Construction, Additions, and Alterations (Updated)

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$4.88	$1.51	3.23
2	$4.98	$1.51	3.30
3	$4.56	$1.51	3.02
4	$4.79	$1.51	3.17
5	$4.48	$1.51	2.96
6	$4.50	$1.51	2.98
7	$4.40	$1.51	2.91
8	$4.99	$1.51	3.31
9	$4.28	$1.51	2.83
10	$4.68	$1.51	3.10
11	$5.57	$1.51	3.69
12	$5.53	$1.51	3.66
13	$6.37	$1.51	4.22
14	$5.65	$1.51	3.74
15	$5.37	$1.51	3.56
16	$4.98	$1.51	3.29
		Average B/C Ratio	**3.31**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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. Note: these energy cost savings do not include the additional occupied standby savings calculated in this addendum.

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.

First-Year Statewide Impacts

Statewide Energy and Energy Cost Savings

The Statewide CASE Team updated the calculated first-year statewide savings by using the same methodology described in Section 2.5 of the Final CASE Report. The statewide new construction forecast for 2023 and the Statewide CASE Team's assumptions are presented in Appendix A of the Final CASE Report.

The Statewide CASE Team calculated the updated statewide savings from new construction to be 38.58 GWh, and the statewide savings from additions and alterations be 59.93 GWh. The updated first-year peak electric demand reduction is 4.54 MW for new construction and 7.05 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 23 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 24 presents the first-year statewide energy and energy cost savings from alterations and additions by climate zone.

Table 25 presents first-year statewide savings from new construction, additions, and alterations.

Table 23: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.10	0.13	0.01	0.01	$0.47
2	0.58	0.87	0.10	0.02	$2.87
3	2.95	4.26	0.52	0.09	$13.45
4	1.53	2.39	0.27	0.04	$7.35
5	0.28	0.41	0.05	0.01	$1.26
6	2.04	3.35	0.42	0.03	$9.17
7	1.40	2.23	0.29	0.02	$6.14
8	2.99	5.08	0.63	0.05	$14.94
9	5.35	8.85	1.03	0.09	$22.91
10	1.74	2.95	0.33	0.04	$8.12
11	0.40	0.67	0.07	0.01	$2.21
12	2.88	4.65	0.51	0.10	$15.93
13	0.73	1.26	0.14	0.02	$4.66
14	0.48	0.80	0.09	0.02	$2.70
15	0.23	0.46	0.05	0.00	$1.25
16	0.14	0.21	0.03	0.01	$0.71
TOTAL	**23.82**	**38.58**	**4.54**	**0.55**	**$114.14**

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

Table 24: Statewide Energy and Energy Cost Impacts – Alterations and Additions

Climate Zone	Statewide Alterations and Additions 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 (MMTherms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.15	0.20	0.02	0.01	$0.75
2	0.91	1.38	0.15	0.04	$4.52
3	4.57	6.60	0.80	0.14	$20.82
4	2.37	3.69	0.42	0.06	$11.35
5	0.45	0.65	0.07	0.01	$2.01
6	3.17	5.22	0.65	0.05	$14.27
7	2.34	3.73	0.49	0.03	$10.30
8	4.60	7.82	0.96	0.07	$22.99
9	7.89	13.05	1.52	0.13	$33.78
10	3.04	5.17	0.58	0.06	$14.24
11	0.63	1.06	0.11	0.02	$3.49
12	4.32	6.97	0.77	0.15	$23.88
13	1.13	1.95	0.22	0.03	$7.22
14	0.79	1.31	0.15	0.03	$4.44
15	0.39	0.78	0.08	0.00	$2.10
16	0.23	0.34	0.04	0.01	$1.15
TOTAL	**36.99**	**59.93**	**7.05**	**0.86**	**$177.30**

Table 25: 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 (MMTherms)	15-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	23.82	38.58	4.54	0.55	$114.14
Additions and Alterations	36.99	59.93	7.05	0.86	$177.30
TOTAL	**60.81**	**98.52**	**11.58**	**1.41**	**$291.44**

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 of the Final CASE Report 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 26 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 31,349 metric tons of carbon dioxide equivalents (metric CO2e) would be avoided.

Table 26: 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] (MMtherms /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]	98.52	23,680	1.41	7,670	31,349

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/MMTherms.

c. Includes savings and GHG emission reductions result from HVAC occupied-standby.

Nonresidential Indoor Lighting

2022-NR-LIGHT2-F **|** Nonresidential Lighting **|** September 2020 FINAL CASE REPORT

Prepared by Energy Solutions

Please submit comments to info@title24stakeholders.com.

This report was prepared by the California Statewide Codes and Standards Enhancement (CASE) Program that is funded, in part, by California utility customers under the auspices of the California Public Utilities Commission.

Document Information

Category:	Codes and Standards
Keywords:	Statewide Codes and Standards Enhancement (CASE) Initiative; California Statewide Utility Codes and Standards Team; Codes and Standards Enhancements; 2022 California Energy Code; 2022 Title 24, Part 6; efficiency; occupancy sensors, LPD; lighting power density; lighting controls.
Authors:	Marissa Lerner, Jasmine Shepard, Christopher Uraine, Yao-Jung Wen (Energy Solutions); Bernard Bauer (Integrated Lighting Concepts); Jonathan McHugh (McHugh Energy)
Prime Contractor	Energy Solutions
Project Management:	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, and Sacramento Municipal Utility District.

Table of Contents

List of Tables

List of Figures

Executive Summary

This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared.

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (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 Final CASE Report is to present a code change proposal for multi-zone occupancy sensing in large offices and lighting power densities that will clarify code language and foster energy-saving use of available cost-effective technologies. The report contains pertinent information supporting the code change.

Measure Description

Background Information

Multi-zone Occupancy Sensing in Large Offices

2019 Title 24, Part 6 currently mandates shut-off controls for large offices, allowing a single occupancy sensor controlling areas between 1,000 to 2,000 ft^2, with multiple occupancy sensors jointly controlling an area as large as 5,000 ft^2. However, occupants in large offices are away from their desks frequently for meetings or other tasks, leaving significant portions of the office area unoccupied. Occupants staying after hours may need to walk over to a manual control switch to enable an override control. Using separate occupancy controls can reduce lighting energy consumption in unoccupied parts of large workspaces where there is often partial vacancy.

However, occupant sensing control requirements for office spaces greater than 250 square feet (ft^2) are not currently mandatory. 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. 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 requiring rewiring and use of ladders to access systems.

Another popular control implementation is luminaire level lighting control (LLLC), where sensors are an integral part of the luminaires, so each luminaire has its own sensor. This luminaire and sensor configuration can 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.

This proposal aligns with the 2018 International Energy Conservation Code (IECC) C405.2.1.3 Open Plan Office Control which mandates similar requirements. Industry stakeholders highlighted the challenge of needing to comply with multiple standards simultaneously, and shared that increased coordination across standards would benefit the industry.

Lighting Power Densities

Over the past 30 years, lighting efficacy has continued to improve. As a result, the allowed indoor lighting power density (LPD) values in Title 24, Part 6 have been updated every cycle. During the 2019 update of the LPDs, the basis of standards shifted from the legacy lighting technologies (such as fluorescent, metal halide, and infrared reflecting halogen light) to light emitting diode (LED) light sources. The Statewide CASE Team updated LPD values during the 2019 Title 24, Part 6 code cycle to represent an all LED (light emitting diode) baseline.

The savings associated with this proposal are relatively modest compared to the 2019 code cycle since the proposal is comparing LEDs available 3 years ago to LEDs available now. Though this proposal's statewide lighting energy savings are only 5.6 percent of the baseline energy consumption, this small fraction is multiplied by a large value (the total lighting power installed in all new and retrofitted buildings) and results in approximately 100 GWh/yr savings for each year's new construction. These savings are realized while increasing the flexibility of how additional lighting power allowances are calculated which should reduce compliance burden.

During this code cycle, the Statewide CASE Team refined this previous work by updating the calculation method and models to more accurately account for technology advancements and to better reflect lighting industry standards. LEDs are typically dimmable and the distribution of light is more controllable, allowing for higher optical efficiencies. Over the last three years, the Statewide CASE Team documented efficacy increases for luminaires with high color rendering index (CRI) LED sources, color tuning, and dim-to-warm controllability.

Proposed Code Change

Multi-zone Occupancy Sensing in Large Offices

The multi-zone occupancy sensing in large offices measure proposes two major changes:

1) A mandatory control requirement for nonresidential indoor lighting systems in "large" offices, defined as enclosed offices greater than 250 ft^2. The term "open plan office" is undefined in Title 24, Part 6, and this proposal would remove all mentions of "open plan office."

2) Since the general lighting in large offices would be required to have occupancy sensors and large offices can have ventilation rates set to zero during occupied standby mode, large office spaces would be required to have HVAC occupied standby controls and enable HVAC occupied standby mode.

The proposed code change would mandate a maximum 600 ft^2 control zone size and specify that all control zones shall be switched separately, controls shall automatically turn off all lighting in 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.

The proposed code change applies to general lighting, with an exception for under shelf or furniture-mounted supplemental task lighting. It impacts all new construction and certain additions and alterations.

In response to comments from stakeholders, this proposal includes clarifications to the occupancy sensing HVAC zone control requirements.

Technology to implement this code change is already readily available in the market. 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 1.025 kWh/ft^2/yr in per-unit savings.

Lighting Power Densities (LPD)

The LPD measure proposes to:

1) 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.
2) Update the definitions, mandatory, and prescriptive sections of Title 24, Part 6 to improve clarity and readability, offer design flexibility and simplify documenting compliance.

The Statewide CASE Team has updated models based on revisiting Illuminating Engineering Society (IES) Recommended Practice (RP) 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 include:

- Detailed documentation of the target illuminance values used for the general, task, supplemental and wall wash systems, and references to the various IES RPs.
- 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 (i.e., cleanliness) from IES RP-36 specific to luminaire type and primary function area.

The proposed LPD updates do not prevent light levels that are compliant with the IES RPs 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 for task work, display, and ornamental lighting. There are also additional wattage allowances for several special scenarios, such as additional lighting wattage for providing extra light to areas occupied by the elderly or visually impaired. Compliance options have been simplified for the additional power allowances in the area category method using the combined “Display/Decorative” qualifying allowances. Of the 71 primary function areas for the Area Category Method LPDs, 10 increase, 30 decrease, and 31 of the combined general lighting and additional lighting allowances stay the same.

The LPDs for the Complete Building Method have been updated. The Tailored Method LPDs have updated to account for the increased efficacy of high CRI lighting sources. Many LPDs in both the Complete Building Method and Tailored Method decrease slightly; in most cases there is a 0.05 decrease.

This proposal also updates requirements in Section 130.0(c)2 for downlights with a line voltage socket. Specifically, downlights with a line voltage socket would be based on installed wattage on luminaire labeling alone and would no longer use the higher of the luminaire labeled wattage and 50 watt per socket (except if the lamps in the luminaire are JA8 rated). 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	100.1, 120.2(e)3, 130.1(c)6, 130.1(f), 140.6-A	Appendix NA7	Yes	NRCI-LTI-05-E, NRCC-LTI-E, NRCC-PRF-01-E, NRCA-MCH-19-A 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 (ATTs). Section 2.2.1 describes market actor roles in detail.

Interviews with fourteen industry stakeholders, responses during publicly held utility-sponsored stakeholder meetings, market feasibility research, a survey with lighting designers, and industry expertise and professional judgment from members of the Statewide CASE Team led to the conclusion that the technology needed 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. As such, control zones can be reprogrammed, added, and rearranged at the control panel or remotely through computer, or 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 programmed 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 perspectives 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 Appendix G.2. The proposed code change also clarifies a widespread misconception around delay timing between occupancy sensing controls and HVAC systems in the NA7.5.17 Occupied Standby acceptance tests.

Additionally, this proposal 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 market structure for indoor lighting sources has not changed significantly over the past three years. Lighting designers continue to 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 product costs have. Almost all luminaires specified for new construction or major alterations make use of Light Emitting Diode (LED) technology. Products containing LED light sources are no longer considered a premium product. Purchasing costs have declined, specification rates have increased, and LED products are now considered the default choice. The Statewide CASE Team conducted research through interviews with manufacturers and other stakeholders, and collection of equipment performance data from product cutsheets and IES electronic photometric files. This research and outreach yielded both efficacy data and cost information.

Section 140.6 of Title 24, Part 6 includes existing requirements 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. Additionally, based on the findings for the large office controls proposal, the primary function area "open plan office" has been removed and is replaced with "office > 250 ft^2". This proposal does not recommend any categorical changes to the tables that support 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 1.26. 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 for high CRI light sources has increased but cost has stayed the same or decreased, as has been the case with ornamental lighting. A broader cost trend has been that, on average, the cost of LED luminaires has been dropping over the past three years. This cost reduction was applied to both the 2019 base case design and the 2022 proposed design. However, in some cases, the luminaire type chosen for 2022 that matches common applications (such as the basket troffer) has higher efficacy, and lower cost than the luminaires used for developing the 2019 standards.
- In reviewing the design illuminance values for each primary application area, the Statewide CASE Team found that the design illuminance values for some

applications in the 2019 LPD model were higher than the IES recommended illuminances or that task illuminance values were applied to the entire space including circulation areas. When it was appropriate to reduce design illuminance, this would result in designs that used fewer luminaires and/or lower output luminaires. This results in either a first cost savings or an unchanged first cost (negative or zero incremental cost) while saving energy.

Detailed lighting system cost assumptions used in the 2019 base case model and in the 2022 proposed model are tabulated in Appendix S.[1]

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 (MMTherms/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 (MMTherms /yr)	TDV Energy Savings (Millions of TDV kBtu)
Multi-zone Occupancy Sensing in Large Offices	**62.44**	**10.17**	**0.02**	**1,981**
New Construction	24.46	3.98	0.01	776
Additions and Alterations	37.98	6.18	0.01	1,205
Lighting Power Densities	**101.9**	**26.4**	**0**	**2,763.6**
New Construction	25.0	20.2	0	677.0
Additions and Alterations	76.9	6.2	0	2,086.6

The multi-zone occupancy sensing in large office measure energy analysis revealed a significant savings potential for a typical office occupancy pattern, as described in

[1] Base case refers to cost assumptions for a lighting system designed to meet the 2019 LPD values.

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 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 LPD proposal updated values for all three compliance paths (Complete Building Method, Area Category Method and Tailored Method), statewide savings are based on the Area Category Method, as it is the most commonly used method used for determining lighting power compliance. Of the 81 primary function areas in the Area Category Method, the combined general lighting and additional lighting allowance LPDs in this proposal would increase in 10 function areas, decrease in 30 areas, and stay the same for 31 areas. Overall, the total savings are approximately a quarter of the savings associated with LPD changes in the 2019 Title 24, Part 6 Standards. The 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 represent minor adjustments to improve upon the proposals 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	15,103	$1,603,964
Lighting Power Densities	24,496	$2,601,516
Total	**39,599**	**$4,205,480**

Water and Water Quality Impacts

These measures are 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

This proposed code change will increase complexity due to control integration required for lighting and mechanical systems. A key component in compliance and a smooth design and build process would be the need for increased coordination between lighting design teams, mechanical design teams, lighting representatives, controls contractor, and lighting and mechanical ATTs.

As described in Section 2.6.3, this proposed code change would include a new acceptance test, which will allow for control zone overlap and verification of control zone size. The proposed code change would also clarify a common misconception on delay timing for the acceptance test for HVAC occupied standby mode.

Upon adoption, the proposed code change would automatically trigger the requirement for large office spaces to comply with HVAC occupied standby controls integration. It is imperative that market actors involved in designing and commissioning such spaces are aware of this change. 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.

Lighting Power Densities

This proposal is not changing the organizational structure of the LPDs in Title 24, Part 6, but is proposing updates to the values applied to each primary function area of building types. However, this proposal is recommending combining display and decorative lighting categories when calculating additional lighting power allowances. This increases compliance flexibility and reduces compliance burden required to separately tabulate display lighting from decorative lighting. Enforcement remains unchanged.

For areas where the LPDs are increasing, the lighting designer has more flexibility in design choices for that space. Lower LPDs that account for increases in LED efficacy help retain the structure of Title 24, Part 6 where designers need to judiciously select and locate luminaires to meet task illuminance levels.

For areas where lower LPDs are recommended, the margin between installed wattage and allowed wattage is reduced, and thus for the performance approach compliance, building designers have less wattage to trade off with HVAC and envelope measures. As a result, compliant HVAC and envelope designs using the performance approach would need to more closely match their baseline efficiencies.

For approximately half of the primary function areas, there is no change to the LPDs.

Compliance and enforcement procedures remain unchanged.

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. The proposed acceptance test language in Section 2.6.3 was also informed by the proposed changes to the shut-off controls acceptance test language included in the Energy Commission Staff docketed pre-rulemaking document (Staff Recommendations for the 2022 Energy Code Acceptance Test Technicial Certification Provider Program 2022). Additionally, this proposed code change clarifies delay timing for the HVAC occupied standby acceptance test.

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

1. Introduction

This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared.

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (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 Final CASE Report is to present a code change proposal for multi-zone occupancy sensing in large offices and lighting power densities measures that will clarify code language and foster energy-saving use of available, cost-effective technologies. 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 public stakeholder workshops 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 Final 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.
- 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.
- Appendix T: Description of the detailed radiosity method models used for large office LPDs

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 250 square feet (ft^2). This proposed measure covers open office workstations, although the term “open plan office” itself is undefined in Title 24, Part 6. The proposed code change impacts general lighting, with an exception for under shelf or furniture-mounted supplemental task lighting. Under shelf and furniture-mounted supplemental task lighting are exempted due to the feasibility and technical challenges to including them in the same lighting circuit controlled by the occupancy sensors.

The proposed measure mandates that each occupancy sensor in a large office control no more than 600 ft^2. The 600 ft^2 limit ensures both cost effectiveness and alignment with the national model code 2018 International Energy Conservation Code (IECC).[2] The neighboring states of Washington and Nevada make use of the 2018 IECC including the multi-zone occupancy controls requirements for open plan offices. 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 general 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 lower power level allowed by either control.
- When a control zone becomes unoccupied:
    - The occupancy sensing controls in the control zone shall uniformly reduce general 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

[2] Aligning with national model codes is advantageous because it means practitioners whose markets and clientele span multiple codes do not need to provide specialized products and services tailored to each specific code requirement.

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 general lighting and all other 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 25 minutes after vacancy is sensed in all spaces served by the same HVAC zone. HVAC Occupied standby mode turns off ventilation and resets thermostat setpoints.

The above requirements do not dedicate a specific control system architecture, nor do they mandate the control zones be able to communicate with each other. When using a system without communication between control zones, the requirements can be met by uniformly turning the lighting off in the control zone within 20 minutes after the control zone becomes unoccupied. It is notable that this was the least preferred implementation by most stakeholders due to the potential impact on lighting design aesthetics and occupant amenity experience. 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 only required for alterations complying with Section 141.0(b)2Ii, and includes an exemption for alterations complying with Sections 141.0(b)2Iii and 141.0(b)2Iiii.

Title 24, Part 6 has Power Adjustment Factors (PAFs) for occupant sensing controls in large offices which vary by control zone size.[3] 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, as well as a clarification of delay timing in NA7.5.17. In addition to updating the PAF values, this measure would update the PAF to specify that it applies to office spaces that are greater than 250 square feet as opposed to open plan offices.

"Open plan office" is an ambiguous term that is not a defined term in Title 24, Part 6, IECC, or ASHRAE 90.1 (Energy Standard for Buildings except Low-rise Residential Buildings). Furniture is often a visual indication of how the space is intended to be used,

[3] Found in Table 140.6-A of Title 24, Part 6.

but furniture may not installed at the time the certificate of occupancy is issued. Therefore, open plan office cannot be reliably defined based on the presence of office furniture. The main commonality between uses of “open plan office” is that the space is large and does not have ceiling height walls dividing it into smaller spaces. The ASHRAE 90.1 definition of enclosed space is:

- A volume substantially surrounded by solid surfaces, such as walls, floors, roofs, and openable devices, such as doors and operable windows.

Similarly, the definition of enclosed space in Title 24, part 6 is:

- **ENCLOSED SPACE** is space that is substantially surrounded by solid surfaces, including walls, ceilings or roofs, doors, fenestration areas, and floors or ground.

When a space is divided by ceiling-height fixed-location walls, it is no longer a single space but multiple spaces. Therefore, the proposed code language will instead be applicable to “large offices,” or offices greater than 250 square feet. To improve clarity, all mentions of “open plan office” will be removed from the Title 24, Part 6 Standards.

The proposed code change would require large offices to be controlled by occupancy sensors, which coincides with a current requirement for office spaces to reduce ventilation to zero during unoccupied times (when they are required to have occupancy sensors), otherwise known as entering HVAC occupied standby mode. Large offices are not currently required to have occupancy sensors. Therefore, this proposal would require large offices to comply with the HVAC occupied standby requirement. Currently, four interrelated sections of Title 24, Part 6 that are required to comply with the HVAC occupied standby requirements lack cross-referencing: the definition of occupied standby in Section 100.1, Section 110.9(b)4 (lighting occupancy controls), Section 120.1(d)5 Occupant Sensor Ventilation Control Devices, and Section 120.2(e)3 Occupancy Sensing Zone Controls. The proposed code language seeks to reduce widespread market practitioner confusion around delay timing. Section 120.2(e)3 clarifies:

- Occupied standby mode only applies during scheduled occupied periods. This clarification is in the definition of occupied standby but is not described elsewhere.
- Spaces are not considered unoccupied until after the occupancy sensor timeout period described in Section 110.9(b)4.
- Additional ventilation requirements in Section 120.1(d)5 apply to this control.

After the control has entered occupied standby mode and occupancy sensors have detected zero occupancy for 20 minutes, there is an additional time delay of no longer than five minutes before HVAC setpoints are reset and ventilation is set to zero.[4]

The proposed measure would require updates to the compliance software to accommodate the updated PAF and mandatory control requirements, for which details can be found in Section D.3.3.

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 areas between 1,000 to 2,000 ft^2, with multiple occupancy sensors jointly controlling 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

[4] There are two steps to this process: 1) all occupancy control zones within the office space are unoccupied, and within a time delay of no more than 20 minutes, the occupancy sensing controls indicate the entire office space is unoccupied (lights shut off). 2) after the occupancy sensing controls have indicated all spaces served by the HVAC zone are unoccupied, there is an additional five minute time delay allowed to reset setpoints and set ventilation to zero. Note that in addition to the said office space, the HVAC zone may be simultaneously serving other spaces. The HVAC zone only needs to enter occupied standby mode after all spaces served by the same HVAC zone are unoccupied.

manual control switch to enable an override control. Additionally, the code change would simplify the standard by displacing a portion of the PAFs for Occupant Sensing Controls in Large Open Plan Offices (Table 140.6-A). Specifically, the PAF for 251 to 500 square feet office spaces would be removed, while the 126 to 250 square feet and 125 square feet and less would remain (with reduced values). Additionally, the term “Large Open Plan” has been removed to further clarify the code language.

As shown in Section 2.3, the proposed measure is estimated to achieve 1.025 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 general 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 HVAC 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 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 programmed, added, and rearranged at the control panel or remotely through computer, or mobile phone applications, rather than requiring labor-intensive investment in rewiring.

Control implementation through the use of luminaire level lighting control (LLLC), where sensors are an integral part of individual luminaires, continue to increase in market share. This luminaire and sensor configuration increases the granularity of the control area as each on-board sensor controls an individual luminaire. With LLLCs, the luminaires may also be networked together to coordinate with each other and act as a single, larger zone as needed. As mentioned via stakeholder feedback, designers using an LLLC implementation would likely opt to include a communication network to enable the dim to 20 percent pathway and reduce the need to turn control zones fully off, supporting occupant preferences and office lighting design aesthetics.

2.1.2.4 Demand Response

The proposed measure could support peak demand reduction through reducing the lighting system energy use and mitigating 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 specific large office occupancy schedule, the proposed code change would likely reduce energy usage by this predicted amount as compared to a large office using a time-switch control with manual override. These baseline assumptions were derived from 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 2.6 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 100.1 – Definitions and Rules of Construction:** The purpose of the changes in this section is to clarify which exact systems can be considered mechanical cooling and heating systems. These changes are necessary to reduce confusion and improve clarity about which systems count for mechanical cooling and heating in the Title 24, Part 6 Standards.
- **Section 120.2(e)3 – REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS: Occupancy Sensing Zone Controls:** The purpose of the changes in this section is to clarify the application of occupied standby controls in practice by confirming that occupied standby mode only applies during scheduled occupied periods, addressing confusion around acceptance test delay timing, and listing which additional ventilation requirements in Section 120.1(d)5 apply to this control. These changes are necessary to reduce widespread market practitioner confusion around acceptance test and control setting delay timing.

Previously, HVAC time delays between HVAC occupied standby controls and occupancy sensing lighting controls were in conflict with each other.

— **SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS**

- **Section 130.1(c)6 – Areas where full or partial OFF occupant sensing controls are required:** The purpose of the changes to this section is to describe how general lighting in large offices shall be controlled by occupancy sensing controls. These changes are necessary to describe a new occupancy controls requirement, specify control zone maximum size, and mandate 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**: The purpose of the changes in this section is to clarify how automatic daylighting controls and HVAC occupied standby mode interact with occupant sensing controls. For automatic daylighting controls, power shall remain at the lowest lighting power level allowed by either control. These changes are necessary to clarify control interactions related to the proposed code change.

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

- **Table 140.6-A – Lighting Power Adjustment Factors (PAF):** The purpose of the changes in this section is to modify the PAFs for Occupant Sensing Controls in Office Spaces Greater than 250 Square Feet, remove the ambiguous term "open plan office" and replace it with offices greater than 250 ft^2, and clarify that the PAFs apply to general lighting in alignment with Section 140.6-A2. These changes are necessary to update the PAFs and improve code clarity.

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

- **TABLE 141.0-F – Control Requirements for Indoor Lighting System Alterations:** The purpose of the change in this section is to specify that the multi-zone occupancy sensing controls requirement in Section 130.1(c)6D does not apply to alterations projects complying with Sections 141.0(b)2Iii and 141.0(b)2Iiii. This change is necessary to clarify the exception for additions, alterations, and repairs to the proposed code change.

2.1.3.2 Summary of Changes to the Reference Appendices

This proposal modifies the sections of the Reference Appendices identified below. The proposed modifications were also informed by the proposed changes to the shut-off controls acceptance test language included in the Energy Commission Staff docketed pre-rulemaking document (Staff Recommendations for the 2022 Energy Code Acceptance Test Technicial Certification Provider Program 2022). 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**

- **NA7.5.17 – Occupied Standby:** The purpose of the proposed changes to the requirements is to clarify delay timing requirements and their interaction with occupancy sensing controls and pre-occupancy ventilation rate correct functioning in compliance with Section 120.1(d)2.
- **NA7.6.2.3 – Occupancy Sensing Lighting Control Functional Testing**: The purpose of the proposed requirements is to update the acceptance test to confirm lighting is limited to at most 20 percent of full power when the control zones are unoccupied, that all lighting is off when the entire room is unoccupied, and that control zones comply with the maximum control zone size.

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 from “open office” to “office spaces greater than 250 square feet” to improve clarity and align with proposed code language.
- CBECC-Com would need to update Table N4, and the ACM Reference Manual should also be updated to reflect this change if any clarification is deemed necessary.

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

Full details of the changes to CBECC-Com can be found in Section D.3.3. In summary, CBECC-Com would need to be updated to reflect the new PAF values shown in Section 2.6.2 so the software can be used to accurately calculate the appropriate compliance credit. Additionally, Table N4 in the CBECC-Com option for the compliance document NRCC-PRF-01-E should be updated to reflect the mandatory controls requirements of the proposed code change. The Nonresidential ACM Reference Manual should be modified in parallel for any instruction needed to reflect such changes in CBECC-Com. 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.

2.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

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

- **Section 4.5.1.3:** Add a table showing all building space types required to have occupied standby controls, clarify the required delay timing and interaction with occupant sensing controls, and update Example 4-26 to describe a control sequence with an exception for DOAS systems.
- **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, including its interaction with the HVAC system.
- **Section 13.4:** Reflect the changes to acceptance tests as specified in Section 2.6.3, both the occupied standby acceptance test (NRCA-MCH-19) as well as the Full or Partial OFF Occupant Sensing Controls acceptance test (NRCA-LTI-02).

See Section 2.6.5 of this report for the detailed proposed revisions to 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:** Update Table H for the mandatory controls and Table P for the PAFs to reflect the proposed code change.
- **NRCC-PRF-01-E:** Update Table N3 to reflect the updated PAF values and Table N4 to reflect the updated mandatory controls requirements.
- **NRCA-MCH-19-A:** Update to reflect changes to delay timing of acceptance test and that occupied standby mode is not triggered during unoccupied hours and does not override pre-occupancy ventilation mode.
- **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 a two hour timed manual override (minimal compliance) and an occupancy sensor that can monitor the full space, although sensor functionality limitations typically control 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.

The lighting power densities (LPDs) measure, described later in this report, proposes to revise the existing 2019 Title 24, Part 6 LPD requirements and have some overlap. There is also overlap with the Statewide CASE Team's nonresidential HVAC controls CASE Report which is proposing updates to HVAC systems; the multizone occupancy sensing requirements being proposed tie to existing HVAC occupied standby requirements. The Statewide CASE Team has included proposed language in this CASE Report to clarify how these requirements tie together and to increase clarity in the existing requirements.

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 requirement in 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. 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. The manufacturer representative helps educate specifiers on design characteristics, settings, and other uses of lighting control products and can help answer questions related to the California Energy Code.
- **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 do not 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 G.2.1, 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, NRCC-PRF-01-E, NRCA-MCH-19-A, 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, updated tables in the NRCC-PRF-01-E document, clarifications to the delay timing and other details for the acceptance test in the NRCA-MCH-19-A document, and the addition of a functional test in the last document. The new acceptance test requirements would need to be 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 considered 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 G.2.1. 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.
- The survey results indicated that floorplans are the most popular document to help ATTs discern occupancy zones, followed by lighting plans.

The survey results were taken into consideration when drafting the proposed acceptance test, especially the advice 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 Appendix G.2.1, 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.

The Statewide CASE Team has further simplified compliance by removing the ambiguous term “open plan office” from the PAF in Table 140.6-C. As noted in Section 2.1.1, “open plan office” is not a defined term in Title 24, Part 6, IECC, or ASHRAE 90.1. Merriam Webster defines “open plan” as "having or consisting of a large room that is not divided into smaller rooms or areas." This definition causes confusion as open plan offices are often considered large rooms divided into smaller areas (cubicles). Other dictionaries have both similar and different “open plan” definitions which furthers confusion. To rectify this, the Statewide CASE Team’s proposal clarifies the language by referring to office size. Please also see Section 3.1.3.1 for additional information on clarifying the term “open plan office.”

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. Multiple stakeholders have mentioned the importance of increased communication and coordination between lighting and mechanical designers and engineering teams throughout the building process. Additionally, industry stakeholders underscored the importance of matching the lighting and HVAC zones of the office design as much as possible. Further details on impacts can be found in Appendix E.

There has been confusion about the implementation of HVAC occupied standby in both Title 24, Part 6 and in ASHRAE 90.1. The intent of the proposal for both of these standards was for occupied standby to occur within five minutes of sending the control signal from the lighting system occupancy sensors to the HVAC system indicating that the space is vacant. Occupancy sensor technology is typically designed to instantaneously sense motion, but also to delay in sending a vacancy signal (to dim or turn off lights) until after a sufficient amount of time has elapsed (provides reasonably high confidence that the space is vacant). Section 110.9(b)4 of Title 24, Part 6 specifies that this time delay between vacancy being sensed and the space being declared "vacant" shall be no longer than 20 minutes.

The HVAC occupied standby requirement is sometimes interpreted by stakeholders to mean that the occupancy sensor controlling occupied standby should declare the space vacant after a five minute time delay of no motion sensed (throughout the entire large office). This perception is supported by the following text in the NA7.5.17 Occupied Standby test:

"Step 7: Confirm that within 5 minutes of being vacated the setpoint is setup or setback and the zone is within the occupied standby deadband."

This perception is problematic, as it will result in shorter time delays being required, which leads to an excessive amount of false positives. These false positives equate to lights turning off or dimming when people are still in the large office and the HVAC system cycling needlessly. This proposal recommends sample "clean-up" text for Section 120.1(e)3A and Nonresidential Appendix NA7.5.17 that would better reflect the intent of how the occupied standby control is to be implemented.

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.

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, only changes to the 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 potential compliance and enforcement concern could be ATTs altering the sensors between lighting and mechanical acceptance testing such that the controls are non-compliant. Education around this interaction would help mitigate issues.

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. The Statewide CASE Team strongly encourages the approval of a registry as it would provide numerous benefits through access to rich data to understand how this and other measures are applied in practice.

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 the 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 luminaires and controls.

Distributors make product recommendations as needed to the contractors who buy their products.

- Manufacturer sales representatives are agencies focusing 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. They can play a key educational role for the manufacturer by helping educate specifiers on the design characteristics, settings, and uses of various lighting control products. They can answer questions on the California Energy Code and may help translate designs into specific Bills of Material used to ensure required sequences of operation are being met.
- 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 mobile phone applications, rather than rewiring. Online product reviews, database assessments, and interviews with stakeholders confirmed the availability of the necessary technology to implement the proposed measure. A survey distributed by the California Energy Alliance (CEA) to lighting designers, of which 86 percent work primarily in California, showed that 52 percent of the 21 lighting designers who responded are designing lighting control systems that comply with the relevant 2018 IECC. Full details from the survey can be found in Appendix G.2.2.

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 as needed.

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. Both interviews with stakeholders and the survey with lighting designers, for which full details can be found in Appendix G.2.2, 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 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 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 and energy savings. Some stakeholders raised the concern of facility managers overriding the system due to frustration with the way the office looks when unoccupied control zones are off while occupied control zones are on for the low cost on/off occupancy sensor implementation and advised avoiding this implementation. The stakeholders mentioned the potential for distraction and a "checkerboard" visual effect due to the on/off occupancy sensor implementation.

While 43 percent (9) of lighting designers who responded to the survey deemed the proposed code change was useful and/or appropriate and 33 percent (7) said it was not, the remaining 24 percent (5) described the main reason for being undecided as the concern over allowing the lights to be turned off completely upon control zone vacancy rather than dimming to a 20 percent background level. With the dimming design path taken into account, 62 percent (13) responded their overall impression of multi-zone occupancy sensing in large offices was useful and/or appropriate and 38 percent (8) did not. Full details can be found in Appendix G.2.2.

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 list represents a sample of the of manufacturers offering lighting controls to support the California market:

- 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 Legrand/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 lighting designers, electrical engineers and/or contractors to specify a code compliant control strategy. The design, installation, and compliance processes would most certainly 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 believes 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 bolster 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 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. A common theme throughout interviews and survey responses was the need for technical education and training that will enable correct system functioning.

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 Appendix G.2.

2.2.2.4 Market and Technological Critical Barriers

Incremental first cost for implementation has been brought up as a barrier for the proposed measure. In both interviews and the survey found in Appendix G.2.2, 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. 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. 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 main concern with the aesthetics of large offices was over non-uniform lighting appearance of lights dimming to 20 percent of full power, as found from the survey results in Appendix G.2.2. The next top three concerns were occupant sensitivity to different light levels and non-uniformity, visibility across the office when areas are unoccupied, and user acceptance. Based on stakeholder feedback from interviews and surveys, it seems there will be some impact to the aesthetics of the space for implementing the proposed code change.

In addition to the survey, the Statewide CASE Team corresponded directly with a lighting designer who noted some key takeaways from the Illuminating Engineering Society (IES) Standards Handbook (The Lighting Handbook, 10th edition) and a summary of the "Square Law Dimming" on perceived brightness changes. The results showed that the perception of brightness changes from dimming lights is typically far less than the actual reduction or increase of illuminance and/or luminance within a space. For example, when a system is dimmed to 20 percent, observers will often estimate that light was cut by 50 percent, rather than the 80 percent that actually occurred. Likewise, with architectural systems that dim to one percent, observers will estimate that the dimming was to 80 percent. Additionally, gradual, smooth rates of change of luminance output minimize a perceived change in brightness while abrupt, on/off changes in luminance output make perceived changes in brightness evident (Illuminating Engineering Society 2011). While the square law of dimming has been used in IES scientific documentation previously, research on brightness perception supports the relationship between luminance and brightness perception is closer to a power law (Bernecker, et al. n.d.).

Based on feedback from those implementing the 2018 IECC in Texas and California, survey results found in Appendix G.2.2, and IES scientific documentation, it seems the impact to aesthetics is appropriate and acceptable when implementing a dim to 20 percent design path, and using the on/off design path would noticeably and drastically impact the perception of the space, albeit save more energy.

2.2.2.5 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 proposal. Section 120.2(e)3 of Title 24, Part 6 already requires HVAC occupied standby capabilities for multiple spaces, including offices less than 250 ft^2. 2019 Title 24, Part 6 requires such capabilities for all spaces where occupancy sensing is required and spaces are allowed to reduce ventilation to zero, as per Table 120.1-A and Note F for offices. The proposed measure requires occupancy sensors in offices greater than 250 ft^2, which is a space where ventilation can be reduced to zero. Mandatory occupancy sensors requirements would mandate offices greater than 250 ft^2 to have HVAC occupied standby capability due to existing Title 24, Part 6 language. After receiving widespread stakeholder feedback about confusion on delay timing between acceptance testing and occupancy sensors, the Statewide CASE Team also determined a need to update Section 120.2(e)3 to clarify the original intent of the delay timing, without altering the scope. The Statewide CASE Team solicited input from the California Energy Commission and multiple industry actors to develop the proposed code changes to Sections 100.1 and 120.2(e)3.

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).[5] 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).

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

Construction Sectors	Establishments	Employment	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 measure to add 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

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

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	Establishments	Employment	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)[6] code specifically assigned to energy consultants. Instead, businesses that focus on consulting related to

[6] 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

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.[7] 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 6 provides an upper bound indication of the size of this sector in California.

Table 6: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	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.

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.

[7] 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.

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 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. 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

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

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by 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)	361	$23.9	$31.7	$52.4
Indirect Effect (Additional spending by firms supporting Commercial Builders)	79	$5.7	$9.1	$17.6
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	157	$8.9	$15.8	$25.9
Total Economic Impacts	**597**	**$38.5**	**$56.6**	**$95.8**

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

[8] 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.

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)	40	$4.1	$4.1	$7.3
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	25	$1.7	$2.3	$3.7
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	31	$1.7	$3.1	$5.1
Total Economic Impacts	**96**	**$7.6**	**$9.5**	**$16.0**

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.[9] 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).[10] 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.)

Estimated increase in investment in California:

Change in Total Estimated Proprietor Income ($4,865,622) * 0.31 = $1,504,671.

---

[9] 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.

[10] 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.

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.

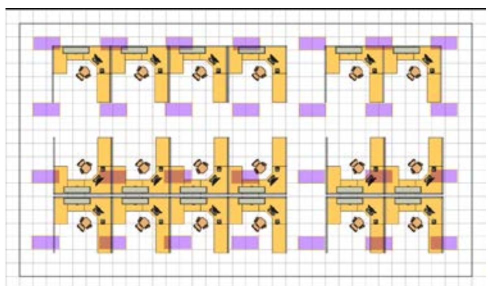
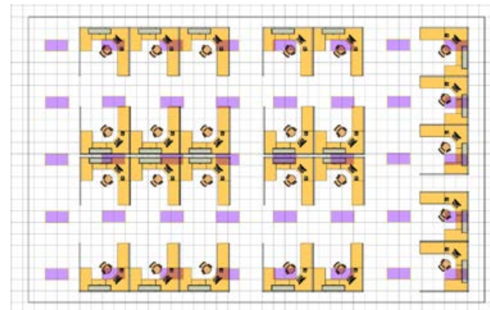
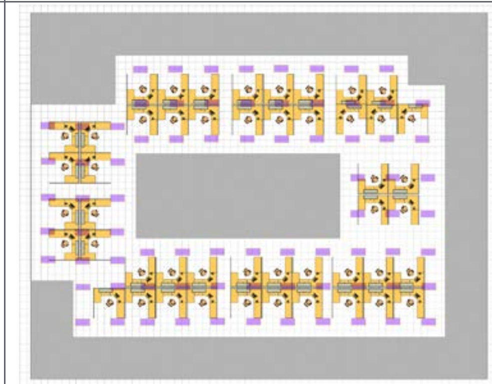
2.3 Energy Savings

2.3.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the TDV released in June 2020. The TDV factors use 20-year global warming potential (GWP) values and a retail rate adjustment that is no longer "flat" across all hours, but 15 percent of this adjustment is proportional to avoided costs. The electricity TDV factors used in the energy savings analyses were obtained via email from Energy and Environmental Economics, Inc. (E3), the contractor that developed 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".

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	78
General lighting layout	95 ft^2/luminaire	100 ft^2/luminaire	97 ft^2/luminaire
Total lighting load[(c)]	1,120 W	1,600 W	3,120 W
Lighting power density[(c)]	0.43 W/ft^2	0.40 W/ft^2	0.41 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 only general lighting in the space.

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. A sample implementation of occupancy sensor layout for these three office models that meets the requirements of the proposed code language and was used in the energy impact and cost analysis is included in Appendix H.

2.3.1.3 Assumption on the Number of Control Zones

The number of control zones was determined based on an occupancy sensor layout that provides a sufficient coverage of the entire floor area using occupancy sensors with a circular coverage pattern of 573 ft^2 (27 feet diameter). The occupancy sensor layout is provided as a sample in Appendix H. 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. 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. The coverage pattern of a typical occupancy sensor is 1,000 ft^2 detecting large motions with a smaller section of the coverage area more sensitive to minor occupant movements, thus some overlap is often necessary to reduce dead zones. 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. This is due to modeling complexity and feasibility. Including daylighting controls could improve the accuracy of the energy savings estimate. For example, if there is a significant amount of daylight in the space and the light level is dimmed due to daylighting controls, the actual energy savings in the unoccupied control zones would be the difference between the lower light level and off, resulting in an overestimate in the current energy savings analysis. To mitigate the potential deficiency of this modeling approach, other assumptions were intentionally selected to be more conservative as specifically pointed out in other parts of this assumptions section.

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.
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.

Egress lighting was not modeled as part of the control method in the energy savings analysis. Egress lighting, up to 0.2 watts per square foot, can be continuously on and is exempted from occupancy shutoff controls.

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”[11] was used as the fraction of large offices in these building types. For other building types, DEER provided only fraction of general office[11] 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 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.

[11] 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.

2.3.1.8 Assumptions on the Impact on Statewide Existing Building Stock

It is assumed that the proposed code change would impact the statewide existing building stock over a period of 15 years by way of addition and alteration, and the impact is evenly distributed across the 15 years. In other words, one-fifteenth of the existing building stock would be impacted by the proposed code change in the first year.

In addition, based on the 2017 C&S Lighting Alteration Survey, 48 percent of the lighting alteration projects chose either the performance compliance pathway or the prescriptive compliance pathway in accordance with Section 141.0(b) 2Ii, the compliance pathways that will trigger the proposed code change (Statewide CASE Team 2017). This is generally consistent with other data points and anecdotal information provided by stakeholders. Given that the 2017 C&S Lighting Alteration Survey was based on a higher lighting power density allowance and that a lower lighting power density for offices larger than 250 square feet is proposed for the 2022 code cycle, more projects using the prescriptive compliance pathway will likely need to comply with Section 141.0(b)2Ii. Therefore, it was assumed that 50 percent of the lighting alteration projects in 2023 will need to meet the proposed requirement.

In summary, 50 percent of the one-fifteenth of the statewide existing building stock is assumed to be impacted in the first year and considered in the statewide energy impact analysis.

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. Moreover, 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;
- Number of occupancy sensors required to sufficiently cover the entire floor area;
- 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.

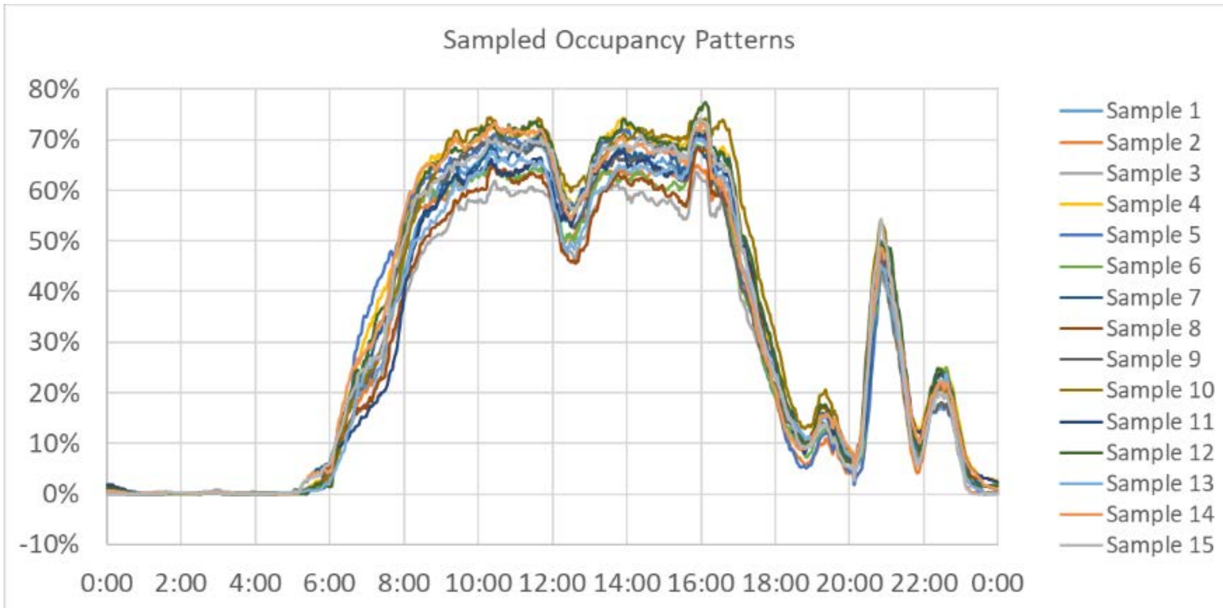


Figure 1: Average daily occupancy pattern from 15 random sample runs.

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[12] 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.

[12] 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.

Therefore, the additional energy savings from HVAC occupied standby are included in the energy impact analysis in this Final CASE Report.

The scope of this proposed code change only applies to office spaces larger than 250 ft^2, and an office building, regardless of size, will likely be composed of other space types in addition to large offices. Conversely, many other building types will also have office spaces larger than 250 ft^2. The prototypical model provided by the Energy Commission did not have each thermal zone subdivided into office spaces. Therefore, it was not feasible to precisely model large office spaces within the prototypical building models provided by the Energy Commission. It was also not practical to study the energy impact of occupied standby on all types and configurations of HVAC systems. Therefore, the Statewide CASE Team used the prototypical model for small office buildings provided by the Energy Commission as a way to obtain the electricity and gas savings from HVAC occupied standby control. The HVAC system used in this particular prototypical model comprises five single-zone air-cooled unitary air conditioners and a single warm-air gas fired furnace with a fan operating at constant air volume. 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.

In comparison to the HVAC system in the small prototypical buildings, the HVAC system in the medium office prototypical building is composed of three packaged variable air volume (PVAV) systems with hot water reheating and a gas fired hot water boiler. The HVAC system in the large office prototypical building consists of an electric powered water-cooled chiller, gas fired hot water boiler, and cooling tower with a fan and variable speed drive (VSD) control. The variety in HVAC system types and configurations could be a source of uncertainty in the estimated energy impact for occupied standby.

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 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 case 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 assumed an average savings for each model office to fall at the 50 percentile between the worst- and best-case savings scenarios.

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 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. While there are some present value TDV natural gas cost savings, the values are small and displayed as $0.00 due to rounding.

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

Model Office Floor Plan	Climate Zone	Electricity Savings (kWh/ft²)	Peak Electricity Demand Reductions (W/ft²)	Natural Gas Savings (therms/ft²)	TDV Energy Savings (TDV kBtu/ft²)
Model Office A (2,584 ft²)	All	0.938	0.160	0.00021	30.049
Model Office B (4,000 ft²)	All	0.999	0.165	0.00021	31.621
Model Office C (7,540 ft²)	All	1.137	0.177	0.00021	35.589
Average	**All**	**1.025**	**0.167**	**0.00021**	**32.420**

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 PV TDV Electricity Cost Savings (2023 PV$)	15-Year PV TDV Natural Gas Cost Savings (2023 PV $)	Total 15-Year PV TDV Energy Cost Savings (2023 PV$)[13]
Model Office A (2,584 ft²)	All	$2.67	$0.00	$2.67
Model Office B (4,000 ft²)	All	$2.81	$0.00	$2.81
Model Office C (7,540 ft²)	All	$3.16	$0.00	$3.17
Average	**All**	**$2.88**	**$0.00**	**$2.89**

[13] 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

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.

---

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 0.472 kWh/yr, followed by 0.365 kWh/yr for small office buildings. Demand reductions are expected to be 0.077 W and 0.060 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	0.365	0.060	0.00007	11.561
Large Office	All	0.472	0.077	0.00009	14.920
Retail	All	0.036	0.006	0.00001	1.152
Non-Refrigerated Warehouse	All	0.036	0.006	0.00001	1.126
Refrigerated Warehouse	All	0.026	0.004	0.00001	0.825
Schools	All	0.056	0.009	0.00001	1.767
Colleges	All	0.045	0.007	0.00001	1.436
Hospitals	All	0.028	0.005	0.00001	0.887

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 control zones such as luminaire level lighting controls. Depending upon the prevalence of use and the long term savings from luminaire level lighting 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. It should be noted that compared to the 600 ft^2 control zone in the proposed code change, smaller control zones would be more effective in saving energy in the worst-case scenario where present occupants spreading across the entire office.

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 60th percentile between the best- and worst-case scenarios, weighted towards the worst-case scenario. This approach gives more credit to smaller control zones for the ability to more effectively save energy in 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)	0.07	0.33	0.09	0.54
Model Office B (4,000 ft^2)	0.04	0.35	0.05	0.43
Model Office C (7,540 ft^2)	0.02	0.35	0.03	0.44
Average	0.05	0.34	0.06	0.47
Weighted Average	0.30		0.23	
Recommended PAF	**0.30**		**0.20**	
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.[14] For both additions and alterations, 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 commercial peak periods typically occur 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, 44 percent of the energy savings in large office spaces from the proposed code change would occur during peak periods.

[14] The proposed code change exempts alterations projects complying with Sections 141.0(b)2Iii and 141.0(b)2Iiii.

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 PV TDV Electricity Cost Savings (2023 PV$)	15-Year PV TDV Natural Gas Cost Savings (2023 PV$)	Total 15-Year PV TDV Energy Cost Savings (2023 PV$)
Small Office	All	$1.03	$0.00	$1.03
Large Office	All	$1.33	$0.00	$1.33
Retail	All	$0.10	$0.00	$0.10
Non-Refrigerated Warehouse	All	$0.10	$0.00	$0.10
Refrigerated Warehouse	All	$0.07	$0.00	$0.07
Schools	All	$0.16	$0.00	$0.16
Colleges	All	$0.13	$0.00	$0.13
Hospitals	All	$0.08	$0.00	$0.08

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

2.4.3 Incremental First Cost

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

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 12 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 “select all” poll question (the responses will not add up to 100 percent) 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. The third round of outreach occurred after the Draft CASE Report was published and it involved significant sales representatives representing a variety of key industry manufacturers as well as some direct manufacturer input to verify and update cost assumptions to be more accurate.

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, stakeholder outreach, and the fact that a PIR sensor is the minimum compliant technology needed to meet the proposed code change.

The Statewide CASE Team conferred with the Energy Commission in April and received guidance that $74.11/hr seemed like a low estimate. 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 ATT, and for installation and startup labor, respectively. The final estimate utilized the higher rates to present a more conservative B/C ratio. The design labor rate came from a designer's estimate of $180/hr for a designer in San Francisco. Using the same California average scaling factor of 129.6 percent compared to national average, and a San Francisco relative factor of 193.5 percent, the final design labor rate was calculated to be $120.58/hr.

Results in this Final CASE Report are a combination of stakeholder feedback and RSMeans. Input from lighting representatives, controls sales representatives, and manufacturers were incorporated to verify reasonable assumptions were made in design methodology and actual cost estimates.

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. The average values are weighted averages based on comparable products available on the market.

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	$5.34	Manufacturers
Commissioning and ATT Labor ($/hour)	$91.35	$176.76	$118.41	$118.41	RSMeans
Design Labor ($/hour)	N/A	N/A	N/A	$120.58	Designer
HVAC Occupied Standby Integration	N/A	N/A	N/A	$0.13	2019 Final CASE Report Proposals Based on ASHRAE 90.1
Installation and Startup Labor ($/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	$83.67	$70.17	$55.63	Multiple Stakeholders
Power Cable ($/1′)	N/A	N/A	N/A	$0.73	RSMeans
Room Controllers ($/item)	$69.82	$121.60	$98.64	$104.50	Multiple Stakeholders
Time-switch ($/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. The same dollar per hour rate for commissioning was used for the lighting ATT, as per suggestion from a lighting ATT on the Statewide CASE Team. The designer hours and rate were both provided during outreach with a lighting design firm in California.
- 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 installation estimate includes startup time to program the system, which is often performed by the manufacturer or manufacturer representative. The commissioning estimates 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. The ATT labor time was estimated by a certified lighting ATT 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 Labor (includes startup):
        - Time-switch scenario = c*5.109 + d*1.28
        - Occupancy sensor base case = a*3.374 + b*0.399 + d*1.28
        - Occupancy sensor proposed case = a*(3.374+0.1) + b*(0.399+0.083) + d*1.28
        - Note: startup time assumes 5 minutes per occupancy sensor and 6 minutes per wired room controller, informed by a manufacturer estimate. It is only included for the proposed case, where there would be a need for programming the system. While actual installation and startup may occur at different times throughout the building process, they were grouped together in this equation because they were assumed to use the same labor rate.
    - Commissioning:
        - Time-switch scenario = c*4.506
        - Occupancy sensor scenarios = a*0.57 + b*0.399
        - Note: The formula for commissioning hours for occupancy sensors is applicable to both the occupancy sensor base case and the proposed case.
    - Design Labor:
        - Both base cases = (5 hours / 2,000 ft^2)*(model office square footage)
        - Proposed case = (10 hours / 2,000 ft^2)*(model office square footage)
    - ATT Labor:
        - Time-switch scenario = 30 minutes for Model Office A and model Office B. 45 minutes for Model Office C.
        - Occupancy sensor base case = (12 minutes/ control zone)*(number of control zones)
        - Occupancy sensor proposed case = (12 minutes/ control zone)*(number of control zones)
- The occupancy sensor cost was obtained from a vendor, and the model selected is a wireless PIR sensor that is fully capable of meeting the proposed code change.

- 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
ATT Labor ($/hour)	$118.41	0.5	$59.21
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.56
Design Labor ($/hour)	$120.58	6.46	$778.92
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	12.789	$1,312.54
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	**$3,102.51**

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
ATT Labor ($/hour)	$118.41	0.5	$59.21
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	4.506	$533.56
Design Labor ($/hour)	$120.58	10	$1,205.76
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	17.909	$1,838.00
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	**$4,156.06**

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
ATT Labor ($/hour)	$118.41	0.75	$88.81
Cable Connector ($/item)	$5.34	N/A	N/A
Commissioning Labor ($/hour)	$118.41	9.012	$1,067.11
Design Labor ($/hour)	$120.58	18.85	$2,272.85
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	33.258	$3,413.27
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	**$7,830.50**

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
ATT Labor ($/hour)	$118.41	0.2	$23.68
Cable Connector ($/item)	$5.34	2	$10.68
Commissioning Labor ($/hour)	$118.41	3.762	$445.46
Design Labor ($/hour)	$120.58	6.46	$778.92
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	14.246	$1,462.07
Junction Box	$3.35	1	$3.35
Occupancy Sensors ($/item)	$55.63	8	$445.04
Power Cable ($/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	**$3,447.46**

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
ATT Labor ($/hour)	$118.41	0.4	$47.36
Cable Connector ($/item)	$5.34	4	$21.36
Commissioning Labor ($/hour)	$118.41	6.327	$749.18
Design Labor ($/hour)	$120.58	10	$1,205.76
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	24.735	$2,538.55
Junction Box	$3.35	2	$6.70
Occupancy Sensors ($/item)	$55.63	13	$723.19
Power Cable ($/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	**$5,798.00**

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
ATT Labor ($/hour)	$118.41	0.8	$94.73
Cable Connector ($/item)	$5.34	8	$42.72
Commissioning Labor ($/hour)	$118.41	11.856	$1,403.87
Design Labor ($/hour)	$120.58	18.85	$2,272.85
HVAC Occupied Standby Integration ($/ft^2)	$0.13	N/A	N/A
Installation Labor ($/hour)	$102.63	46.112	$4,732.47
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	**$10,856.34**

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
ATT Labor ($/hour)	$118.41	1.6	$189.46
Cable Connector ($/item)	$5.34	16	$85.44
Commissioning Labor ($/hour)	$118.41	7.752	$917.91
Design Labor ($/hour)	$120.58	12.92	$1,557.84
HVAC Occupied Standby Integration ($/ft^2)	$0.13	2,584	$335.92
Installation and Startup Labor ($/hour)	$102.63	39.328	$4,036.23
Junction Box	$3.35	8	$26.80
Occupancy Sensors ($/item)	$55.63	8	$445.04
Power Cable ($/1′)	$0.73	240	$175.20
Room Controllers ($/item)	$104.50	8	$836.00
Time-Switch ($/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	**$8,757.70**

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
ATT Labor ($/hour)	$118.41	2.6	$307.87
Cable Connector ($/item)	$5.34	26	$138.84
Commissioning Labor ($/hour)	$118.41	12.597	$1,491.61
Design Labor ($/hour)	$120.58	20	$2,411.51
HVAC Occupied Standby Integration ($/ft^2)	$0.13	4,000	$520.00
Installation and Startup Labor ($/hour)	$102.63	64.228	$6,591.72
Junction Box	$3.35	13	$43.55
Occupancy Sensors ($/item)	$55.63	13	$723.19
Power Cable ($/1′)	$0.73	390	$284.70
Room Controllers ($/item)	$104.50	13	$1,358.50
Time-Switch ($/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	**$14,124.59**

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
ATT Labor ($/hour)	$118.41	4.8	$568.37
Cable Connector ($/item)	$5.34	48	$256.32
Commissioning Labor ($/hour)	$118.41	23.256	$2,753.74
Design Labor ($/hour)	$120.58	37.7	$4,545.71
HVAC Occupied Standby Integration ($/ft^2)	$0.13	7,540	$980.20
Installation and Startup Labor ($/hour)	$102.63	117.984	$12,108.70
Junction Box	$3.35	24	$80.40
Occupancy Sensors ($/item)	$55.63	24	$1,335.12
Power Cable ($/1′)	$0.73	720	$525.60
Room Controllers ($/item)	$104.50	24	$2,508.00
Time-Switch ($/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	**$26,117.73**

For each office layout, the incremental measure cost was then calculated by subtracting the base case from the proposed measure cost, 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 ($/ft²)	Incremental Measure Cost with Occupancy Sensor; Above Minimal Compliance ($/ft²)	Weighted-Average Incremental Measure Cost by Implementation ($/ft²)
Model Office A 2,584 ft²)	$2.19	$2.06	**$2.11**
Model Office B (4,000 ft²)	$2.49	$2.08	**$2.37**
Model Office C (7,540 ft²)	$2.43	$2.02	**$2.35**
Average	$2.37	$2.05	**$2.27**

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, using the same weighted average used in Table 12 per model office to determine the overall measure incremental first cost, $2.27/ft².

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 n^{th} 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 7.5, by the average square footage per office to determine 1.588×10^{-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 1.32×10^{-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 ($/ft²)**
Installation Labor	$94.75	Hour	1.32×10^{-4}	$0.01254
Battery	$1.50	Item	1.59×10^{-3}	$0.00238
Incremental Maintenance Cost	N/A	N/A	N/A	**$0.01492**

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

$$\text{Present Value of Maintenance Cost } = \$0.01492 \times \left\lfloor \frac{1}{1+0.03} \right\rfloor^{10}$$

Present Value of Maintenance Cost = $0.01110/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 1.18 to 1.35 and has an average value of 1.26. 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, startup, designer, ATT, 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 $2.12/ft^2 - $2.36/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)	$2.67	$2.12	1.26
Model Office B (4,000 ft^2)	$2.81	$2.38	1.18
Model Office C (7,540 ft^2)	$3.17	$2.36	1.35
		Average B/C Ratio	**1.26**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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 conducted a third round of outreach with manufacturers, lighting representatives, and controls sales representatives to verify reasonable assumptions were made in design methodology and actual cost estimates.

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 did not include additional design hours. Detailed data can be found in Appendix F.4.1. The average incremental cost per square foot was $0.70/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)	$2.67	$0.83	3.22
Model Office B (4,000 ft^2)	$2.81	$0.64	4.42
Model Office C (7,540 ft^2)	$3.17	$0.66	4.80
		Average B/C Ratio	**4.14**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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.

The Statewide CASE Team then calculated the B/C ratio with the addition of the missing commissioning, ATT, and design labor hours. This re-calculation of the B/C ratio can be thought of as a “sensitivity analysis” for more accurately comparing the cost effectiveness verification with the original analysis of the Statewide CASE Team. Full details of the calculations can be found in Appendix F.4.1. Table 72 shows the detailed components of the incremental cost used to compute the updated B/C ratio summarized in Table 34.

Table 34: Estimated 15-Year Cost-Effectiveness Summary Per Square Foot – Updated Sensitivity Analysis

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)	$2.67	$1.41	1.90
Model Office B (4,000 ft^2)	$2.81	$1.31	2.14
Model Office C (7,540 ft^2)	$3.17	$1.14	2.77
		Average B/C Ratio	**2.27**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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.

This cost estimate verifies the Statewide CASE Team's incremental first cost estimate as plausible, if not conservative, as the average updated B/C ratio is 1.8 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 Appendix F.4.1.1.

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. The estimate 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 Appendix F.4.1.2.

Table 35 summarizes the incremental equipment and programming cost per model office layout. The weighted-average incremental measure cost uses percentages found in Table 16. Table 36 estimates the B/C ratio using the maintenance costs and labor rates provided by the Statewide CASE Team estimate in Section 2.4.3 in order to provide the most accurate B/C ratio as a form of sensitivity analysis.

Table 35: 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 36: 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)	$2.67	$1.62	1.65
Model Office B (4,000 ft^2)	$2.81	$2.08	1.35
Model Office C (7,540 ft^2)	$3.17	$2.12	1.50
		Average B/C Ratio	**1.50**

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). 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.

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 1.2 times that as the estimate in Table 32. This cost estimate may be more accurate, as it mixes multiple implementations—both wireless and wired, and both fixture level controlled and zone-based solutions. It also uses the same maintenance costs and incremental labor costs as that of the original Statewide CASE Team incremental first cost analysis. Full details can be found in Appendix F.4.1.2.

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 24.46 GWh, and the statewide savings from additions and alterations be 37.98 GWh.

The first-year peak electric demand reduction is 3.98 MW for new construction and 6.18 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 37 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 38 presents first-year statewide savings from new construction, additions, and alterations.

Table 37: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.10	0.10	0.02	0.00	$0.28
2	0.58	0.59	0.10	0.00	$1.67
3	2.95	3.03	0.49	0.00	$8.51
4	1.53	1.58	0.26	0.00	$4.46
5	0.28	0.29	0.05	0.00	$0.81
6	2.04	2.10	0.34	0.00	$5.92
7	1.40	1.44	0.23	0.00	$4.03
8	2.99	3.08	0.50	0.00	$8.74
9	5.35	5.50	0.89	0.00	$15.60
10	1.74	1.78	0.29	0.00	$5.06
11	0.40	0.40	0.07	0.00	$1.13
12	2.88	2.94	0.48	0.00	$8.29
13	0.73	0.75	0.12	0.00	$2.10
14	0.48	0.49	0.08	0.00	$1.38
15	0.23	0.24	0.04	0.00	$0.67
16	0.14	0.15	0.02	0.00	$0.40
TOTAL	**23.82**	**24.46**	**3.98**	**0.01**	**$69.05**

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

Table 38: 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 (MMTherms)	15-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	23.82	24.46	3.98	0.01	$69.05
Additions and Alterations	36.99	37.98	6.18	0.01	$107.23
TOTAL	**60.81**	**62.44**	**10.17**	**0.02**	**$176.28**

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 39 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 15,103 metric tons of carbon dioxide equivalents (metric CO2e) would be avoided.

Table 39: 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] (MMtherms /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]	62.44	15,007	0.02	96	15,103

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/MMTherms.

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 0.32 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 40 summarizes the material impact by weight per component of the proposed code change based on the assumptions previously described.

Table 40: 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 square foot 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 41 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 41 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 41: 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.

Results from the survey described in Appendix G.2.2, mention the following non-energy benefits: real-time occupancy analytics, reduced light pollution at night, luminaire longevity, re-zoning, asset tracking, heat mapping, security benefits, alignment of the Title 24 Standards with the 2018 IECC, consideration for integration HVAC controls with lighting, benefits for specific applications, and comfort.

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. The proposed code change may reduce productivity if lighting in unoccupied control zones are turning on and off throughout the day, for spaces using the on/off occupancy sensor design path, which was described in Section 2.2.2.1. 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

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

MECHANICAL COOLING is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy to directly condition the space. Systems that are solely energy recovery ventilation (ERV) or heat recovery ventilation (HRV) are not considered mechanical cooling. In nonresidential, highrise residential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling.

MECHANICAL HEATING is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy to directly condition the space. Systems that only use solar energy or heat recovery as the heat source are not mechanical heating systems.

OCCUPIED STANDBY MODE is when a zone is scheduled to be occupied and an occupant sensor indicates zero population within the zone.

SPACE-CONDITIONING SYSTEM is a system that provides mechanical heating, or mechanical cooling within or associated with conditioned spaces in a building, and may incorporate use of components such as chillers/compressors, fluid distribution systems (e.g., air ducts, water piping, refrigerant piping), pumps, air handlers, cooling and heating coils, air or water cooled condensers, economizers, terminal units, and associated controls.

SECTION 110.9 – MANDATORY REQUIREMENTS FOR LIGHTING CONTROLS

…

(b) **All Lighting Controls.** Lighting controls listed in Section 110.9(b) shall comply with the requirements listed below; and all components of the system considered together as installed shall meet all applicable requirements for the application for which they are installed as required in Sections 130.0 through 130.5, Sections 140.6 through 140.8, Section 141.0, and Section 150.0(k).

…

4. **Occupant Sensing Controls.** Occupant sensing controls include occupant sensors, motion sensors, and vacancy sensors, including those with a Partial-ON or Partial-OFF function. Occupant sensing controls shall:

   A. Be capable of automatically turning the controlled lights in the area either off or down no more than 20 minutes after the area has been vacated;

B. For manual-on controls, have a grace period of no less than 15 seconds and no more than 30 seconds to turn on lighting automatically after the sensor has timed out; and

C. Provide a visible status signal that indicates that the device is operating properly, or that it has failed or malfunctioned. The visible status signal may have an override that turns off the signal**.**

EXCEPTION to Section 110.9(b)4: Occupant Sensing Control systems may consist of a combination of single or multi-level Occupant, Motion, or Vacancy Sensor Controls, provided that components installed to comply with manual-on requirements shall not be capable of conversion by occupants from manual-on to automatic-on functionality.

SECTION 120.1 – REQUIREMENTS FOR VENTILATION AND INDOOR AIR QUALITY

…

(d) **Operation and Control Requirements for Minimum Quantities of Outdoor Air.**

…

2. **Pre-occupancy**. The lesser of the minimum rate of outdoor air required by Section 120.1(c) or three complete air changes shall be supplied to the entire building during the 1-hour period immediately before the building is normally occupied.

…

5. **Occupant Sensor Ventilation Control Devices.** When occupancy sensor ventilation devices are required by Section 120.2(e)3, occupant sensors shall be used to reduce the rate of outdoor air flow when occupants are not present in accordance with the following:

A. Occupant sensors shall meet the requirements in Section 110.9(b)4 and shall have suitable coverage and placement to detect occupants in the entire space ventilated. If occupant sensors controlling lighting are used for ventilation, the ventilation signal shall be independent of daylighting, manual lighting overrides or manual control of lighting. When a single zone damper or a single zone system serves multiple rooms, there shall be an occupancy sensor in each room and the zone is not considered vacant until all rooms in the zone are vacant.

B. One hour prior to normal scheduled occupancy, the occupancy sensor ventilation control shall allow pre-occupancy purge as described in Section 120.1(d)2.

Modify Section 120.2(e) as follows:

Section 120.2 – Required Controls for Space-Conditioning Systems

Nonresidential, high-rise residential, and hotel/motel buildings shall comply with the applicable requirements of Sections 120.2(a) through 120.2(k).

…

(e) **Shut-off and Reset Controls for Space-conditioning Systems.** Each space-conditioning system shall be installed with controls that comply with the following:

…

3. Occupancy Sensing Zone Controls. Space conditioning system~~s~~ zones serving only ~~room(s)~~ space(s) that are required to have occupant sensing controls in accordance with Section 130.1(c), and where the Table 120.1-A occupancy category permits ventilation air to be reduced to zero when the space is in occupied-standby mode, shall meet the following:

A. Occupancy Sensing Zone Controls shall comply with the Occupant Sensor Ventilation Control Device requirements of Section 120.1(d)5 and allow preoccupancy ventilation requirements of Section 120.1(d)2; and

B. Occupancy sensing controls shall comply with Section 110.9(b)4 and be capable of indicating a space is unoccupied no more than 20 minutes after a space has been vacated; and

C. ~~A.~~ ~~The~~ When the zone is scheduled to be occupied, and occupancy sensing controls in all space(s) served by the zone indicate the spaces are unoccupied, the zone shall be placed in occupied standby mode ~~all room(s) served by the zone are unoccupied for more than 5 minutes~~; and

D. ~~B.~~ ~~During~~ Within 5 minutes of entering occupied standby mode:

  i. Automatically setup the operating cooling temperature set point by 2°F or more and setback the operating heating temperature set point by 2°F or more; or

  ii. For multiple zone systems with Direct Digital Controls (DDC) to the zone level, setup the operating cooling temperature setpoint by 0.5°F or more and setback the operating heating temperature setpoint by 0.5°F or more.

E. ~~C.~~ ~~During~~ Within 5 minutes of entering occupied-standby mode all airflow to the zone shall be shut off whenever the space temperature is between the active heating and cooling setpoints.

Exception to 120.2(e)3: Zones which are only ventilated by a natural ventilation system in accordance with Section 120.1(c)2.

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:

i. The occupancy sensing controls shall be configured so that general lighting shall be controlled separately in control zones of 600 ft^2 or less.

ii. Within 20 minutes of the control zone being unoccupied, the occupancy sensing controls shall reduce general lighting power in the control zone to no more than 20 percent of full power. The general lighting power shall be reduced in a manner that the luminaires in the same control zone are dimmed together to the same power level as a group.

iii. Within 20 minutes of the entire office space being unoccupied, the occupancy sensing controls shall automatically turn off all lighting, including general lighting and all other lighting, in the space.

iv. Upon occupancy within the control zone, lighting in each control zone shall be allowed to automatically turn on to a level that recognizes the control interactions specified in Section 130.1(f)8. When occupancy is detected in any control zone in the space, the general 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.

Note: For luminaires with an embedded occupancy sensor that are capable of reducing power independently from other luminaires, each luminaire can be considered its own control zone.

Note: For control zones equal to or smaller than 250 square feet, additional Power Adjustment Factors are provided in Table 140.6-A

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.

9. For space conditioning system zones serving only room(s) that are required to have occupant sensing controls in accordance with Section 130.1(c), and where the Table 120.1-A occupancy category permits ventilation air to be reduced to zero when the space is in occupied standby mode, the space conditioning zone shall be controlled by Occupancy Sensing Zone Controls complying with Section 120.2(e)3.

Modify Section 140.6 as follows:

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)

<table>
<tr><th>TYPE OF CONTROL</th><th colspan="2">TYPE OF AREA</th><th>FACTOR</th></tr>
<tr><td colspan="4">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</td></tr>
<tr><td>1. Daylight Dimming plus OFF Control</td><td colspan="2">~~Luminaires~~ General lighting luminaires in skylit daylit zone or primary sidelit daylit zone</td><td>0.1</td></tr>
<tr><td rowspan="3">2. Occupant Sensing Controls in ~~Large Open Plan~~ Office Spaces Greater than 250 Square Feet</td><td rowspan="3">One sensor controlling an area that is:</td><td>No larger than 125 square feet</td><td>~~0.40~~ 0.30</td></tr>
<tr><td>From 126 to 250 square feet</td><td>~~0.30~~ 0.20</td></tr>
<tr><td>~~From 251 to 500 square feet~~</td><td>~~0.20~~</td></tr>
<tr><td rowspan="2">3.Institutional Tuning</td><td colspan="2">Luminaires in non-daylit areas. Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.</td><td>0.10</td></tr>
<tr><td colspan="2">Luminaires in daylit areas. Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.</td><td>0.05</td></tr>
<tr><td>4. Demand Responsive Control</td><td colspan="2">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</td><td>0.05</td></tr>
<tr><td>5. Clerestory Fenestration</td><td colspan="2">~~Luminaires~~ General lighting luminaires in daylit areas adjacent to the clerestory. Luminaires that qualify for daylight dimming plus OFF control may also qualify for this PAF.</td><td>0.05</td></tr>
</table>

6. Horizontal Slats	~~Luminaires~~ General lighting 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~~ General lighting 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

Modify Section 141.0(d) as follows:

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

TABLE 141.0-F Control Requirements for Indoor Lighting System Alterations

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

Demand Responsive Controls	130.1(e)	Required	Not Required

2.6.3 Reference Appendices

NA7.5.17 Occupied Standby

NA7.5.17.1 Construction Inspection

Prior to Functional Testing, verify and document the following:

(a) ~~(c)~~ Confirm that ~~the~~ all spaces served by the zone are ~~is designated as elgible~~ eligible to be in occupied standby mode as specified in Section §120.2(e)3.

(b) ~~(a)~~ Verify that the occupancy sensor(s) is placed so that it can detect occupants in the space without obstruction. Repeat for all spaces served by the zone.

(c) ~~(b)~~ Confirm that the mechanical system is controlled by an independent signal if the occupancy sensor also controls the lighting.

NA7.5.17.2 Functional Testing

Step 1: Put the zone in occupied mode (i.e., adjust the occupancy schedule)

Step 2: Physically occupy the space and confirm that the occupancy sensor detect the presence of an occupant in the zone.

Step 3: Adjust the thermostatic control so that the ~~system~~ space temperature is within the deadband.

Step 4: Confirm that the zone is supplied with minimum ventilation.

Step 5: Adjust setpoint outside of occupied heating/cooling ~~deadmand~~ deadband but inside the occupied standby deadband. ~~Conform~~ Confirm the zone is in heating or cooling mode.

Step 6: Physically vacate all spaces served by the zone.

Step 7: Confirm that within 5 minutes of occupancy sensing controls indicating all spaces are unoccupied ~~being vacated~~ the setpoint is setup or setback and the zone is within the occupied standby deadband. (**Note:** occupancy sensing controls are allowed to have a time delay of up to 20 minutes before indicating the space is unoccupied and Occupancy Sensing Zone Controls allow an additional 5 minute time delay after occupancy sensing controls have indicated all rooms served by the zone are unoccupied before resetting zone temperature setpoints and shutting off zone ventilation air).

Step 8: Confirm that no ventilation is being supplied to the space with the occupancy sensor.

Step 9: Put the zone in pre-occupancy ventilation mode (i.e. adjust the occupancy schedule to one hour prior to normal scheduled occupancy).

Step 10: Physically vacate all spaces served by the zone.

Step 11. Confirm that within 5 minutes of occupancy sensing controls indicating that all spaces served by the zone are unoccupied, the zone is supplied with pre-occupancy ventilation rate of Section 120.1(d)2: either the minimum rate of outdoor air required by Section 120.1(c) or three complete air changes is supplied to the zone during the one hour period immediately before the zone is scheduled to be occupied. (See note for Step 7 concerning maximum occupancy sensing control time delay).

Step 12: Occupy a space served by the zone during the one hour immediately prior to scheduled occupancy. Confirm that that the zone is supplied with pre-occupancy ventilation rate of Section 120.1(d)2.

Step ~~9~~ 13: Restore the system to normal operation

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)6 D.

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 general 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) Occupied test. Simulate an occupied condition in the control zone controlled by the occupancy sensor. Verify and document the following:

1. Immediately upon occupancy of the control zone, the occupancy sensor turns on controlled lighting.
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) Unoccupied control zone within an occupied office test. 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. The occupancy sensor uniformly reduces light output of the controlled lighting within a maximum of 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 output during unoccupancy is no more than 20% of the full light output measured in Step (a)1.
3. The occupancy sensing control does not trigger a false on from movement outside of the control zone or from HVAC operation.
    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) Control zone size test. 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 = $\pi * radius^2$.
    a. **Note:** π is the mathematical constant representing the ratio of a circle's circumference to its diameter and is roughly equal to 3.1416. 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) Unoccupied office test. 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 enclosed space turns off within a maximum of 20 minutes from the start of the unoccupied condition.

a. **Note:** While the focus of the acceptance test is general lighting, when all the control zones are unoccupied, all lighting must be turned off within a maximum of 20 minutes. Therefore, this specific test segment must verify all lighting is turned off within a maximum of 20 minutes of the start of the unoccupied condition.

2.6.4 Nonresidential ACM Reference Manual

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

5.4.4 Interior Lighting

The building descriptors in this section are provided for each lighting system. Typically, a space will have only one lighting system but, in some cases, it could have two or more. Examples include a general and task lighting system in offices, or hotel multi-purpose rooms that have lighting systems for different functions. It may also be desirable to define different lighting systems for areas that are daylit and those that are not.

(Sections omitted)

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 office spaces greater than 250 square feet. ~~qualifying enclosed spaces and open offices.~~ 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.
Units	List: eligible control types (see above) linked to PAFs
Input Restrictions	PAF shall be fixed for a given control and area type
Standard Design	PAF is zero
Standard Design: Existing Buildings	PAF is zero

2.6.5 Title 24 Nonresidential Compliance Manuals

The requirements for occupancy sensing controls in large offices not only affect the efficiency of the lighting system but also the efficiency of the HVAC system. Occupied standby controls are required in spaces where both of the following criteria are satisfied: 1) occupancy sensing is required for lighting controls and 2) the ventilation rate is allowed to be set to zero during occupied standby as defined in Table 120.1-A. Offices spaces are already able to have their ventilation rate set to zero in Table 120.1-A due to Note F. With the proposed change for large office occupancy controls, large offices will become the predominant space where occupied standby is required. Section 4.5.1.3 of the Nonresidential Compliance Manual should be modified as follows to highlight this change:

- Insert a table of all building space types that are required to have occupied standby controls. This would apply for all space types where both the occupancy sensing is required and the space types are allowed by Table 120.1-A to control ventilation to zero.
- Revise the description of occupied standby so it is clear that the occupant sensing controls have up to 20 minutes to indicate a space is vacant after no movement is detected, and that there is another five minutes of time delay between indication of vacancy and the HVAC system resetting setpoints and shutting of ventilation air while the zone is “floating” between heating and cooling.
- Update Example 4-26 to describe the sequence of controls operation for a large office (all subzones are unoccupied) and when the exception for ventilation only

DOAS systems applies.

Chapter 5 of the Nonresidential Compliance Manual would also need to be revised. In Section 5.4.3.4, a new subsection for multi-zone occupancy sensing control in large office spaces would need to be added (Subsection C. Part 3). The original Subsection C. Part 3 (partial off occupant sensing controls) would need to be updated to Subsection D. Part 4.

In Section 5.4.7, a new subsection (Subsection E) would need to be added to explain how multi-zone occupancy sensing control works, including an explanation for previously set light levels, dimming interaction with institutional tuning, and controls interaction specified in Section 130.1(f). Regarding previously set light levels, when a control zone becomes occupied, the corresponding general lights can turn on to full power or a previously set light level. For 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. For controls interaction specified in Section 130.1(f), the Nonresidential Compliance Manual should explain that lights can turn on to full power or a previously set light level if no other controls dictate the light level must be lower. If there are other controls, such as automatic daylighting controls, then the light level can either (A) immediately dim to the level dictated by the controls other than the occupant sensing controls, or (B) turn on to full power or the previously set light level, and then immediately dim to the level dictated by the controls other than occupant sensing controls.

Section 13.4.3 (Lighting Controls) would need to be updated to reflect the changes to acceptance tests listed in this report in Section 2.6.3. The updates should clarify that spaces previously referred to as “open plan offices” are actually a type of “large office” space, which are defined as offices greater than 250 ft^2. Section 13.4 would also need to highlight the changes to the occupied standby acceptance test (NRCA-MCH-19).

2.6.6 Compliance Documents (Forms)

Compliance documents NRCI-LTI-05-E, NRCC-LTI-E, NRCC-PRF-01-E, NRCA-MCH-19-A, 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 to update Table H for the mandatory controls and Table P for the PAFs to reflect the proposed code change.

The compliance document NRCC-PRF-01-E would need to update Table N3 to reflect the updated PAF values and Table N4 to reflect the updated mandatory controls requirements of the proposed code changes.

The certificate of acceptance document for occupied standby, NRCA-MCH-19-A, would be updated to reflect changes to the acceptance test including the clarification that there could be as much as 20 minutes time delay between vacating a space and the occupancy sensing control indicating vacancy. There’s also up to an additional five minutes for setpoints to be changed and ventilation air to be set to zero. Additionally, this form would document that occupied standby is not triggered during unoccupied hours and does not override pre-occupancy ventilation mode.

The acceptance testing 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.

- o 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.
- o 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,[15] lighting power adjustments,[16] 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

[15] 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.

[16] 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.

A summary of the rationale behind the proposed changes to the primary function applications is described in Appendix R.

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.

3.1.2 Measure History

3.1.2.1 Measure Background

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.

3.1.2.2 Importance of Lighting Power Density Updates

Most 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 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.

3.1.3 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 Proposed Code 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**. The purpose of the changes to the section is to clarify the definitions of ornamental lighting and decorative lighting. The current definition of "decorative lighting" is convoluted: decorative lighting is defined as a subset of ornamental lighting and also as a separate definition that does not reference ornamental lighting. Decorative lighting is removed as a subset of ornamental lighting, defined once, and clarified to apply to indoor lighting. The ornamental lighting definition is updated to remove reference to decorative lighting.
- **Update Accent Lighting and Display Lighting.** The purpose of the changes to this section is to clarify that accent lighting is a type of display lighting. Likewise, the display lighting definition is clarified to be directional and not contributing to general lighting.
- **Luminaire aperture defined.** The purpose of the changes to this section is to provide a definition to clarify what a luminaire aperture is. A power adjustment is allowed for Small Aperture Tunable-White and Dim-to-Warm Luminaires. However, during interviews with lighting designers, the Statewide CASE Team found that there was some confusion about the definition of "small luminaire aperture." Further discussions are needed to determine what products qualify for a power adjustment as there are some products that do not necessarily have an aperture but should qualify for this power adjustment, such as tape lights.
- **Names of function areas reordered.** The purpose of the change to this section is 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. For example, General Commercial and Industrial Work Area is renamed Manufacturing, 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 purpose of the changes to the section is to simplify code enforcement as there is no longer a need to separately define and calculate dedicated ramp area from parking area. The Statewide CASE Team's analysis found that the required LPD for these two areas were close enough that these zones could be merged.
- **Barber and Spa Treatment added to Beauty Salon function area.** The purpose of the changes to this section is to update the name and definition to provide clarity for compliance on spaces and associated activities. The edit to the name would result in greater clarity for compliance. These other additional functions have similar requirements to the current definition and are likely used as the closest applicable function.

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

- **Section 130.0(c)2 – Luminaire classification and power.** The purpose of the changes to this section is to remove the 50 watt per socket and JA8 requirement for luminaires with line voltage lamp holders and set to the installed lamp wattage instead. This resolves the issue of LED lamps being counted at higher wattages (most LED lamps would be lower than 50 watts) and many spaces not needing a JA8 compliant lamp.[17]

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

- **Section 140.6(a)3. Lighting wattage excluded**

  Medical lighting exemption. The purpose of the changes to this section is to remove the listing of building types to where this exemption applies. 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.

  Lighting Equipment for Sale. The purpose of the changes to this section is to clarify that lighting equipment that is for sale and controlled by automatic shut-off controls specified in Section 130.1(c) are exempt.

  Controlled Environment Horticulture. The purpose of the changes to this section is to clarify that lighting for controlled environment horticulture is covered under the proposed plant lighting requirements in section 120.6(h). This includes

[17] JA8 compliant lamps must meet certain requirements, such as having a CRI of 90 or greater. Commercial spaces oftentimes don't need lamps that meet all the JA8 requirements. Therefore, removing this requirement allows LED lamps to be used without being counted at a higher wattage and without needing to meet other requirements that are not always necessary for the spaces (such as high CRI).

items G, O, P, and W. 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:** The purpose of this change is to update the allowed LPD values to reflect the changes in the Area Category LPDs. Values have been updated for approximately half of the building types. The Complete Building Method LPDs are area-weighted averages of the general lighting power allowances of area categories allocated to each building type. The building type "Museum Building" was added to this table, which was requested so that compliance could be simplified for these building types when installed lighting power density is low.
- **TABLE 140.6-C – AREA CATEGORY METHOD – LIGHTING POWER DENSITIES (WATTS/FT^2):** The purpose of this change is to update the allowed LPD values and the additional LPD allowances in addition to rearranging the table to be easier to read by grouping values alphabetically and 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 table.

  "Office Area: Open plan office" primary function area has been removed. Though open plan office is used in Title 24, Part 6, it is not defined in IECC or ASHRAE 90.1. As described in Section 2.1.5.2 and Section 2.1.1, open plan office is ambiguously defined and some definitions are opposite of what would be consider an open plan office.

  Merriam Webster defines "open plan" as "having or consisting of a large room that is not divided into smaller rooms or areas." This definition is at odds with what is generally considered an open plan office with cubicles.

  McGraw-Hill Dictionary of Architecture and Construction (2003) defines "open-plan office" as "a large space, divided by freestanding, partial-height partitions; usually designed to accommodate a large number of office workers."

  Cambridge dictionary's definition is "an open-plan room or building has few or no walls inside, so it is not divided into smaller rooms."

  Business dictionary's definition is "flexible method of space layout where divisions between separate areas are implied by easily movable elements (such as screens and skeletal construction components, and modular furniture) instead of being defined by permanent walls and fixed shape furniture. Based on the ideas of the US architect Frank Lloyd Wright and French architect Le Corbusier (who called it 'Le plan libre')."

It is unreasonable to expect that furniture has been purchased and installed at the time of certificate of occupancy. Therefore, the open plan office definition cannot be reliably based on the presence of office furniture. The main commonality between definitions is that the space is large and does not have fixed walls breaking up the space. The Title 24, Part 6 definition of enclosed space is a “space that is substantially surrounded by solid surfaces, including walls, ceilings or roofs, doors, fenestration areas, and floors or ground.” Thus, an office space by Title 24, Part 6 definition is not broken by ceiling height walls. Given that open plan office does not have an agreed upon meaning and the presence of partitions does not materially impact the amount of general lighting needed, the added primary function area for open plan office is not needed for defining a unique space.

The primary function areas designation for parking garage parking zone and dedicated ramps were merged into the combined category “Parking Zone and 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.

- **TABLE 140.6-C – AREA CATEGORY METHOD – ADDITIONAL LIGHTING POWER:** The purpose of this code change is to simplify the additional lighting power allowance in the Area Category Method by merging the allowances for “Ornamental,” Decorative,” and “Accent, Display and Feature,” into the single category “Display/Decorative.” In interviews with lighting designers, the complexity of qualifying for additional lighting power was a common frustration. Multiple qualifying product categories exist that over specify the types of non-general lighting that could take the additional power allowance., With this change, enforcement is simplified as well as Display/Decorative lighting systems are characterized primarily as being not general lighting.
- **TABLE 140.6-D – TAILORED METHOD LIGHTING POWER ALLOWANCES:** The purpose of this change is to rename the allowed LPD for “Ornamental/Special Effect Lighting” to “Allowed Decorative Lighting Power Density.” Ornamental Lighting now only applies to outdoor lighting. Decorative lighting has a broader definition than that of ornamental lighting; it is, “lighting or luminaires installed only for aesthetic purposes and that does not serve as display lighting or general lighting.” This covers most of what might have been considered special effect lighting, “lighting installed to give off luminance instead of providing illuminance, which does not serve as general, task, or display lighting.” The only other light source that one might want to call out for special effect lighting is theatrical lighting, but this lighting is exempted as follows in Section 140.6(a)3C: “Lighting for dance floors, lighting for theatrical and other live performances, and theatrical lighting used for religious worship, provided that

these lighting systems are additions to a general lighting system and are separately controlled by a multiscene or theatrical cross-fade control station accessible only to authorized operators."

This proposal has recommended updated LPDs in the Tailored Lighting Method for general illumination, wall display, floor display and decorative lighting power allowances based on higher efficacies for LED light sources with high (90+) CRI (color rendering index). High CRI light sources were the basis of the allowances for the tailored lighting approach for both 2019 Title 24, Part 6 Standard and the proposed 2022 Title 24 Part 6 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: Update this section 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 modifies the compliance documents listed below. Additional info on the revised documents are presented in Section 3.6.6.

- **NRCC-LTI-E:** Modify Section I to reflect updated area category names, LPDs, and additional allowances and adjustments. Section J would also need to be updated for additional allowances and adjustments.

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 besides the simplification of identifying the non-general lighting qualifying for the additional lighting power allowance in the Area Category Method.
- **Construction Phase:** No changes are expected.
- **Inspection Phase:** Overall no major changes are expected. The lumping together non-general lighting qualifying for the additional lighting power allowance in the Area Category Method would have a slight impact on ease of inspection.

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 42 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 42: 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 cumulative distributions 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.

As shown in Figure 2, the cumulative product and manufacture distribution with respect to reported efficacy for low CRI 2 foot by 2 foot troffers is evaluated as follows: The number of products in the DLC database with a lower efficacy than 110 lumens per watt (lm/W) can be determined by drawing a line upwards from a reported efficacy of 110 lm/W to the green line representing “Distinct Count of Model Numbers.” This would correspond to approximately 2,200 models that have efficacies less than 110 lm/W. The total number of distinct models is around 7,200 models. Since only 2,200/7,200 (or 30 percent) have efficacies less than 110 lm/W, approximately 70 percent of the products in the DLC database would use less wattage than the prototypical trigger while providing the same amount of light.

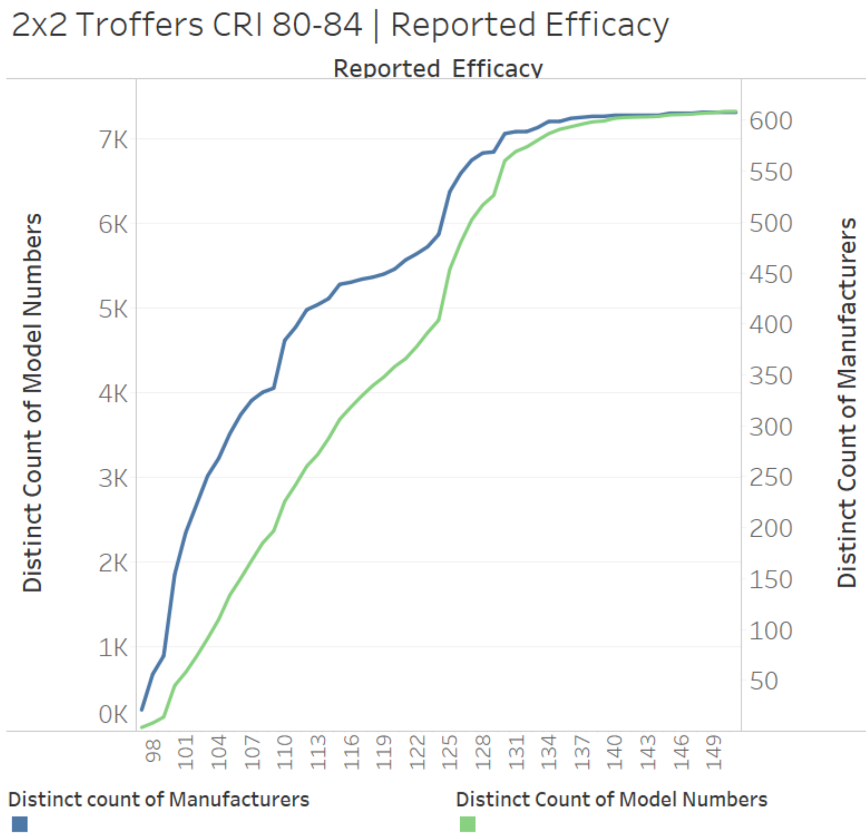


Figure 2: Distinct number of 80-84 CRI 2x2 Troffers and number of manufacturers with their reported efficacy.

When developing this proposal, the Statewide CASE Team strived to confirm that it does not rely on a proprietary technology to ensure that multiple manufacturers can provide compliant technology. Figure 2 can be used to understand what fraction of manufactures in the DLC database produce 2 foot by 2 foot troffers that have efficacies greater than or equal to the prototypical troffer used in the model by the Statewide CASE Team. Drawing a line upwards from a reported efficacy of 110lm/W to the blue line representing “Distinct Count of Manufacturers”, corresponds to approximately 240 manufacturers. There are around a total of 600 manufacturers in the DLC database that produce 2 foot by 2 foot troffers. As a result, the fraction of manufactures who do not produce these troffers at or above 110 lm/W is 360/600 (or 60 percent). Therefore, 40% of manufacturers in the DLC database produce troffers at or above 110 lm/W. This shows that the prototypes are not picking a proprietary technology limited to few manufacturers.

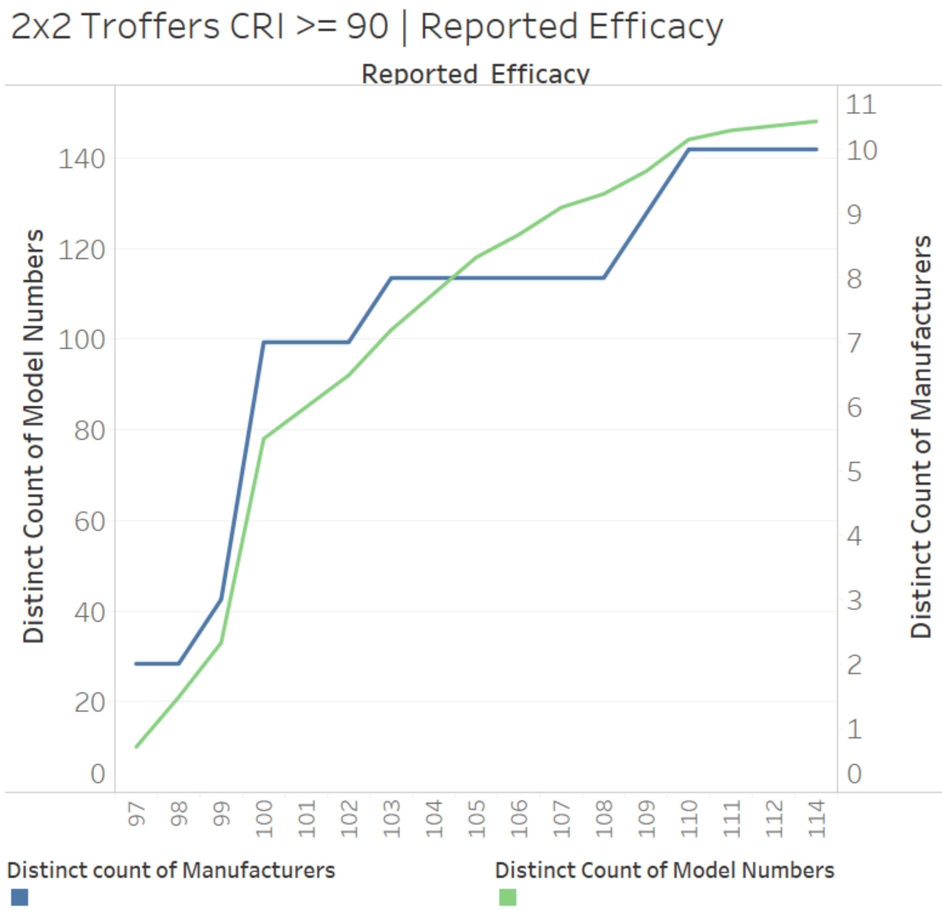


Figure 3: Distinct number of greater than 90 CRI 2x2 Troffers and number of manufacturers with their reported efficacy.

More details and cumulative distribution of a wide range of luminaire types are presented in Appendix L.

The Statewide CASE Team met with three lighting designers individually in August 2020 (after the Draft CASE Report had been released publicly) to discuss their concerns in detail. As a result of these meetings, the Statewide CASE Team performed additional analysis using the lumen method model, which resulted in several modifications, including some LPD revisions.

Though the Statewide CASE Team was using IES recommended illuminances for stairwells, multiple designers expressed concern that this was an area where it would be better to provide additional leniency on the side of higher LPDs and illuminances given safety concerns. The Statewide CASE Team revised the models and recommended increased LPDs for these primary function areas.

One of the designers was concerned about the merging of the large office > 250 square feet occupancy with the open plan office occupancy and using the lower LPD from the

2019 standards. In the 2019 standards the primary function area large office > 250 square feet had a general lighting LPD of 0.65 W/sf, whereas the open plan office primary function area had a general lighting LPD of 0.60 W/sf. The Draft CASE Report had recommended 0.60 W/sf for all large offices > 250 sf (the primary function area open plan office was removed due to a lack of an unambiguous definition). This stakeholder noted that achieving the 0.60 W/sf was not difficult with standard ceiling, wall, and floor reflectances, but might be difficult under other circumstances. Specifically, the stakeholder noted a project where the building owner wanted to keep a brick wall surface in a refurbished building for its visual appeal. Brick has a low reflectance value, so achieving the 0.60 W/sf presented a challenge. Lumen method analysis with revised reflectances resulted in a minor revision to the proposed LPD to address these concerns.

However, since large offices accounts for millions of square feet of new and retrofit lighting projects, the Statewide CASE Team also validated the proposed changes by conducting a detailed AGi32 radiosity model analysis. Besides revisiting the impact of surface reflectances on the proposed large office LPD, this model was also used to perform a thorough analysis of design issues expressed by the designer stakeholders. Other scenarios included evaluating trade-offs between general lighting and accent lighting, and providing higher desktop illuminances without using undercabinet lighting. Additionally, the Statewide CASE Team included models using color tuning luminaires to understand how this will affect LPD values.

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 43).[18] 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).

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

Table 43: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	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 44 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 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 44: 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 45 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)[19] 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.[20] 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 45 provides an upper bound indication of the size of this sector in California.

Table 45: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	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

[19] 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.

[20] 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.

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.

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 46 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. The simplification of the added lighting power allowance by the combined “Display/Decorative” luminaire type would marginally reduce work load.

Table 46: Employment in California State and Government Agencies with Building Inspectors

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

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by 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 47 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.

[21] 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.

Table 47: 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)	(4,157)	($274.9)	($364.2)	($602.5)
Indirect Effect (Additional spending by firms supporting Commercial Builders)	(904)	($65.8)	($104.8)	($202.2)
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	(1,807)	($101.8)	($182.2)	($297.5)
Total Economic Impacts	**(6,868)**	**($442.5)**	**($651.2)**	**($1,102.1)**

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

Table 48: 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	$4.96	$4.90	$8.72
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	31	$2.04	$2.76	$4.39
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	37	$2.09	$3.74	$6.11
Total Economic Impacts	**116**	**$9.10**	**$11.41**	**$19.22**

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 47 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 47 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.[22] 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 domestic investment, or NPDI).[23] As Table 49 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

---

[22] 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.

[23] 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.

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 49: 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 = ($54,791,522) * 31% = ($16,944,030)

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 47 and Table 48 above by 31 percent.

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 released in June 2020 which use 20-year global warming potential (GWP) values, and a retail rate adjustment which is no longer "flat" across all hours but 15 percent of this adjustment is proportional to avoided costs. The electricity TDV factors used in the energy savings analyses were obtained from Energy and Environmental Economics, Inc. (E3), the contractor that is developing the 2022 TDV factors for the Energy Commission, in a spreadsheet titled "2022 TDV CH4_Leak_20yr_15RA.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 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.[24] 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

[24] 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

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 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[25] 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:[26]

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

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 CASE Team has used look up tables but is now using an Excel User Defined

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

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

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 AGi32 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:

$$F2 = WHF \times 0.4 \times RCR$$

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 work plane 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” associated with loss of accuracy is needed for 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 71 primary function areas, 10 increase their LPDs, 30 decrease their LPDs and 31 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. For new construction the area weighted power reduction is 5.6 percent overall. 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. Comparing 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 shows 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 counterexample 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 on color changing lighting in classrooms (Pacific

Northwest National Laboratory 2017). The total LPD for these classrooms were between 0.54 and 0.63 W/ft^2.

In general, the Statewide CASE Team referenced the IES recommended practice values or various applications. However, there were a few instances where the Statewide CASE Team agreed with designers to select higher illuminance values than those recommended by IES, including stairwells and beauty salons.

The Statewide CASE Team found that the efficiency loss for Small Aperture Tunable-White and Dim-to-Warm Luminaires had decreased over the last three years and the adjustment factors for these color changing controls could increase (adjusted indoor power would be de-rated less). The efficiency loss for Large Aperture Tunable-White was still found to be negligible and no adjustment factor was proposed.

For the 2019 Title 24, Part 6 Standards, a 0.1 W/ft^2 additional lighting power allowance for Tunable-White and Dim-to-Warm Luminaires is allocated to healthcare facilities, specifically where patients may not have the opportunity to entrain their circadian system with daylight or avoid circadian disruptive light exposure. This additional lighting power allowance was expanded to the Aging Eye/Low-vision primary function areas because they are also found in senior long-term care, adult day care, senior support facilities. Expanding this credit mirrored the rationale for providing the color tuning allowance to healthcare facilities.

In several of the primary function areas listed below, the only change is a drop in additional lighting power for ornamental lighting 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 between the development of the 2019 Title 24, Part 6 proposed LPDs and this proposal, overall LED efficacies have not increased appreciably but the efficacies for high CRI sources used in modeling ornamental lighting have increased by 12 percent on average. 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.

Table 50: 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	0.75	0.75	0.55	0.20	0.55	0.20	2,831	0	0.000
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	0.50	0.61	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
Dining Area: Family and Leisure	0.20	0.23	0.50	0.30	0.40	0.25	4,787	718	0.075

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)
Kitchen/Food Preparation Area	0.97	0.97	0.95		0.95		4,787	0	0.000
Electrical, Mechanical, Telephone Rooms	0.36	0.36	0.40		0.40		1,735	0	0.000
Exercise/Fitness Center and Gymnasium Area	0.36	0.36	0.50		0.50		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	0.40	0.40	0.45		0.45		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		1.00		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		0.45		3,367	0	0.000
Lounge, Breakroom, or Waiting Area	0.20	0.46	0.65	0.30	0.55	0.25	3,367	505	0.051
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)

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)
Office Area: ≤ 250 square feet	0.45	0.45	0.70	0.20	0.65	0.20	2,322	116	0.006
Office Area: > 250 square feet	0.40	0.51	0.65	0.20	0.60	0.20	2,322	116	0.006
Office Area: Open plan office	0.52	0.60	0.60	0.20	0.60	0.20	2,322	0	0.000
Parking Garage Area: Parking Zone	0.09	0.09	0.10		0.10		6,754	0	0.000
Parking Garage Area: Dedicated Ramps	0.10	0.10	0.25		0.10		6,754	1,013	0.111
Parking Garage Area: Daylight Adaptation Zones	0.96	0.96	0.50		1.00		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
Stairwell	0.59	0.59	0.50	0.35	0.60	0.35	2,322	(232)	(0.013)
Theater Area: Motion picture	0.39	0.39	0.60	0.30	0.50	0.25	3,367	505	0.051
Theater Area: Performance	0.40	0.72	1.00	0.30	0.80	0.25	3,367	842	0.085
Transportation Function : Baggage Area	0.21	0.25	0.40		0.40		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

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)
Videoconferencing Studio	0.86	1.82	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	0.75	0.91	0.80		0.80	0.20	2,322	(464)	(0.026)
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 Hospitals: Exam/Treatment Room	1.20	1.20	1.15		1.15		2,888	0	0.000
Healthcare Facility and Hospitals: Imaging Room	0.44	0.44	1.00		0.60	0.30	2,888	289	0.019
Healthcare Facility and Hospitals: Medical Supply Room	0.47	0.47	0.55		0.55		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)

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)
Healthcare Facility and Hospitals: Operating Room	1.86	1.86	1.90		1.90		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		2.25		3,515	0	0.000
Sports Arena – Playing Area: Class II Facility	1.82	1.82	1.45		1.45		3,515	0	0.000
Sports Arena – Playing Area: Class III Facility	1.14	1.14	1.10		1.10		3,515	0	0.000
Sports Arena – Playing Area: Class IV Facility	0.76	0.76	0.75		0.75		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.

Applications with negative savings values (represented as red and in parenthesis) represent where the combination of the allowable general lighting LPD and the additional lighting power are proposed to increase.

Table 51: 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	0	$0.00	4,800	0	0.000	0	$0
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: High Bay	0	$0.00	12,000	0	0.000	0	$0
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

Primary Function Area	TDV Savings kBtu/ft^2	Energy Cost Savings (PV$/ ft^2)	Proto-type Area (ft^2)	Prototype Annual Energy Savings (kWh/yr)	Prototype Demand Savings (kW)	Prototype TDV Savings kBtu	Prototype Energy Cost Savings (PV$)
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	3	$0.26	600	70	0.004	1,749	$156
Office Area: Open plan office	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	(6)	($0.52)	360	(84)	(0.005)	(2,099)	($187)
Theater Area: Motion picture	14	$1.27	1,560	788	0.079	22,311	$1,986
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

Primary Function Area	TDV Savings kBtu/ft²	Energy Cost Savings (PV$/ ft²)	Proto-type Area (ft²)	Prototype Annual Energy Savings (kWh/yr)	Prototype Demand Savings (kW)	Prototype TDV Savings kBtu	Prototype Energy Cost Savings (PV$)
Aging Eye/Low-vision: Stairwell	(12)	($1.04)	160	(74)	(0.004)	(1,866)	($166)
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 Therapy Room	7	$0.64	1,200	347	0.022	8,651	$770
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

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

Luminaire costs were collected for three to eight 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 52 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 52: 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
	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

	Luminaire ID No.	Short Description	Avg Efficacy	Avg Lumen	Avg Watt	Spec Grade Cost	Contractor Grade Cost
2022 Wall Washing	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
	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	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

	Luminaire ID No.	Short Description	Avg Efficacy	Avg Lumen	Avg Watt	Spec Grade Cost	Contractor Grade Cost
	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
	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	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*.

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 Title 24, Part 6 Standards. Unlike the evaluation of life cycle cost for the 2019 Title 24, Part 6 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. 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 53: 15-Year Cost-Effectiveness Summary Per Prototype Space

Primary Function Area	Prototype Area (ft^2)	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Audience Seating Area	3,200	($1,310)	$4,073	$5,383	$0	Infinite
Auditorium Area	4,500	$7,118	$1,909	$1,909	$7,118	0.27
Auto Repair / Maintenance Area	4,800	$0	$0	$0	$0	NC
Barber, Beauty Salon and Spa Area	1,440	$1,969	$2,321	$2,321	$1,969	1.18
Civic Meeting Place Area	540	$403	$687	$687	$403	1.70
Classroom, Lecture, Training, Vocational Area	1,064	($2,694)	$326	$3,020	$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	($39,863)	$33,849	$73,712	$0	Infinite
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	($3,392)	($166)	$3,392	$166	EC up 20.43
Dining Area: Bar/Lounge and Fine Dining	1,800	$4,409	$3,267	$3,267	$4,409	0.74
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	($3,611)	$560	$4,171	$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	$1,618	$229	$229	$1,618	0.14
Scientific Laboratory Area	672	($7,369)	$589	$7,958	$0	Infinite
Laundry Area	1,200	$0	$0	$0	$0	NC
Library : Reading Area	720	($2,118)	$187	$2,304	$0	Infinite

Primary Function Area	Prototype Area (ft²)	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
Library : Stacks Area	360	($1,665)	$187	$1,852	$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	$4,078	($2,037)	$0	$6,115	EC up 0.00
Office Area: ≤ 250 square feet	140	($94)	$36	$130	$0	Infinite
Office Area: > 250 square feet	600	($1,167)	$156	$1,323	$0	Infinite
Office Area: ~~Open plan office~~ > 250 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	$2,800	($16,684)	$0	$19,484	EC up 0.00
Pharmacy Area	480	$625	$387	$387	$625	0.62
Retail Sales Area: Grocery Sales	4,800	($50,972)	$1,934	$52,906	$0	Infinite
Retail Sales Area: Retail Merchandise Sales	4,800	($13,296)	$1,934	$15,230	$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	($5,304)	($187)	$5,304	$187	EC up 28.39
Theater Area: Motion picture	1,560	($3,036)	$1,986	$5,022	$0	Infinite
Theater Area: Performance	16,000	($29,904)	$33,943	$63,847	$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	($1,396)	($166)	$1,396	$166	EC up 8.41
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

Primary Function Area	Prototype Area (ft^2)	Incremental Cost ($)	Prototype Energy Cost Savings (PV$)	Benefits (PV $)	Costs (PV$)	B/C ratio
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	($454)	($224)	$454	$224	EC up 2.03
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	$80	$770	$770	$80	9.64
Healthcare Facility and Hospitals: Nurse’s Station	200	$1,739	($385)	$0	$2,124	EC up 0.00
Healthcare Facility and Hospitals: Operating Room	900	$0	$0	$0	$0	NC
Healthcare Facility and Hospitals: Patient Room	192	$304	($185)	$0	$489	EC up 0.00
Healthcare Facility and Hospitals: Physical Therapy Room	1,200	($1,208)	$770	$1,978	$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 percent 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 54: Statewide Energy and Energy Cost Impacts – One Year's New Construction

Primary Function Area	Statewide New Construction (Million ft²/yr)	New Construction Energy Savings (GWh/yr)	New Construction Demand Saving (kW)	New Construction Energy Cost Savings (Million PV$)
Audience Seating Area	2.8	1.42	143.7	$3.59
Auditorium Area	2.4	0.40	40.2	$1.00
Auto Repair / Maintenance Area	4.8	0.00	0.0	$0.00
Barber, Beauty Salon and Spa Area	0.5	0.38	18.2	$0.86
Civic Meeting Place Area	1.4	0.70	71.0	$1.77
Classroom, Lecture, Training, Vocational Area	7.5	0.98	64.5	$2.29
Commercial/Industrial Storage: Warehouse	23.4	2.03	77.9	$4.19
Commercial/Industrial Storage: Shipping & Handling	5.7	0.00	0.0	$0.00
Concourse and Atria Area	2.0	2.52	121.8	$5.77
Convention, Conference, Multipurpose and Meeting Area	7.0	3.54	357.3	$8.92
Copy Room	0.2	0.00	0.0	$0.00
Corridor Area	11.6	(1.35)	(74.7)	($3.02)
Dining Area: Bar/Lounge and Fine Dining	0.5	0.34	35.6	$0.87
Dining Area: Cafeteria/Fast Food	2.2	0.00	0.0	$0.00
Dining Area: Family and Leisure	0.9	0.62	64.5	$1.57
Kitchen/Food Preparation Area	3.0	0.00	0.0	$0.00
Electrical, Mechanical, Telephone Rooms	3.3	0.00	0.0	$0.00
Exercise/Fitness Center and Gymnasium Area	2.1	0.00	0.0	$0.00
Financial Transaction Area	1.1	0.37	20.5	$0.83
General/Commercial & Industrial Work Area: Low Bay	3.0	0.00	0.0	$0.00
General/Commercial & Industrial Work Area: High Bay	0.8	0.00	0.0	$0.00
General/Commercial & Industrial Work Area: Precision	0.2	0.00	0.0	$0.00
Hotel Function Area	0.5	0.08	8.1	$0.20
Scientific Laboratory Area	0.5	0.19	12.4	$0.43
Laundry Area	0.2	0.00	0.0	$0.00

Primary Function Area	Statewide New Construction (Million ft^2/yr)	New Construction Energy Savings (GWh/yr)	New Construction Demand Saving (kW)	New Construction Energy Cost Savings (Million PV$)
Library : Reading Area	0.8	0.09	5.0	$0.20
Library : Stacks Area	0.5	0.13	7.0	$0.28
Main Entry Lobby	7.6	5.12	516.5	$12.90
Locker Room	0.4	0.00	0.0	$0.00
Lounge, Breakroom, or Waiting Area	2.8	1.41	141.9	$3.54
Museum Area: Exhibition/Display	0.1	0.00	0.0	$0.00
Museum Area: Restoration Room	0.0	0.00	0.0	$0.00
Office Area: ≤ 250 square feet	11.4	1.32	72.9	$2.95
Office Area: > 250 square feet	5.7	0.67	36.8	$1.49
Office Area: ~~Open plan office~~ > 250 sf	7.4	0.00	0.0	$0.00
Parking Garage Area: Parking Zone	4.5	0.00	0.0	$0.00
Parking Garage Area: Dedicated Ramps	0.4	0.42	45.8	$1.04
Parking Garage Area: Daylight Adaptation Zones	0.1	(0.35)	(38.1)	($0.87)
Pharmacy Area	0.1	0.03	1.4	$0.07
Retail Sales Area: Grocery Sales	4.1	0.73	35.2	$1.67
Retail Sales Area: Retail Merchandise Sales	12.5	2.19	106.1	$5.02
Retail Sales Area: Fitting Room	0.3	0.00	0.0	$0.00
Religious Worship Area	3.4	0.57	57.2	$1.43
Restrooms	5.5	0.00	0.0	$0.00
Stairwell	2.3	(0.53)	(29.5)	($1.19)
Theater Area: Motion picture	0.9	0.43	43.7	$1.09
Theater Area: Performance	0.7	0.58	59.0	$1.47
Transportation Function : Baggage Area	0.0	0.00	0.0	$0.00
Transportation Function : Ticketing Area	0.0	0.00	0.0	$0.00
Videoconferencing Studio	0.0	0.00	0.0	$0.00
Aging Eye/Low-vision: Main Entry Lobby	0.0	0.00	0.0	$0.00
Aging Eye/Low-vision: Stairwell	0.0	(0.01)	(0.4)	($0.02)

Primary Function Area	Statewide New Construction (Million ft^2/yr)	New Construction Energy Savings (GWh/yr)	New Construction Demand Saving (kW)	New Construction Energy Cost Savings (Million PV$)
Aging Eye/Low-vision: Corridor Area	0.0	0.00	(0.2)	($0.01)
Aging Eye/Low-vision: Lounge/Waiting Area	0.0	(0.01)	(1.1)	($0.02)
Aging Eye/Low-vision: Multipurpose Room	0.0	0.01	2.2	$0.04
Aging Eye/Low-vision: Religious Worship Area	0.0	0.00	0.0	$0.00
Aging Eye/Low-vision: Dining	0.0	0.00	0.0	$0.00
Aging Eye/Low-vision: Restroom	0.0	0.00	0.0	$0.00
Healthcare Facility and Hospitals: Exam/Treatment Room	2.3	0.00	0.0	$0.00
Healthcare Facility and Hospitals: Imaging Room	0.1	0.02	1.5	$0.05
Healthcare Facility and Hospitals: Medical Supply Room	0.1	0.00	0.0	$0.00
Healthcare Facility and Hospitals: Nursery	0.1	0.04	2.6	$0.09
Healthcare Facility and Hospitals: Nurse's Station	0.0	(0.04)	(2.6)	($0.09)
Healthcare Facility and Hospitals: Operating Room	0.1	0.00	0.0	$0.00
Healthcare Facility and Hospitals: Patient Room	0.3	(0.14)	(8.9)	($0.31)
Healthcare Facility and Hospitals: Physical Therapy Room	0.2	0.06	3.6	$0.12
Healthcare Facility and Hospitals: Recovery Room	0.2	0.00	0.0	$0.00
Sports Arena – Playing Area: Class I Facility	0.1	0.00	0.0	$0.00
Sports Arena – Playing Area: Class II Facility	0.0	0.00	0.0	$0.00
Sports Arena – Playing Area: Class III Facility	0.0	0.00	0.0	$0.00
Sports Arena – Playing Area: Class IV Facility	0.0	0.00	0.0	$0.00
New Construction Statewide Totals per year	**162.7**	**24.95**	**2,018.7**	**$60.2**

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

Table 55: Statewide Energy and Energy Cost Impacts – One Year's Alterations

Primary Function Area	Statewide Alterations (Million ft^2/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	0.00	0.0	$0.0
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 (Million ft^2/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	17.2	2.00	110.6	$4.5
Office Area: ~~Open plan office~~ > 250 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	(1.64)	(90.4)	($3.7)
Theater Area: Motion picture	2.6	1.31	131.7	$3.3
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	(0.02)	(1.1)	$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 (Million ft^2/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 per year	**506.5**	**76.94**	**6,210.8**	**$185.7**

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 56: 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	($1.15)	Infinite
Auditorium Area	0.40	$1.00	$3.74	0.3
Auto Repair / Maintenance Area	0.00	$0.00	$0.00	NC
Barber, Beauty Salon and Spa Area	0.38	$0.86	$0.73	1.2
Civic Meeting Place Area	0.70	$1.77	$1.04	1.7
Classroom, Lecture, Training, Vocational Area	0.98	$2.29	($18.89)	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	($6.80)	Infinite
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)	($61.64)	EC up 20.43
Dining Area: Bar/Lounge and Fine Dining	0.34	$0.87	$1.17	0.7
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	($5.34)	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	$1.42	0.1
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	($2.29)	Infinite
Library: Stacks Area	0.13	$0.28	($2.52)	Infinite

Primary Function Area	NC Energy Savings (GWh/yr)	NC Energy Cost Savings (Million PV$)	NC Incremental Cost (Million $)	B/C ratio
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	($7.64)	Infinite
Office Area: > 250 square feet and ≤ xxx sf	0.67	$1.49	($11.16)	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)	$0.15	EC up 0.00
Pharmacy Area	0.03	$0.07	$0.11	0.6
Retail Sales Area: Grocery Sales	0.73	$1.67	($43.96)	Infinite
Retail Sales Area: Retail Merchandise Sales	2.19	$5.02	($34.53)	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	(0.53)	($1.19)	($33.90)	EC up 28.39
Theater Area: Motion picture	0.43	$1.09	($1.67)	Infinite
Theater Area: Performance	0.58	$1.47	($1.30)	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	(0.01)	($0.02)	($0.14)	EC up 8.41
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
Aging Eye/Low-vision: Multipurpose Room	0.01	$0.04	($0.07)	Infinite

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: 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	$0.00	EC up 2.03
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	$0.01	9.6
Healthcare Facility and Hospitals: Nurse's Station	(0.04)	($0.09)	$0.40	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)	$0.51	EC up 0.00
Healthcare Facility and Hospitals: Physical Therapy Room	0.06	$0.12	($0.20)	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	**24.95**	**$60.2**	**($290.8)**	**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 57: Statewide Energy and Energy Cost Impacts – First-Year New Construction, Alterations, and Additions

Construction Type	Annual Construction (Million ft^2/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	25.0	20.2	$60.2
Additions and Alterations	506.5	76.9	6.2	$185.7
STATEWIDE TOTALS	**669.2**	**101.9**	**26.4**	**$246.0**

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 58 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 24,496 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 58: First-Year Statewide GHG Emissions Impacts

Construction Type	Electricity Savings (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Ton CO2e)
New Construction	25.0	5,999
Additions and Alterations	76.9	18,497
STATEWIDE TOTAL	**101.9**	**24,496**

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.[27] 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 but has still included results in Table 59. Ultimately, the lower LPDs will result in a reduction of material use.

[27] 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 59: 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 Building Types in Table 140.6-BComplete Building Method and the primary function areas in Table 140.6-C Area Category Method have been re-ordered to simplify looking up the building types or applications. The result is most of the building types and 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.” Similarly, the primary application type “open plan office” is stricken as it has been merged with the rest of Office Area: > 250 ft^2

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.

The additional lighting power allowance in the Area Category Method has been significantly simplified, and designers provided greater flexibility by allocating this additional lighting power for lighting systems that are defined as “Display/Decorative.” Enforcement is simplified as well as Display/Decorative lighting systems are characterized primarily as being not general lighting.

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.

…

LIGHTING definitions:

Accent Lighting is ~~directional~~ display lighting designed to highlight or spotlight objects. It can be recessed, surface mounted, or mounted to a pendant, stem, or track.

Chandelier is a ceiling-mounted, close-to-ceiling, or suspended decorative luminaire that uses glass, crystal, ornamental metals, or other decorative material.

Decorative (Lighting/Luminaire) is indoor lighting or luminaires installed only for aesthetic purposes and that does not serve as display lighting, task lighting or general lighting.

Display Lighting is directional lighting that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance. Display lighting shall not include general lighting. Types of display lighting include:

Floor: supplementary lighting required to highlight features, such as merchandise on a clothing rack, sculpture or free-standing of artwork, which is not displayed against a wall.

Wall: supplementary lighting required to highlight features, such as merchandise on a shelf, or wall-mounted artwork, which is displayed on perimeter walls.

Window: lighting of objects such as merchandise, goods, and artifacts, in a show window, to be viewed from the outside of a space through a window.

Case: lighting of small art objects, artifacts, or valuable collections which involves customer inspection of very fine detail from outside of a glass enclosed display case.

Luminaire Aperture is the opening in the luminaire through which usable light exits.

Ornamental Lighting ~~for compliance with Part 6 is the following:~~

~~**Luminaires**~~ is luminaires installed outdoors 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 not providing general lighting or task lighting.~~

~~**Special Effects Lighting** is lighting installed to give off luminance instead of providing illuminance, which does not serve as general, task, or display lighting.~~

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.

~~**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.

…

~~**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.~~

~~**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 served by ~~not containing~~ ~~permanently installed~~ drivers, 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 with a luminaire aperture length longer than 18 inches, shall ~~be~~ have a luminaire aperture no wider than four inches. Qualifying luminaires with a luminaire aperture length of 18 inches or less shall ~~be~~ have a luminaire aperture 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.

…

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

…

E. In addition to the allowed indoor Lighting Power allotments for general lighting calculated according to Sections 140.6(c)3F, as applicable, the building may add additional lighting power allowances for wall display lighting, floor display lighting and task lighting, decorative ~~ornamental/special effects~~ lighting, and very valuable display cases lighting according to Section 140.6(c)3G through J.

…

I. Determine additional allowed power for decorative ~~ornamental/special effects~~ lighting as follows:

i. Qualifying decorative ~~ornamental~~ lighting includes luminaires such as chandeliers, sconces, lanterns, neon and cold cathode, light emitting diodes, theatrical projectors, moving lights and light color panels when any of those lights are used in a decorative manner that does not serve as display lighting or general lighting.

ii. Additional lighting power for decorative ~~ornamental/special effects~~ lighting shall be used only if allowed by Column 5 of TABLE 140.6-D.

iii. Additional lighting power for decorative ~~ornamental/special effects~~ lighting shall be used only in areas having decorative ~~ornamental/special effects~~ lighting. The square footage of the floor area shall be determined in accordance with Section 140.6(c)3C and D, and it shall not include floor areas not having decorative ~~ornamental/special effects~~ lighting.

iv. The additional allowed power for decorative ~~ornamental/special effects~~ lighting for each applicable area shall be the smaller of:

a. The product of the “allowed decorative ~~ornamental/special effects~~ lighting power” determined in accordance with Section 140.6(c)3~~K~~Iii, multiplied by the floor square footage determined in accordance with Section 140.6(c)3~~K~~Iiii; and

b. The Adjusted Indoor Lighting Power of allowed ornamental/special effects lighting.

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
Bank or Financial Institution Building	0.65
Grocery Store Building	~~0.95~~ 0.90
Gymnasium Building	~~0.65~~ 0.60
Healthcare Facility	0.90
Industrial/Manufacturing Facility Building	0.60
Library Building	0.70
Motion Picture Theater Building	~~0.70~~ 0.60
Museum Building	0.65
Office Building	~~0.65~~ 0.60
Parking Garage Building	0.13
Performing Arts Theater Building	~~0.80~~ 0.75
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
All other~~s~~ buildings	0.40

TABLE 140.6-C AREA CATEGORY METHOD - LIGHTING POWER DENSITY VALUES (WATTS/FT²)

Primary Function Area		Allowed Lighting Power Density for General Lighting (W/ft²)	Additional Lighting Power[1]: Qualified Lighting Systems	Additional Lighting Power[1]: Additional Allowance (W/ft², unless noted otherwise)
Audience Seating Area		~~0.60~~ 0.50	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Auditorium Area		0.70	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.45
			~~Accent, display and feature~~[3]	~~0.20~~
Auto Repair / Maintenance Area		0.55	Detailed Task Work[7]	0.20
Barber, Beauty Salon, Spa Area		~~0.80~~ 0.65	Detailed Task Work[7]	0.20
			~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Civic Meeting Place Area		~~1.00~~ 0.90	~~Ornamental~~ Display/Decorative	~~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~~ Display/Decorative	~~0.30~~ 0.25
Convention, Conference, Multipurpose and Meeting Area		~~0.85~~ 0.75	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Copy Room		0.50	-	-
Corridor Area		~~0.60~~ 0.40	~~Ornamental~~ Display/Decorative	0.25
Dining Area	Bar/Lounge and Fine Dining	~~0.55~~ 0.45	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.35
	Cafeteria/Fast Food	~~0.40~~ 0.45	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
	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	-	-

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)
Financial Transaction Area		~~0.80~~ 0.70	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Hotel Function Area		0.85	~~Ornamental~~ Display/Decorative	~~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~~ Display/Decorative	~~0.30~~ 0.25
	Stacks Area	~~1.10~~ 1.00	-	-
~~Main Entry~~ Lobby, Main Entry		~~0.85~~ 0.70	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Locker Room		0.45	-	-
Lounge, Breakroom, or Waiting Area		~~0.65~~ 0.55	~~Ornamental~~ Display/Decorative	~~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] Display/Decorative	~~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	Display/Decorative and 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~~	-	-

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)
	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~~
			Display/Decorative	~~0.15~~ 0.35
	Retail Merchandise Sales	~~1.00~~ 0.95	~~Accent, display and feature[3]~~	~~0.20~~
			Display/Decorative	~~0.15~~ 0.35
	Fitting Room	0.60	External Illuminated Mirror[5]	40 W/ea
			Internal Illuminated Mirror[5]	120 W/ea
Religious Worship Area		0.95	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Restrooms		0.65	~~Accent, display and feature[3]~~	~~0.20~~
			Display/ Decorative[4]	~~0.15~~ 0.35
Stairwell		~~0.5~~ 0.60	~~Accent, display and feature[3]~~	~~0.20~~
			Display/ Decorative[4]	~~0.15~~ 0.35
Storage, Commercial/Industrial ~~Storage~~	Warehouse	~~0.45~~ 0.40	-	-
	Shipping & Handling	0.60	-	-
Theater Area	Motion picture	~~0.60~~ 0.50	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
	Performance	~~1.00~~ 0.80		
Transportation Function	Baggage Area	0.40	-	-
	Ticketing Area	0.45	~~Accent, display and feature[3]~~ Display/Decorative	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	Display/Decorative[4]	~~0.15~~ 0.30
	Dining	0.80	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	Lounge/Waiting Area	~~0.75~~ 0.80	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	~~Main Entry~~ Lobby, Main Entry	0.85	~~Ornamental~~ Display/Decorative	0.30
			Transition Lighting OFF at night[12]	0.95
			Tunable white or dim-to-warm[10]	0.10
	Multipurpose Room	~~0.95~~ 0.85	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	Religious Worship Area	1.00	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	Restroom	~~0.80~~ 1.00	~~Accent, display and feature[3]~~ Display/Decorative	0.20
	Stairwell	0.80	Display/Decorative	0.30
Healthcare Facility and Hospitals	Exam/Treatment Room	1.15	-	-
	Imaging Room	~~1.00~~ 0.60	Display/Decorative	0.20
			Tunable white or dim-to-warm[10]	0.10
	Medical Supply Room	0.55	-	-

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)
	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	Display/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	-	-
All other		0.40	-	-

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~~ Decorative~~/ 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, Main Entry	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 60: 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	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**
//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	Display/Decorative	0.25	0	0.00
Auditorium Area	0.70	Ornamental	~~0.30~~	Accent, display and feature (Note 3)	0.20	0.70	Display/Decorative	0.45		
Auto Repair / Maintenance Area	0.55	Detailed Task Work (Note 7)	0.20	0	0.00	0.55	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	Display/Decorative	0.25
Civic Meeting Place Area	~~1.00~~	Ornamental	~~0.30~~	0	0.00	0.90	Display/Decorative	0.25	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 (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	Display/Decorative	0.25	0	0.00
Convention, Conference, Multipurpose and Meeting Area	~~0.85~~	Ornamental	~~0.30~~	0	0.00	0.75	Display/Decorative	0.25	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	Display/Decorative	0.25	0	0.00
Dining Area (Bar/Lounge and Fine Dining)	~~0.55~~	Ornamental	~~0.30~~	0	0.00	0.45	Display/Decorative	0.35	0	0.00
Dining Area (Cafeteria/Fast Food)	~~0.40~~	Ornamental	~~0.30~~	0	0.00	0.45	Display/Decorative	0.25	0	0.00

TABLE SpaceFunctionData	2019	2019	2019	2019	2019	2022	2022	2022	2022	2022
FuncType	IntLP DReg	AllowType1	Allow Area1	AllowTy pe2	Allow Area2	IntLP DReg	AllowType1	Allow Area1	AllowType2	Allow Area2
//SpaceBySpace	W/ft^2		W/ft^2		W/ft^2	W/ft^2		W/ft^2		W/ft^2
Dining Area (Family and Leisure)	~~0.50~~	Ornamental	~~0.30~~	0	0.00	0.40	Display/Decorative	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	Display/Decorative	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	Display/Decorative	0.20	Tunable while or dim-to-warm	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

TABLE SpaceFunctionData	2019	2019	2019	2019	2019	2022	2022	2022	2022	2022
FuncType	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**
//SpaceBySpace	**W/ft²**		**W/ft²**		**W/ft²**	**W/ft²**		**W/ft²**		**W/ft²**
Healthcare Facility and Hospitals (Patient Room)	~~0.55~~	Decorative	0.15	Tunable while or dim-to-warm (Note 10)	0.10	0.70	Display/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 (Note 10)	0.10	0	0.00	0.75	Tunable while or dim-to-warm (Note 10)	0.10	0	0.00
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	Display/Decorative	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	Display/Decorative	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	Display/Decorative	0.25	0	0.00
Main Entry Lobby	~~0.85~~	Ornamental	~~0.30~~	0	0.00	0.70	Display/Decorative	0.25	0	0.00
Museum Area (Exhibition/Display)	0.60	Accent, display and feature (Note 3)	~~0.50~~	0	0.00	0.60	Display/Decorative	0.45	0	0.00
Museum Area (Restoration Room)	~~0.75~~	Detailed Task Work (Note 7)	~~0.20~~	0	0.00	0.70	Detailed Task Work	0.35	0	0.00

TABLE SpaceFunctionData	2019	2019	2019	2019	2019	2022	2022	2022	2022	2022
FuncType	IntLP DReg	AllowType1	Allow Area1	AllowType2	Allow Area2	IntLP DReg	AllowType1	Allow Area1	AllowType2	Allow Area2
//SpaceBySpace	W/ft^2		W/ft^2		W/ft^2	W/ft^2		W/ft^2		W/ft^2
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	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	Display/Decorative and Portable lighting for office areas	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~~	~~0.10~~	~~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 (W/ea)	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

TABLE SpaceFunctionData	2019	2019	2019	2019	2019	2022	2022	2022	2022	2022
FuncType	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**
//SpaceBySpace	**W/ft²**		**W/ft²**		**W/ft²**	**W/ft²**		**W/ft²**		**W/ft²**
Retail Sales Area (Grocery Sales)	~~1.05~~	Accent, display and feature (Note 3)	0.20	Decorative	0.15	1.00	Display/Decorative	0.35		
Retail Sales Area (Retail Merchandise Sales)	~~1.00~~	Accent, display and feature (Note 3)	0.20	Decorative	0.15	0.95	Display/Decorative	0.35		
~~Scientific~~ Laboratory, Scientific 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	0.60	Display/Decorative	0.35		
Theater Area (Motion Picture)	~~0.60~~	Ornamental	~~0.30~~	0	0.00	0.50	Display/Decorative	0.25	0	0.00
Theater Area (Performance)	~~1.00~~	Ornamental	~~0.30~~	0	0.00	0.80	Display/Decorative	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	Display/Decorative	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

TABLE SpaceFunctionData	2019	2019	2019	2019	2019	2022	2022	2022	2022	2022
FuncType	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**	**IntLP DReg**	**AllowType1**	**Allow Area1**	**AllowType2**	**Allow Area2**
//SpaceBySpace	**W/ft^2**		**W/ft^2**		**W/ft^2**	**W/ft^2**		**W/ft^2**		**W/ft^2**
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	Display/Decorative	0.30	0	0.00
Aging Eye/Low-vision (Dining)	0.80	Ornamental	0.30	0	0.00	0.80	Display/Decorative	0.30	Tunable while or dim-to-warm	0.10
Aging Eye/Low-vision (Lounge/Waiting Area)	~~0.75~~	Ornamental	0.30	0	0.00	0.80	Display/Decorative	0.30	Tunable while or dim-to-warm	0.10
Aging Eye/Low-vision (Main Entry Lobby)	0.85	Ornamental	0.30	Transition Lighting OFF at night (Note 12)	0.95	0.85	Display/Decorative	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	Display/Decorative	0.30	Tunable while or dim-to-warm	0.10
Aging Eye/Low-vision (Religious Worship Area)	1.00	Ornamental	0.30	0	0.00	1.00	Display/Decorative	0.30	Tunable while or dim-to-warm	0.10
Aging Eye/Low-vision (Restroom)	~~0.80~~	Accent, display and feature (Note 3)	0.20	0	0.00	1.00	Display/Decorative	0.20	0	0.00
Aging Eye/Low-vision (Stairwell)	~~0.80~~	0	0.00	0	0.00	0.70	Display/Decorative	0.30	0	0.00
All other	0.40	0	0.00	0	0.00	0.40	0	0.00	0	0.00

3.6.5 Title 24 Nonresidential Compliance Manuals

Since the structure of the LPDs are essentially not changing, changes to the Nonresidential Compliance Manual would be relatively small. Proposed changes include:

- Given 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.
- Updated allowed LPDs should be used in the examples.
- Application examples of ways to use the newly combined “Display/Decorative” additional lighting power allowance. This will highlight the added flexibility to apply this to virtually all non-general lighting luminaires. Examples will be given also when they do not apply.
- How to apply the Color Tuning/Dim to Warm adjustment factor with a description of the equipment and documentation requirements. This would include an application example to show how this allowance could be applied to a design scenario in primary function areas with and without the additional lighting power allowance for Color Tuning/Dim to Warm lighting.
- The rationale for mounting height adjustment adder and how to use it in the Tailored Method. A number of designers did not understand why it is applied to the wattage of the lighting instead of as a credit for the entire space.
- A description of how the institutional PAF is used and several application examples. Several designers had indicated that they had certain projects that needed more light but none of these designers had used the Institutional Tuning PAF. Given that these designers were designing for maintained illuminance values, their designs would over-light the space when first installed and over years the light output would degrade to the maintained illuminance value. This initial period when light output is higher than maintained light output is an opportunity to save energy through institutional tuning, which the PAF recognizes and gives credit for. For systems that are dimmable and are controlled by central lighting control, there is no added equipment cost, only technical adjustment of high end trim during set-up (and an acceptance test to validate that high end trim has been set). Several worked examples in the compliance manual that highlight this opportunity to designers who are looking for additional lighting power and how this is conveyed to the electrical engineer could help raise awareness about this PAF that can be widely applied. Examples should be created for spaces most likely to benefit from the PAF including Bar Lounge and Fine Dining and Large Office Space.

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 and the broader qualification criteria for added lighting power allowances would change to correspond with the adopted changes in LPDs and additional lighting power in the Area Category method, Complete Building method, and Tailored method.

Bibliography

n.d. http://bees.archenergy.com/Documents/Software/CBECC-Com_2016.3.0_SP1_Prototypes.zip.

Acuity Brands, Inc. 2016. "Occupancy Sensor Technologies: Microphonics vs. Ultrasonic." *www.acuitybrands.com.* Accessed February 2020. https://www.acuitybrands.com/brands/lighting-controls/-/media/abl/acuitybrands/files/sensor-switch/occupancy-sensor-technologies-white-paper-pdf.pdf.

Association, National Energy Assistance Directors. 2011. "2011 National Energy Assistance Survey Final Report." Accessed February 2, 2017. http://www.appriseinc.org/reports/Final%20NEADA%202011%20Report.pdf.

Bernecker, Craig, Samuel Hewett, Paola Bernal Arguelles, Sudtida Benchahiransak, Selin Ergeneli, Ketryna Fares, Ariel Gonzalez, Fabienne Hierzer, Sergio Taveras, and Nura Venta Martinez. n.d. "Square Law Dimming: Presumed Perception or Reality?" *LEDucation.*

BW Research Partnership. 2016. *Advanced Energy Jobs in California: Results of the 2016 California Advanced Energy.* Advanced Energy Economy Institute.

California Air Resouces Board. 2019. "Global Warming Potentials." https://www.arb.ca.gov/cc/inventory/background/gwp.htm#transition.

California Department of Water Resources. 2016. "California Counties by Hydrologic Regions." Accessed April 3, 2016. http://www.water.ca.gov/landwateruse/images/maps/California-County.pdf.

California Energy Commisison. 2020. *Nonresidential Construction Forecasts.* https://www.energy.ca.gov/title24/participation.html.

California Energy Commission. 2015. *2016 Building Energy Efficiency Standards: Frequently Asked Questions.* http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/2016_Building_Energy_Efficiency_Standards_FAQ.pdf.

—. 2020. *2020 Workshops and Meetings.* https://ww2.energy.ca.gov/title24/2022standards/prerulemaking/documents/.

—. 2022. "Energy Code Data for Measure Proposals." *energy.ca.gov.* https://www.energy.ca.gov/title24/documents/2022_Energy_Code_Data_for_Measure_Proposals.xlsx.

—. 2019. "Housing and Commercial Construction Data - Excel." https://ww2.energy.ca.gov/title24/documents/2022_Energy_Code_Data_for_Measure_Proposals.xlsx.

—. 2018. "Impact Analysis: 2019 Update to the California Energy Efficiency Standards for Residential and Non-Residential Buildings." *energy.ca.gov.* June 29. https://www.energy.ca.gov/title24/2019standards/post_adoption/documents/2019_Impact_Analysis_Final_Report_2018-06-29.pdf.

California Public Utilities Commission (CPUC). 2015b. "Water/Energy Cost-Effectiveness Analysis: Revised Final Report." Prepared by Navigant Consulting, Inc. http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5360.

California Public Utilities Commission. 2015a. "Water/Energy Cost-Effectiveness Analysis: Errata to the Revised Final Report." Prepared by Navigant Consulting, Inc. . http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5350.

Energy + Environmental Economics. 2016. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2019 Time Dependent Valuation (TDV) Data Sources and Inputs." Prepared for the California Energy Commission. July. http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf.

Energy + Environmental Economics. 2020. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2022 Time Dependent Valuation (TDV) and Source Energy Metric Data Sources and Inputs."

Ettenson, Lara , and Christa Heavey. 2015. *California's Golden Energy Efficiency Opportunity: Ramping Up Success to Save Billions and Meet Climate Goals.* Natural Resources Defense Council & Environmental Entrepreneurs (E2).

Federal Reserve Economic Data. n.d. https://fred.stlouisfed.org .

Goldman, Charles, Merrian C. Fuller, Elizabeth Stuart, Jane S Peters, Marjorie McRay, Nathaniel Albers, Susan Lutzenhiser, and Mersiha Spahic. 2010. *Energy Efficiency Services Sector: Workforce Size and Expectations for Growth.* Lawrence Berkeley National Laboratory.

Heschong, Lisa, and Jon McHugh. 2000. "Skylights: Calculating Illumination Levels and Energy Impacts." *Journal of the Illuminating Engineering Society.*

Illuminating Engineering Society . 2012. "American National Standard Practice for Office Lighting." ANSI/IES RP-1-12, New York.

Illuminating Engineering Society. 2013. "American National Standard Practice on Lighting for Educational Facilities." ANSI/IES RP-3-13.

Illuminating Engineering Society. 2017. "Design Guide for Hospitality Lighting." IES DG-25-17, New York.

Illuminating Engineering Society. 2017. "Guide for Security Lighting for People, Property, and Critical Infrastructure." IES G-1-16.

Illuminating Engineering Society. 2016. "Lighting and the Visual Environment for Seniors and the Low Vision Population." ANSI/IES RP-28-16 .

Illuminating Engineering Society. 2017. "Lighting for Hospitals and Healthcare Facilities." ANSI/IES RP-29-16.

Illuminating Engineering Society. 2013. "Recommended Practice for Library Lighting." IES RP-4-13.

Illuminating Engineering Society. 2017. "Recommended Practice for Lighting Industrial Facilities." ANSI/IES RP-7-17.

Illuminating Engineering Society. 2015. "Recommended Practice for Lighting Maintenance." IES RP-36-15.

Illuminating Engineering Society. 2017. "Recommended Practice for Museum Lighting." ANSI/IES RP-30-17 .

Illuminating Engineering Society. 2018. "Recommended Practice for Retail Lighting." IES RP-2-17.

Illuminating Engineering Society. 2015. "Sports and Recreational Area Lighting." IES RP-6-15.

Illuminating Engineering Society. 2011. "The Lighting Handbook, 10th Edition."

Kenney, Michael, Heather Bird, and Heriberto Rosales. 2019. *2019 California Energy Efficiency Action Plan.* Publication Number: CEC- 400-2019-010-CMF , California Energy Commission. Kenney, Michael, Heather Bird, and Heriberto Rosales. 2019. 2019 California Energy Efficiency Action Plan. California Energy Commission. Publication Number: CEC- 400-2019-010-CMF .

Leviton. 2019. "Deciphering 2018 IECC-- Occupancy Sensors and Open Office Requirements." *Leviton Blog.* June 20. Accessed February 2020. https://blog.leviton.com/deciphering-2018-iecc%E2%80%94occupancy-sensors-and-open-office-requirements.

Lim, Seong-Rin, Daniel Kang, Ogunseitan A Oladele, and Julie M Shoenung. 2013. "Potential Environmental Impacts from the Metals in Incandescent, Compact Fluorescent Lamp (CFL), and Light-Emitting Diode (LED) Bulbs." (Environmental Science & Technology).

Lutron. 2020. "Vive Solutions IECC 2018: Commercial Application Guide." *Lutron.com.* January. Accessed February 2020. http://www.lutron.com/TechnicalDocumentLibrary/3672756_IECC_2018_Application_Guide.pdf.

National Energy Assistance Directors' Association. 2011. *2011 National Energy Assistance Survey Final Report.* http://www.appriseinc.org/reports/Final%20NEADA%202011%20Report.pdf.

NLPIP. 2015. "Comparison of Wired and Wireless Lighting Controls for Single Rooms." *LRC.rpi.edu.* July. Accessed February 2020. https://www.lrc.rpi.edu/programs/nlpip/lightingAnswers/wirelessControls/abstract.asp.

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

2020. *PG&E Time of Use Rates.* Accessed February 2020. https://www.pge.com/en_US/small-medium-business/your-account/rates-and-rate-options/time-of-use-rates.page.

R. Athalye, R. Hart. 2015. "Cost-effectiveness Analysis of Expanding use of Occupancy Sensors." *2018 IECC commercial code.* Pacific Northwest National Laboratory. September. Accessed 2020. https://www.energycodes.gov/sites/default/files/documents/iecc2018_C-6_analysis_final.pdf.

Sagehorn, Michele. 2020. "What No One Tells You About HVAC & Lighting Integration." *Redcar Analytics.* April 8. Accessed May 2020. http://www.redcaranalytics.com/2020/04/08/what-no-one-tells-you-about-hvac-lighting-integration/.

1998. *Specifier Reports: Occupancy Sensors.* Lighting Research Center, RPI (Rensselaer Polytechnic Institute), National Lighting Product Information Program. https://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SROS2.pdf.

Staff Recommendations for the 2022 Energy Code Acceptance Test Technicial Certification Provider Program. 2022. 19-BSTD-03 (California Energy Commission, August 13).

State of California, Employment Development Department. n.d. https://www.labormarketinfo.edd.ca.gov/cgi/dataanalysis/areaselection.asp?tablename=industry .

Statewide CASE Team. 2019a. "Lighting Part 2 - Nonresidential Indoor Lighting Meeting Notes." *title24stakeholders.com.* September. Accessed February 21, 2020. https://title24stakeholders.com/wp-content/uploads/2019/08/T24-Lighting-part-2-Meeting-Notes-.pdf.

Statewide CASE Team. 2011. *Measure Information Template - Indoor Lighting Controls.* Codes and Standards Enhancement Initiative.

Statewide CASE Team. 2017. "Nonresidential Indoor Lighting Alterations – Final Report."

—. 2019. "Nonresidential Indoor Lighting Submeasure Summaries." *title24stakeholders.com.* September. Accessed 2020. https://title24stakeholders.com/wp-content/uploads/2019/08/T24-2022-Stakeholder_Meeting_NR_Indoor_Lighting_Submeasure_Summaries.pdf.

—. 2020. "Presentation - March 3 - Lighting Utility-Sponsored Stakeholder Meeting." *title24stakeholders.com.* March 3. Accessed 2020. https://title24stakeholders.com/event/lighting-utility-sponsored-stakeholder-meeting-2/.

—. 2019b. "Presentation - Sept 12 - Nonresidential Indoor Lighting Utility-Sponsored Stakeholder Meeting." *title24stakeholders.com.* September. Accessed February 21, 2020. https://title24stakeholders.com/wp-content/uploads/2019/08/2022-Stakeholder-Meeting_Indoor-Lighting_Master.pdf.

—. 2017. "Proposals Based on ASHRAE 90.1." *Title24Stakeholders.com.* August. Accessed 2020. The estimate assumes an HVAC controls contractor’s labor for programming and variable mapping at 0.5 hour per control zone along with additional costs required for commissioning the controls. This estimate assumes no additional wires are required and the .

—. 2020. "Submeasure Summary - Nonresidential Multi-zone Occupancy Sensing in Large Offices." *title24stakeholders.com.* March 3. Accessed 2020. https://title24stakeholders.com/wp-content/uploads/2020/01/2022_T24_Submeasure-Summary_Update-LPDs_20200303-1.pdf.

—. 2020. "Submeasure Summary - Nonresidential Update LPDs." *title24stakeholders.com.* March 03. Accessed 2020. https://title24stakeholders.com/event/lighting-utility-sponsored-stakeholder-meeting-2/.

Stone, Nehemiah, Jerry Nickelsburg, and William Yu. 2015. *Codes and Standards White Paper: Report - New Home Cost v. Price Study.* Pacific Gas and Electric Company. Accessed February 2, 2017.

http://docketpublic.energy.ca.gov/PublicDocuments/Migration-12-22-2015/Non-Regulatory/15-BSTD-01/TN%2075594%20April%202015%20Codes%20and%20Standards%20White%20Paper%20-%20Report%20-%20New%20Home%20Cost%20v%20Price%20Study.pdf.

Thornberg, Christopher, Hoyu Chong, and Adam Fowler. 2016. *California Green Innovation Index - 8th Edition.* Next 10.

U.S. Census Bureau, Population Division. 2014. "Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014." http://factfinder2.census.gov/bkmk/table/1.0/en/PEP/2014/PEPANNRES/0400000US06.05000.

U.S. EPA (United States Environmental Protection Agency). 2011. "Emission Factors for Greenhouse Gas Inventories." Accessed December 2, 2013. http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

United States Environmental Protection Agency. 1995. "AP 42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources." https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors#5thed.

United States Environmental Protection Agency. 2018. "Emissions & Generation Resource Integrated Database (eGRID) 2016." https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

Zabin, Carol, and Karen Chapple. 2011. *California Workforce Education & Training Needs Assessment: For Energy Efficiency, Distributed Generation, and Demand Reponse.* University of California, Berkeley Donald Vial Center on Employment in the Green Economomy. Accessed February 3, 2017. http://laborcenter.berkeley.edu/pdf/2011/WET_Appendices_ALL.pdf.

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 61. 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 62. 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 61. 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 63 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

A.1. 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 64 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. 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 64.

A.2. Lighting Power Densities

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 68 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 67 presents percentage of floorspace assumed to be impacted by the proposed change by climate zone.

Table 61: Estimated New Nonresidential Construction Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	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 62: Estimated Existing Nonresidential Floorspace Impacted by Proposed Code Change in 2023 (Alterations), by Climate Zone and Building Type (Million Square Feet)

Climate Zone	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 63: 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 64: 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%	0.48%
Restaurant	N/A	0%	0%
Retail	N/A	3.55%	0.05%
Stand-Alone Retail	10%	0%	0%
Large Retail	75%	4.18%	0.06%
Strip Mall	5%	0%	0%
Mixed-Use Retail	10%	4.14%	0.06%
Food	N/A	0%	0%
Non-Refrigerated Warehouse	N/A	3.47%	0.05%
Refrigerated Warehouse	N/A	2.54%	0.03%
Schools	N/A	5.45%	0.07%
Primary School	60%	5.61%	0.07%
Secondary School	40%	5.20%	0.07%
College	N/A	4.43%	0.06%
Community College	5%	4.88%	0.07%
University	15%	3.98%	0.05%
Hospital	N/A	2.73%	0.04%
Hotel/Motel	N/A	0%	0%
Offices	N/A	46.02%	0.61%
Medium Office	50%	46.02%	0.61%
Large Office	50%	46.02%	0.61%

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 65: 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%	0.20%
2	14.31%	0.20%
3	15.57%	0.21%
4	15.74%	0.22%
5	14.85%	0.21%
6	15.96%	0.20%
7	14.45%	0.20%
8	16.27%	0.20%
9	17.59%	0.22%
10	10.17%	0.13%
11	10.58%	0.14%
12	14.20%	0.19%
13	9.83%	0.13%
14	12.03%	0.15%
15	9.65%	0.13%
16	11.12%	0.14%

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

Table 66: Percent of Floorspace Impacted by Proposed Measure, by Building Type: Lighting Power Densities

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	100%	7%
Restaurant	N/A	100%	7%
Retail	N/A	100%	7%
Stand-Alone Retail	10%	100%	7%
Large Retail	75%	100%	7%
Strip Mall	5%	100%	7%
Mixed-Use Retail	10%	100%	7%
Food	N/A	100%	7%
Non-Refrigerated Warehouse	N/A	100%	7%
Refrigerated Warehouse	N/A	100%	7%
Schools	N/A	100%	7%
Primary School	60%	100%	7%
Secondary School	40%	100%	7%
College	N/A	100%	7%
Community College	5%	100%	7%
University	15%	100%	7%
Hospital	N/A	100%	7%
Hotel/Motel	N/A	100%	7%
Offices	N/A	100%	7%
Medium Office	50%	100%	7%
Large Office	50%	100%	7%

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 67: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone: Lighting Power Densities

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

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

C.1. Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric tons CO2e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tons/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide) and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low Nox burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons per MMTherms.

C.2. GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – $106.20 per metric ton CO_2e.

C.3. 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

D.1. 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.

D.2. 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.

D.3. Description of Software Change

D.3.1. 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.

D.3.2. 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.

D.3.3. 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 control 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. CBECC-Com would need to reflect the updated PAF values to accurately calculate the appropriate compliance credit.
2. Table N4 in the CBECC-Com option for the compliance document NRCC-PRF-01-E should be updated to reflect the mandatory controls requirements of the proposed code change.
3. 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 .
4. 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*.

D.4. 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

D.5. Simulation Engine Inputs

D.5.1. 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.

D.5.2. 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.

D.6. Simulation Engine Output Variables

The proposed code change would not alter simulation engine output variables.

D.7. Compliance Report

The proposed code change would not alter the compliance report.

D.8. 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, NRCA-MCH-19-A, 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.

D.9. Testing and Confirming CBECC-Com Modeling

The proposed code change would not alter any inputs or assumptions for testing and confirming CBECC-Com modeling.

D.10. 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 software revisions associated with the proposed code changes would involve updating the PAFs for the appropriate zone sizes, updated PAF values, updating the language to refer to “office spaces greater than 250 square feet,” and ensuring Table N4 in the CBECC-Com option for the compliance document NRCC-PRF-01-E is updated to reflect the mandatory controls requirements.

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 60 in Section 3.6.4 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.

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 68 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 68 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.

E.1. Multi-zone Occupancy Sensing in Large Offices

As shown in Table 101 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). Stakeholders also highlighted the importance of aligning lighting and HVAC zones as much as possible, which may not have previously been considered during design phases. 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.

E.1.1. 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.

Table 68: 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 commissioning agent or Acceptance Test Technician (ATT) as necessary.	• 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.

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
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.

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
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 Final 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.

F.1. 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.

F.2. 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.

F.2.1. 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 conducted a third round of outreach with lighting representatives and manufacturers to verify reasonable assumptions were made in incremental first cost design methodology and actual cost estimates, which in turn affect cost effectiveness. Detailed results and data are included in Section F.4.1, and the summary of the cost effectiveness verification effort can be found in Section 2.4.5.1. The cost effectiveness verification estimates support the Statewide CASE Team's original cost effectiveness analysis by showing that a variety of equipment and control strategies can be used to comply with the proposed code change and still be cost effective. The third round of outreach informed essential cost estimate updates to which types of labor were included, labor rates themselves, and equipment cost assumptions. The third round of outreach also provided crucial feedback on proposed code language changes and critical barriers, which in turn spurred further research to improve the integrity and accuracy of the Final CASE Report.

F.2.2. 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 conglomerate manufacturers 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 conglomerate manufacturers 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 Final 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.

F.3. Other Outreach Mechanisms

F.3.1. 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.

F.3.2. Additional Meetings with International Association of Lighting Designers (IALD) & Illuminating Engineering Society (IES)

The Statewide CASE Team met with representatives from IALD and IES again on July 22, 2020 but the focus of this meeting was not to discuss the Indoor Lighting CASE Report. However, the Statewide CASE Team was able to append the meeting with a brief discussion of the indoor lighting proposals. While the conversation was brief and the stakeholders had not much time to review the indoor lighting proposal, they had a general concern about dropping LPDs as the 2019 updates had resulted in less lighting power leeway than in the past. After this meeting, the Statewide CASE Team followed up with all of the lighting designers on this call to further discuss their questions and concerns. These one on one discussions resulted in the Statewide CASE Team performing additional analysis to modify several lighting power densities. The Statewide CASE Team will validate this analysis with more detailed scenarios using the AGi32 radiosity lighting simulation tool as described in *Section 3.2.2.*

F.3.3. 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.

F.4. Cost Effectiveness Verification for Multi-Zone Occupancy Sensing in Large Offices

F.4.1. 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.

Table 69: 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 70: 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 71: 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

The labor estimate originally included neither additional commissioning and ATT nor design labor hours. The Statewide CASE Team additionally calculated a B/C ratio while incorporating any missing information, such as maintenance costs and additional incremental labor costs. The following tables describe the additional calculations.

The incremental additional labor costs were calculated by taking the weighted average incremental additional labor hours per labor category per model office and then multiplying that hours per square foot estimate by the labor rate for each labor category.

Table 72: Additional Incremental First Measure Costs for Sensitivity Analysis

Large Office Square Footage (ft^2)	Raw Data Incremental Cost ($\$/ft^2$)	Maintenance Cost ($\$/ft^2$)	Design Labor Incremental Cost ($\$/ft^2$)	Commissioning and ATT Labor Incremental Cost ($\$/ft^2$)	Total Incremental Cost ($\$/ft^2$)
Model Office A (2,584)	$0.82	$0.01082	$0.35	$0.23	$1.41
Model Office B (4,000)	$0.63	$0.01136	$0.39	$0.29	$1.31
Model Office C (7,540)	$0.65	$0.01113	$0.20	$0.28	$1.14

F.4.1.1. 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 73: 2022 Projected Costs Representing About 50 Percent Wired Solution Market Preference

Large Office Square Footage (ft2)	Total Cost per Square Foot ($/ft2)	Average Total Product Cost ($)	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 74: 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 75: 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%**

F.4.1.2. 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 76: 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 77: 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 78: 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 79: 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 80: 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 81: 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 82: 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 83: 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 84: 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 85: 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**

Table 86: Additional Incremental First Measure Costs for Sensitivity Analysis

Model Office Layout	Raw Data Incremental Equipment and Programming Cost ($/ft^2)	Maintenance Cost ($/ft^2)	Labor Incremental Cost ($/ft^2)	Total Incremental Cost ($/ft^2)
Model Office A (2,584)	$0.06	$0.01082	$1.55	$1.62
Model Office B (4,000)	$0.34	$0.01136	$1.72	$2.08
Model Office C (7,540)	$0.41	$0.01113	$1.70	$2.12

Appendix G: Multi-zone Occupancy Sensing in Large Office Outreach Survey Scripts and Results

G.1. 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:

G.1.1. 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?

G.1.2. 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?

G.1.3. 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?

G.1.4. Manufacturers

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?

G.2. Additional Surveys and Results for Multi-Zone Occupancy in Large Offices

G.2.1. 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.

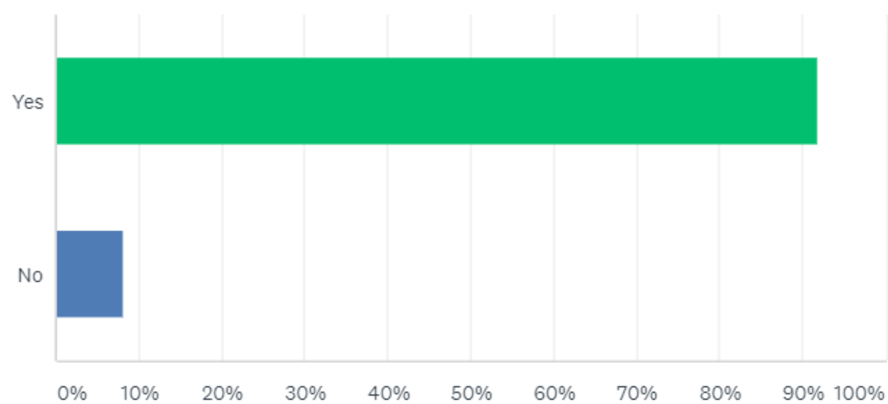


Figure 4: Results from question one in the pre-draft ATT survey.

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."

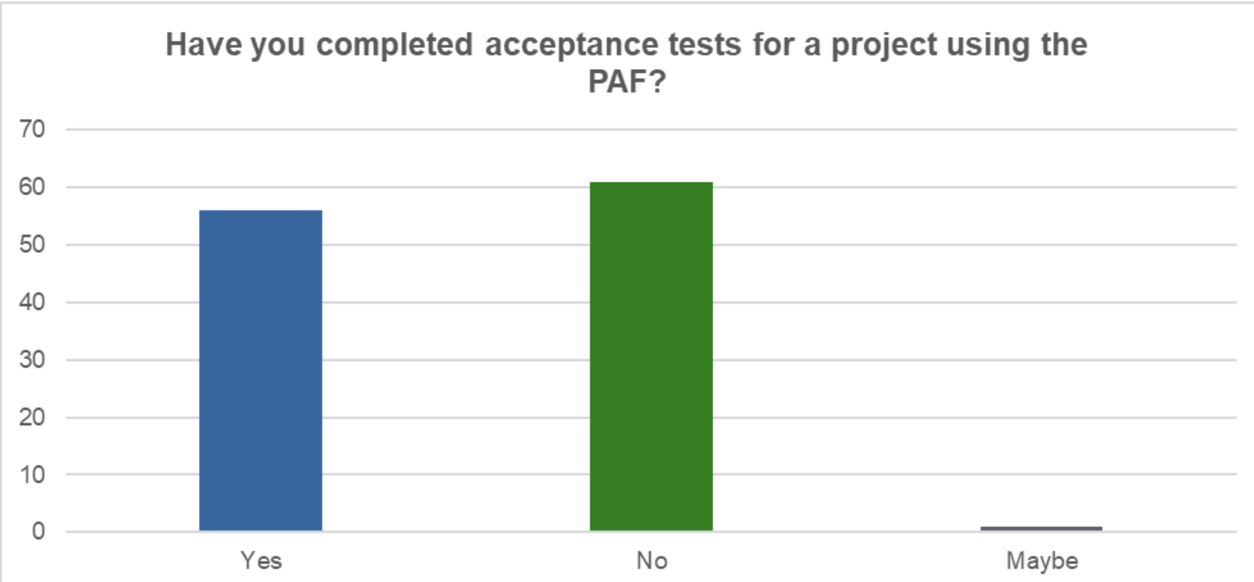


Figure 5: Results from question two in the pre-draft ATT survey.

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."

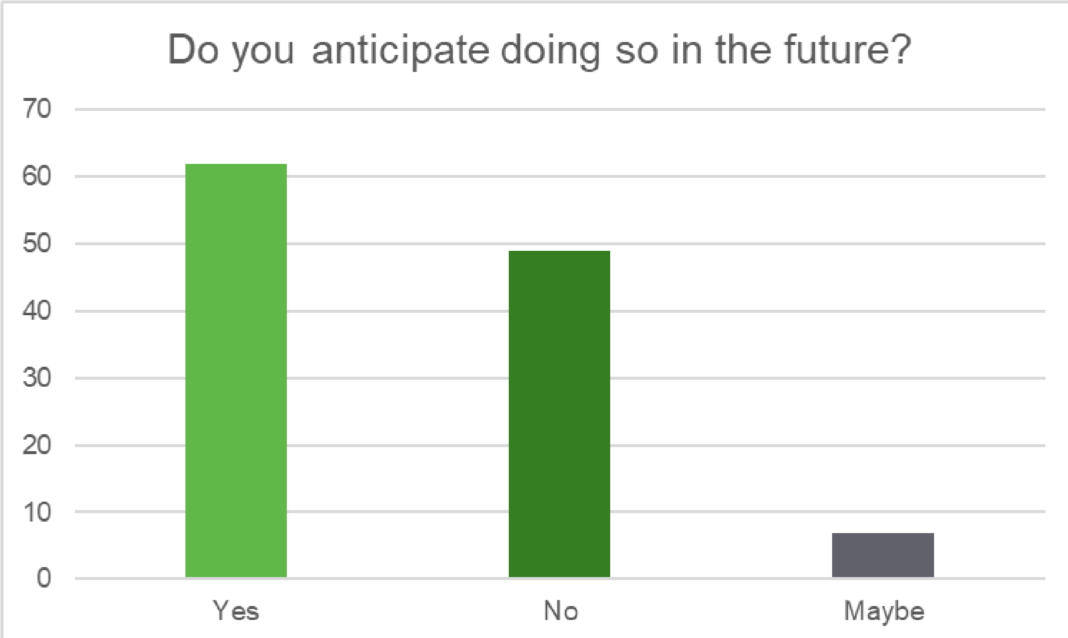


Figure 6: Results from question three in the pre-draft ATT survey.

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.”

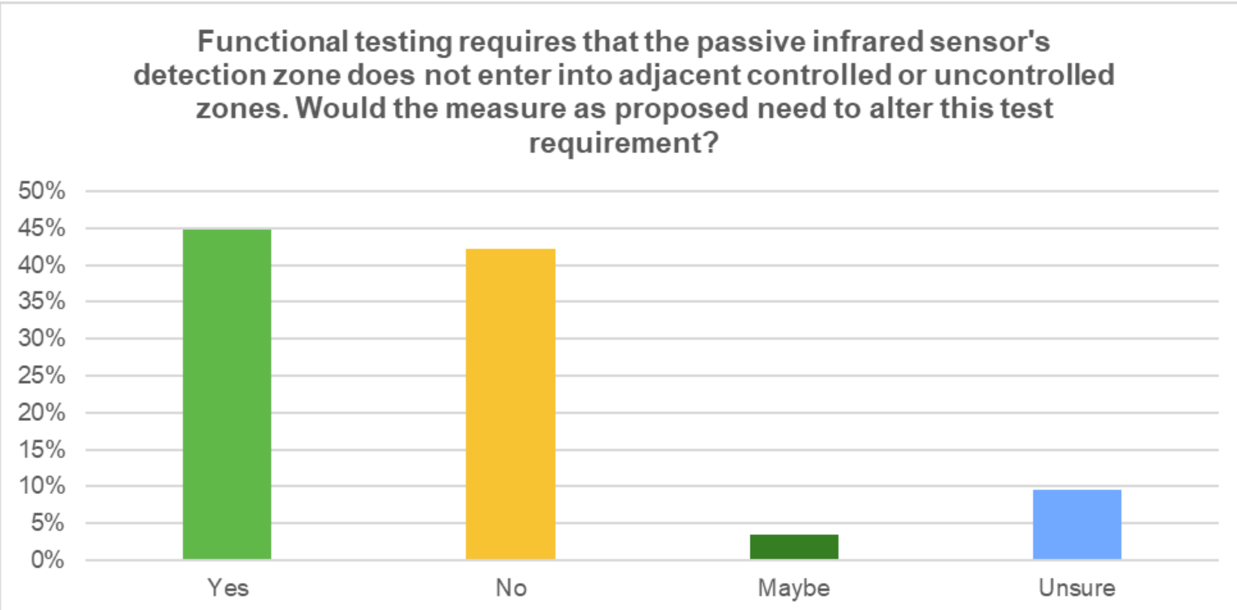


Figure 7: Results from question four in the pre-draft ATT survey.

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).

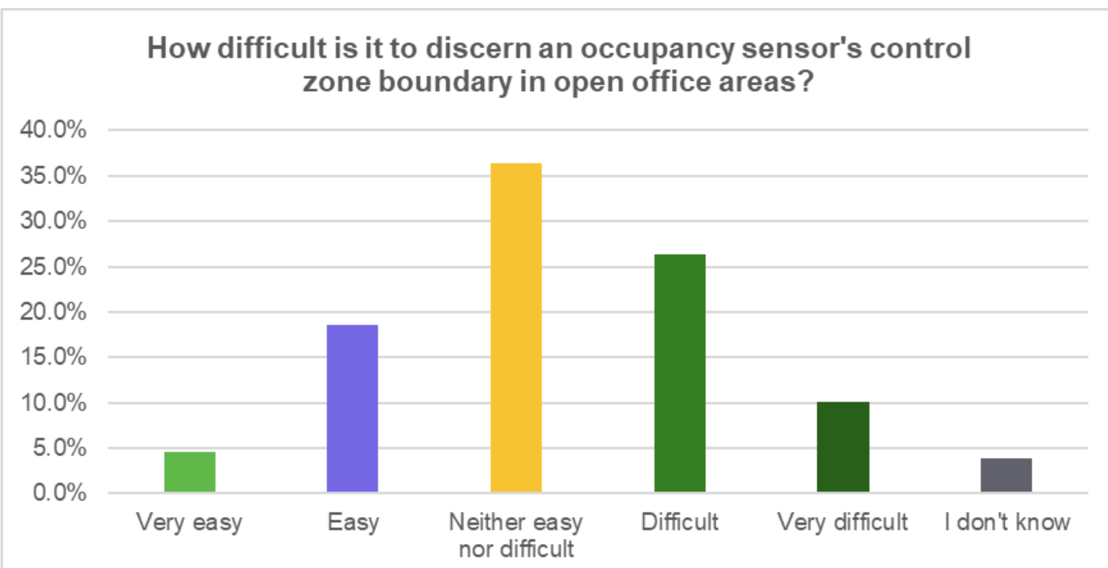


Figure 8: Results from question five in the pre-draft ATT survey, as a bar chart.

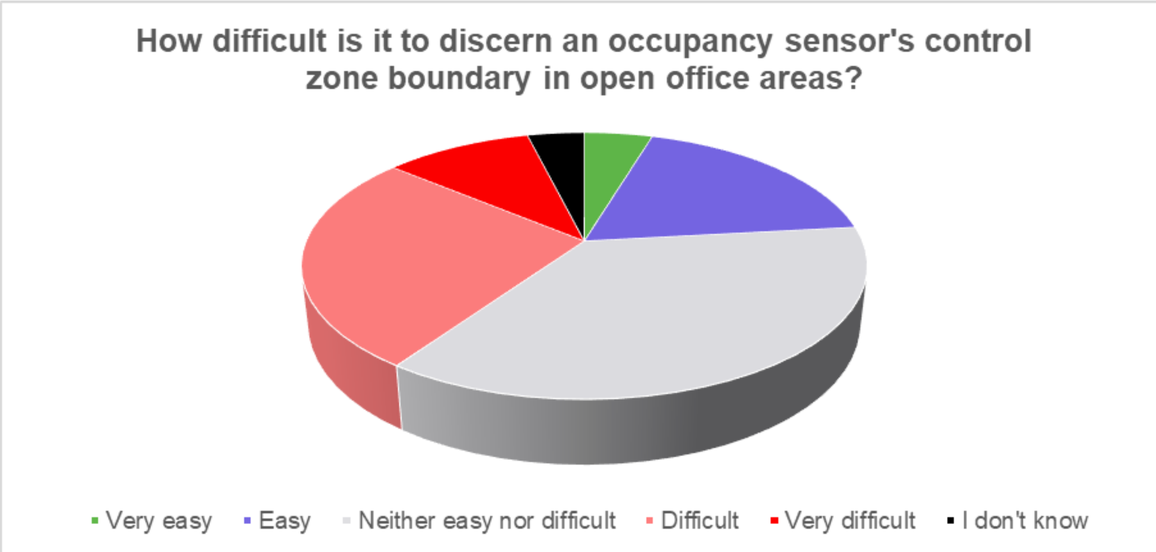


Figure 9: Results from question five in the pre-draft ATT survey, as a pie chart.

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 87 summarizes the recommended documents, in order of prevalence in the responses. Note: respondents could specify more than one type of document.

Table 87: 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 88.

Table 88: 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

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 G.2.1, 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.

G.2.2. Multi-Zone Occupancy Sensing Perception and Use Survey Data

This survey was distributed during August, 2020 via the CEA to gather data on the perception and use of multi-zone occupancy sensing from the perspective of lighting designers and building operators. 46 responses were received, 10 of which needed to be discounted because they were incomplete. The final results for the survey had a sample size of N = 36. Of the survey respondents, 21 were lighting designers, 1 was a building operator, and 14 identified as "none of the above." While there was an option to specify the respondent's role in the industry, none of the 14 respondents did so. Unfortunately, there is no further information to characterize these individuals' responses. The Statewide CASE Team can note that those who responded "none of the above" often aligned with the responses of the lighting designers in terms of general questions about overall impression, implementation issues, amenity issues, and benefits of the proposed code change. However, there is no way to know exactly which industry role these "none of the above" survey respondents represent. Where relevant, the Statewide CASE Team shares the lighting designer specific data.

Background Information

The survey results showed the sample size as 36, with 21 being lighting designers, 1 being a building operator, and 14 being "none of the above." The following figures share more background information from the survey respondents.

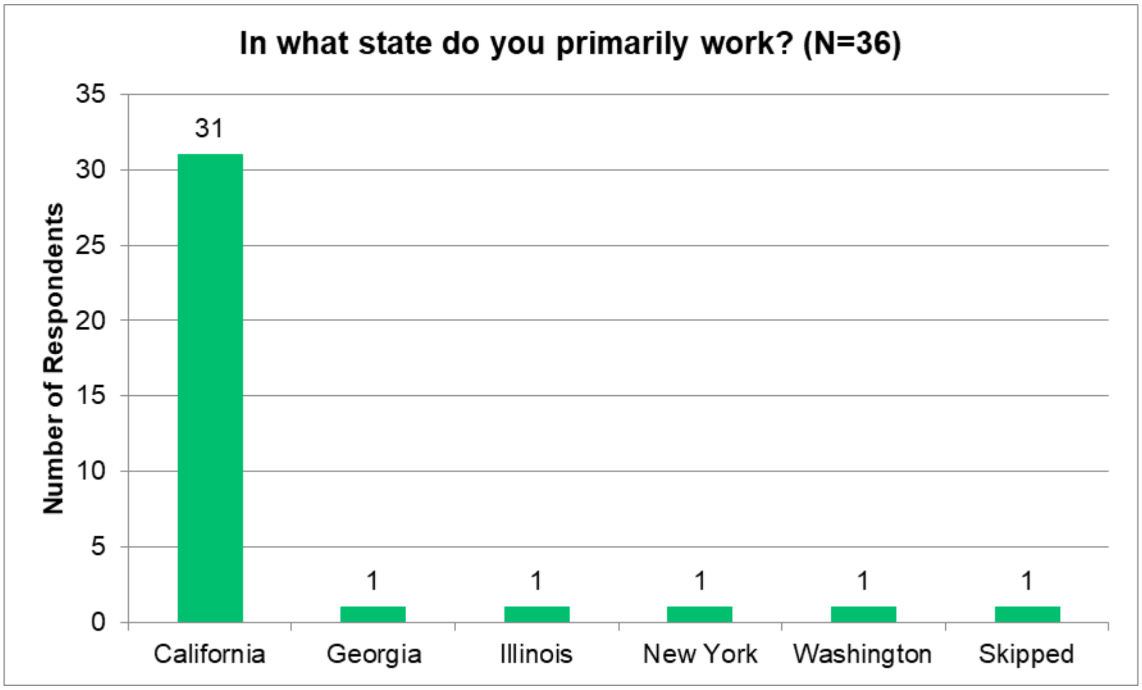


Figure 10: Location of work of survey respondents.

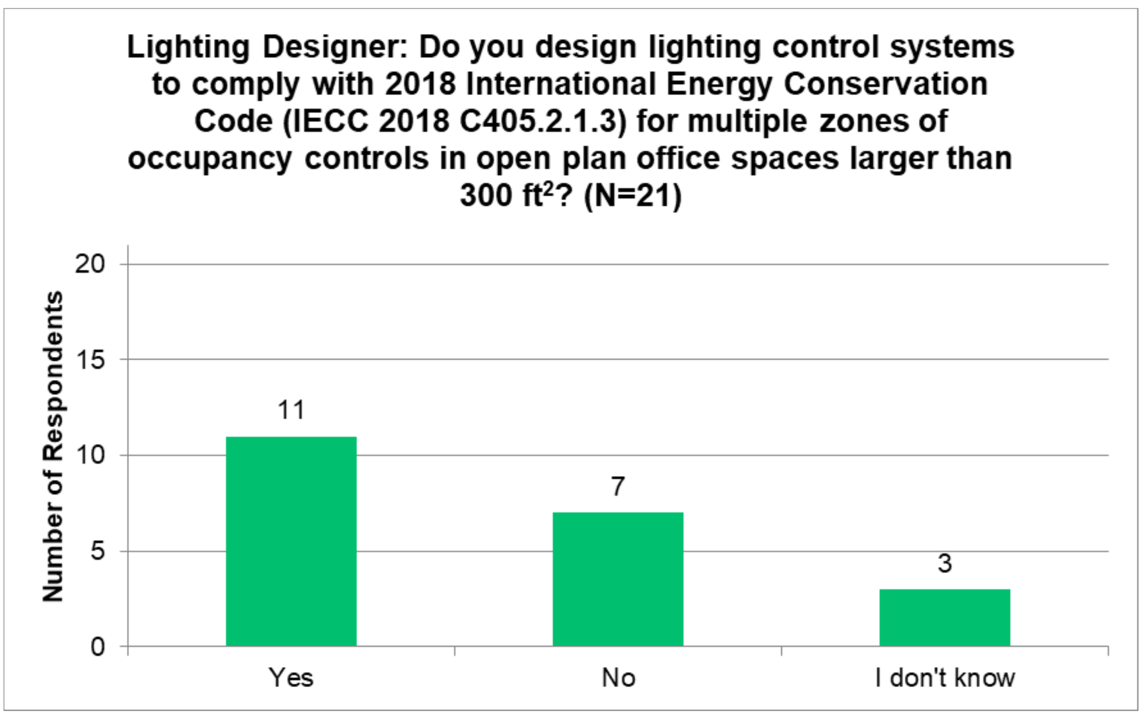


Figure 11: Lighting designers' percent designing lighting control systems in compliance with the 2018 IECC.

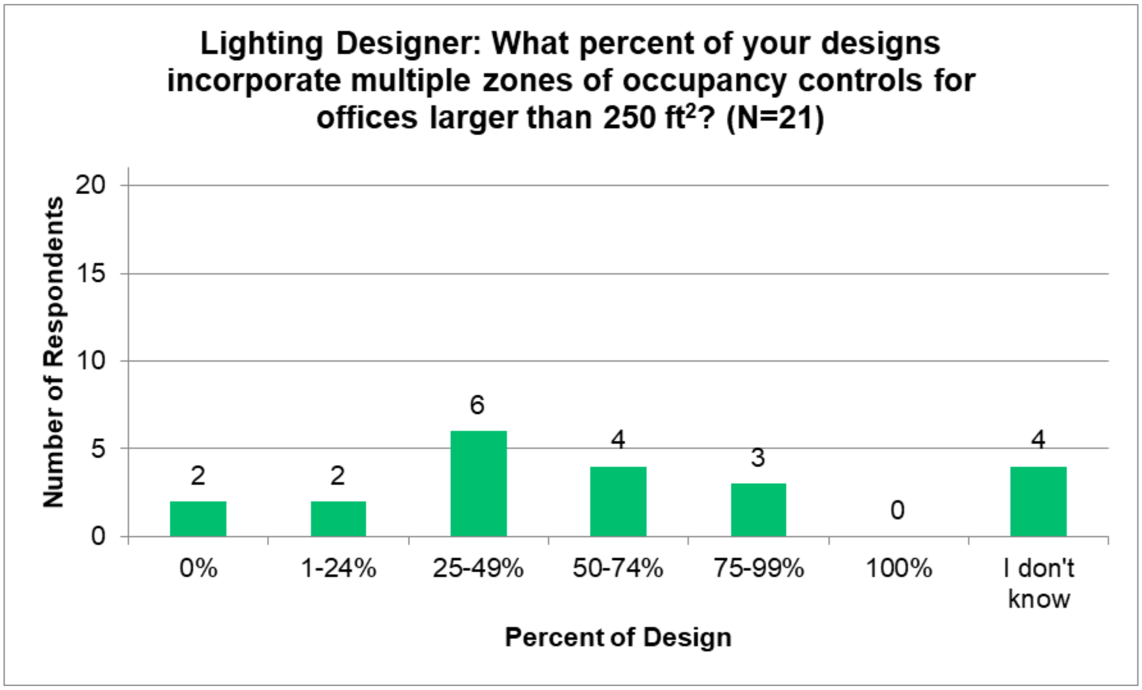


Figure 12: Percent of lighting designers whose designs incorporate multiple zones of occupancy controls.

Table 89: Lighting Designers' Responses to "What type of occupancy controls do you normally implement office spaces larger than 250 ft^2?"

Answer Choices	Responses	Percent of Response
On/Off	2	10%
Partial off (dim between 100 and 20%)	7	33%
Partial off (dim to 20% or lower)	4	19%
Both	6	29%
Other (please specify)	2	10%

Overall Impression: What is your overall impression of multi-zone occupancy sensing in office spaces larger than 250 ft^2?

For the lighting designers, 21 responses were recorded.

Table 90: Lighting Designer Overall Impression Survey Results

Answer Choices	Responses	Percent of Lighting Designers	Overall Response Percentage
Useful and/or Appropriate	9	43%	24%
Unnecessary and/or inappropriate	7	33%	19%
Other (please specify)	5	24%	14%

Below are direct quotes from the survey participants who responded “Other” to this question:

- “If dims rest of office, I think OK. Would not like it if it turned OFF the rest of the office, leaving a small 600sf area on if I was the only one working in the office at the time.”
- “I think that most people would not want to sit in a bright section of a dark space. Perhaps if the sensors could be programmed to dim but not to completely turn off the other lights in a large space it would be all right, but I hope they aren't required to completely turn them off because that would be uncomfortable. What about daylighting zones?”
- “I think it makes sense trying to have more localized occupancy control but the more sensors and equipment, the more complex the system, the greater chance of issues and the greater occupant frustration.”
- “Yes it is appropriate to dim during normal office hours. You cannot turn off areas immediately surrounding an area, the occupants at the edge of a zone will get eye strain, fatigue or migraine headaches. System needs to be capable of dimming to the needs of the individuals. That is not say that every occupant gets to choose the lower light level. You set the lower light level but you will find that some individuals cannot tolerate the contrast. Where the person sits in relation to daylight dimming will also dictate how low a light level they can tolerate. Having said that my experience is by making smaller zones and dimming when unoccupied the energy savings are amazing.”
- “Really unnecessary, but I wanted to explain. Today's LED products are so low wattage, that any occupancy sensors are often not cost effective saving energy, and mandating them can cause lighting retrofit projects not to happen because overall payback is too bad.”

Analyzing the “other” responses shows that four out of the five are most close to “useful and/or appropriate” with one response being closer to “unnecessary and/or inappropriate.”

Only one building operator responded to the survey. Their response to this question was “Useful if occupancy is verified to function as designed by Skilled Trained Labor.” This response highlights the need for sufficient education and training to enable proper functioning of installed systems.

Table 91 shows responses for the “other survey respondents,” those who neither identified as a lighting designer nor a building operator.

Table 91: Other Overall Impression Survey Results

Answer Choices	Responses	Percent of Other Survey Respondents	Overall Response Percentage
Useful and/or Appropriate	10	48%	27%
Unnecessary and/or inappropriate	2	10%	5%
Other (please specify)	2	10%	5%

The “other” responses included:

- While I really believe in the idea, conceptually, my concern would be that it would discourage the implementation of simpler measures such as LEDs in order to avoid the mandate for occ sensors.
- I would put that this would be "Unnecessary and/or inappropriate", but also need to state that many open offices already are zoned this way when you factor in daylight zones.

Analyzing the sentiment of the comments provided by the respondents who answered “other”, the Statewide CASE Team classified these responses into either “useful and/or appropriate” or “unnecessary and/or inappropriate”. The “useful and/or appropriate” and “unnecessary and/or appropriate” columns in Figure 13 show the overall impression after the “other” responses were reclassified into the other two categories. The reclassified responses were leveled as “other responses” in the legend. The “other (please specify)” column preserved the original “other” responses for reference.

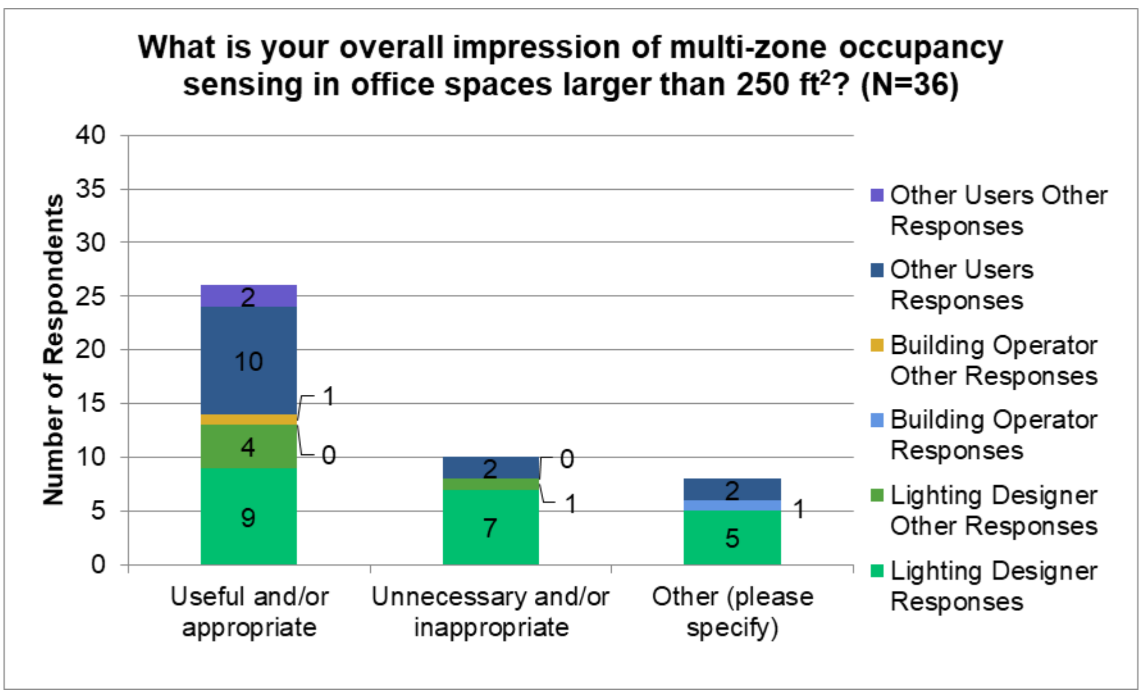


Figure 13: Overall impression, summarized with percentages.

Main Barriers

The table below summarizes lighting designer's perspective on the main barriers to adopting the proposed code change. This was a select all question.

Table 92: Lighting Designers' Perspective on the Main Barriers for Adopting Multi-Zone Occupancy Control Systems in Office Spaces Larger than 250 ft^2

Answer Choices	Percent Response	Responses	Overall Percent
System complexity	67%	14	64%
Installation cost	62%	13	59%
Integration with existing lighting	43%	9	41%
Unclear energy savings	33%	7	32%
Visual aesthetics of different zones being dim, off, and at full brightness	76%	16	73%
Interest in pursuing lighting controls	10%	2	9%
Occupant comfort	33%	7	32%
Other (please explain)	10%	2	9%

The responses to "other" include:

- Distraction
- Understanding how much more it will cost compared to baseline

The one building operator response voted for system complexity as the main barrier to adoption.

Implementation Issues

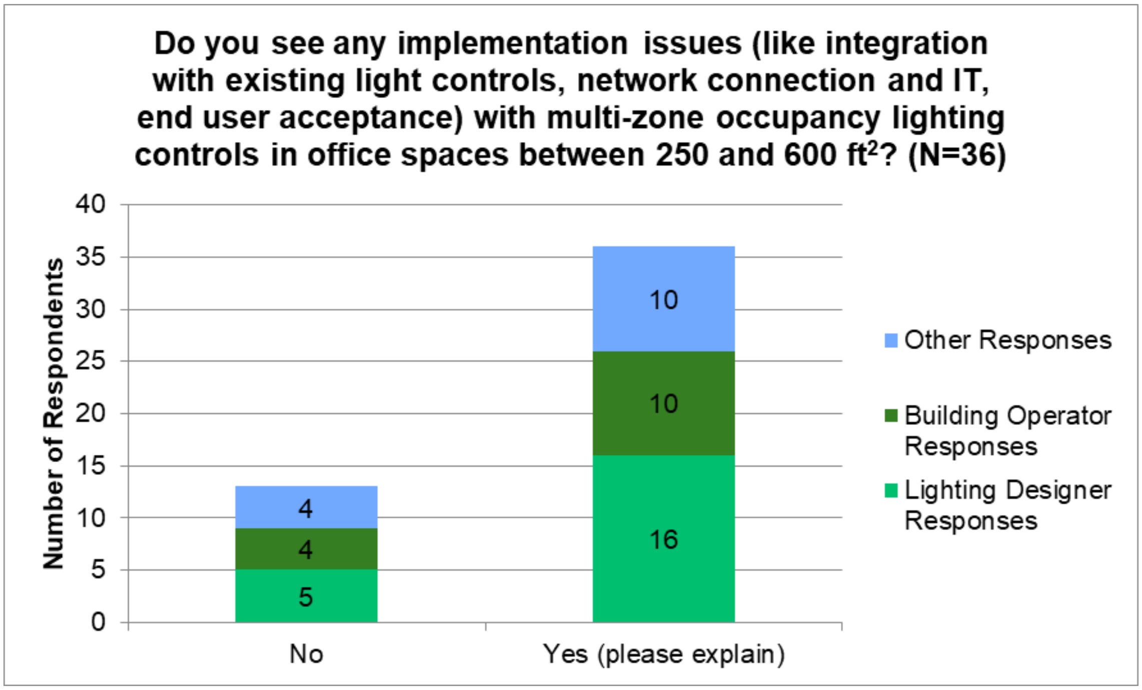


Figure 14: Survey responses to implementation issues inquiry.

The following table summarizes the implementation issues flagged by survey respondents.

Table 93: Implementation Issues Summarized

Perceived Implementation Issue	Percent of Respondents	Number of Respondents
Integration	58%	15
Complexity	46%	12
User acceptance	35%	9
Cost	31%	8
Lack of understanding by users	19%	5
Network connection and IT	15%	4
Not cost effective	15%	4
Code need operation sequence	8%	2
Control zones may turn off lighting next to office occupant creating nonuniformity	4%	1
Increased sensor density and granularity	4%	1
Safety and security	4%	1
Should exclude private offices	4%	1

Amenity Issues

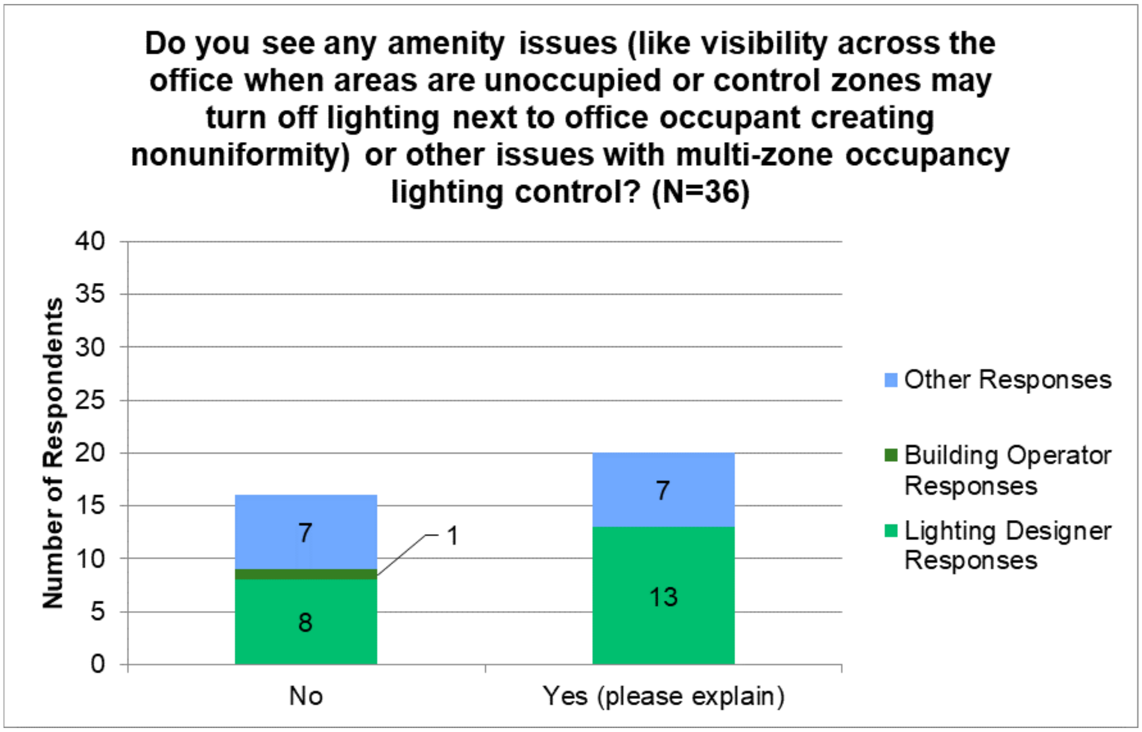


Figure 15: Survey responses to amenity issues inquiry.

Table 94: Amenity Issues Summarized

Perceived Amenity Issue	Percent of Respondents	Number of Respondents
Control zones may turn off lighting next to office occupant creating nonuniformity	70%	14
Occupants are sensitive to different light levels/ non-uniformity	30%	6
Visibility across the office when areas are unoccupied	20%	4
User acceptance	20%	4
Safety and security	15%	3
Code needs to dictate sequence of operations	10%	2
Lack of understanding by users	10%	2
Transition areas	10%	2
Code needs to dictate sequence of operations	5%	1
Decorative lighting should stay on	5%	1
Integration with daylighting	5%	1
Need a better definition to exclude private offices	5%	1
Who makes the decisions? Potentially contentious.	5%	1
Uniform dimming in space is better	5%	1
300 ft^2 too small	5%	1

Benefits

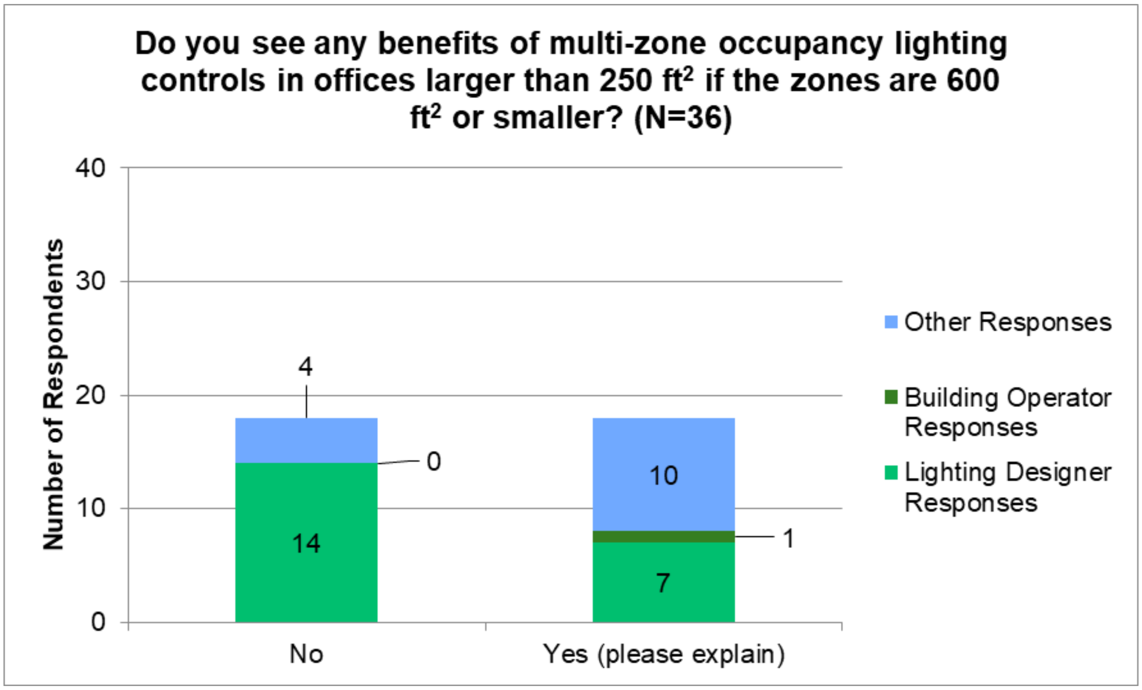


Figure 16: Survey responses to benefits inquiry.

Table 95: Benefits Summarized

Perceived Benefit	Percent of Respondents	Number of Respondents
Reduce energy use	72%	13
Real time occupancy	11%	2
Reduced light pollution at night	6%	1
Lamp longevity	6%	1
Re-zoning	6%	1
Asset tracking	6%	1
Heat mapping	6%	1
Security benefits	6%	1
Alignment of Title 24 with IECC	6%	1
Consider integrating HVAC controls with lighting	6%	1
Only in specific applications	6%	1
Comfort	6%	1

Appendix H: Multi-zone Occupancy Sensing in Large Offices Energy Savings Calculation Details

H.1. 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.

H.1.1. Model Office A

Figure 17 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 40W 2’-by-4’ luminaires, the pink rectangular, are installed in a 10’-by-10’ grid. Each purple circle represents the coverage area, i.e. the control zone, of an occupancy sensor, and the center of the circle is the location of the occupancy sensor.

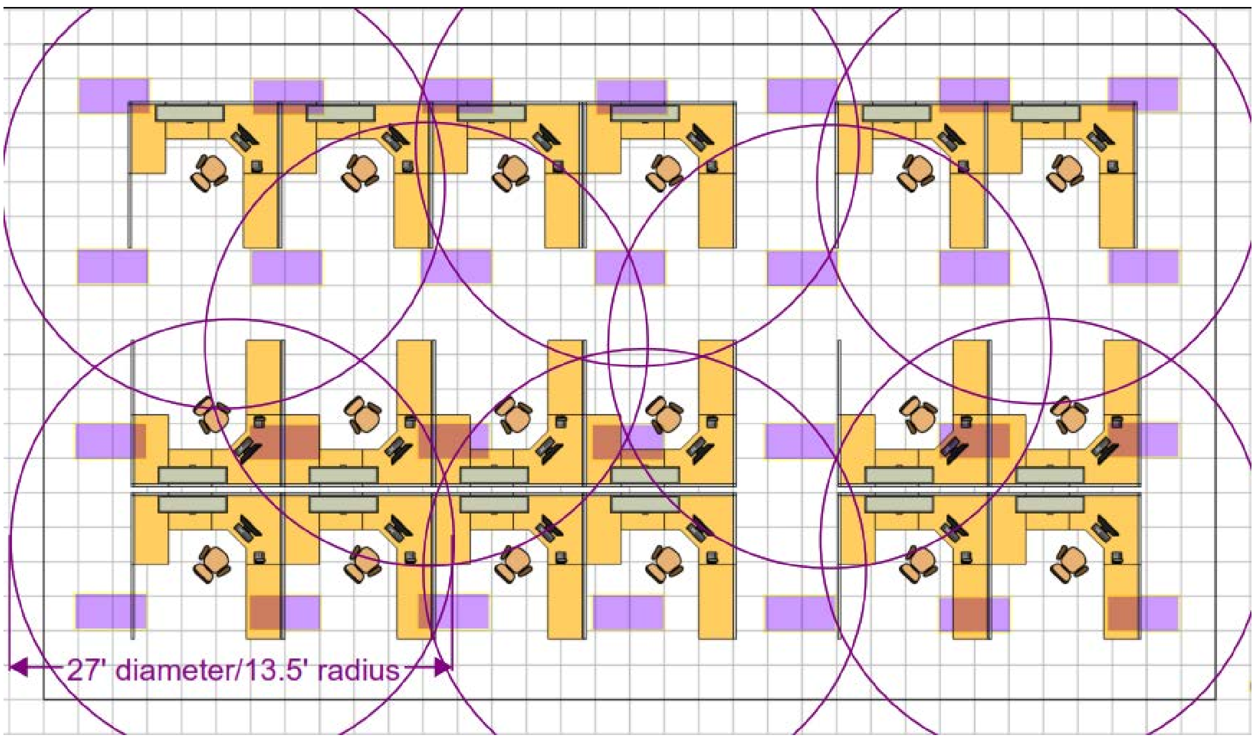


Figure 17: Floor plan of Model Office A with a sample occupancy sensor layout.

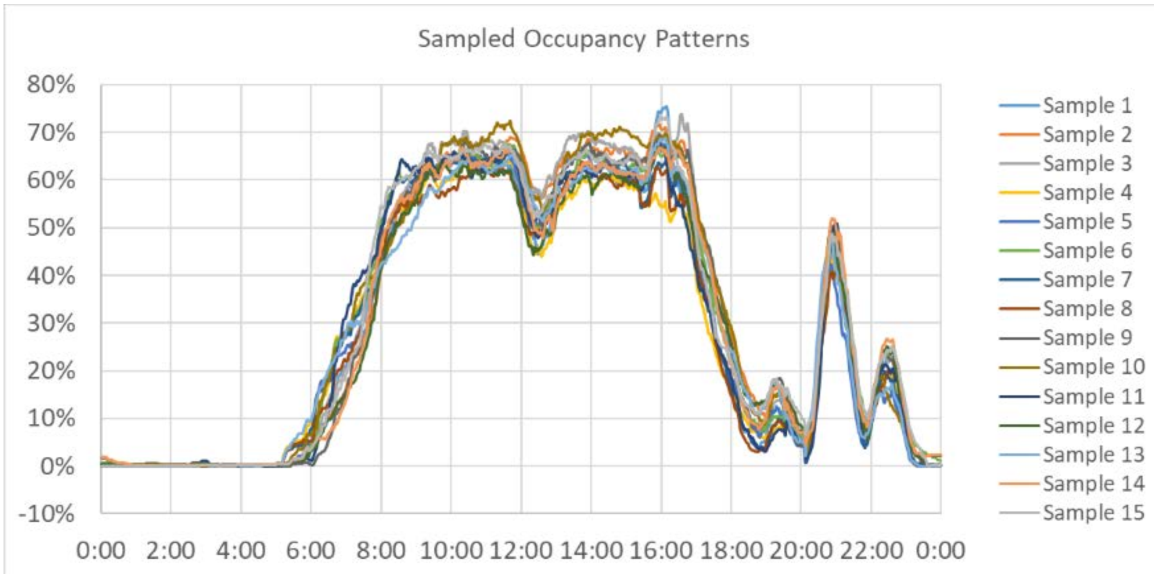


Figure 18: Average daily occupancy pattern of 15 random samples of 18 occupants.

Table 96: Per-unit energy savings of the sample runs for Model Office A.

Per-unit Energy Savings (kW/ft²/yr)		
Sample Run	Best Case	Worst Case
Sample Run 1	1.053	0.449
Sample Run 2	1.147	0.526
Sample Run 3	0.967	0.364
Sample Run 4	1.307	0.683
Sample Run 5	1.253	0.644
Sample Run 6	1.073	0.448
Sample Run 7	1.036	0.445
Sample Run 8	1.021	0.426
Sample Run 9	0.979	0.368
Sample Run 10	0.986	0.396
Sample Run 11	1.096	0.514
Sample Run 12	1.290	0.649
Sample Run 13	1.008	0.361
Sample Run 14	1.284	0.678
Sample Run 15	1.029	0.387
Average of all Sample Runs	**1.102**	**0.489**

H.1.2. Model Office B

Figure 19 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 40W 2’-by-4’ luminaires, the pink rectangular, are installed in a 10’-by-10’ grid. Each purple circle represents the coverage area, i.e. the control zone, of an occupancy sensor, and the center of the circle is the location of the occupancy sensor.

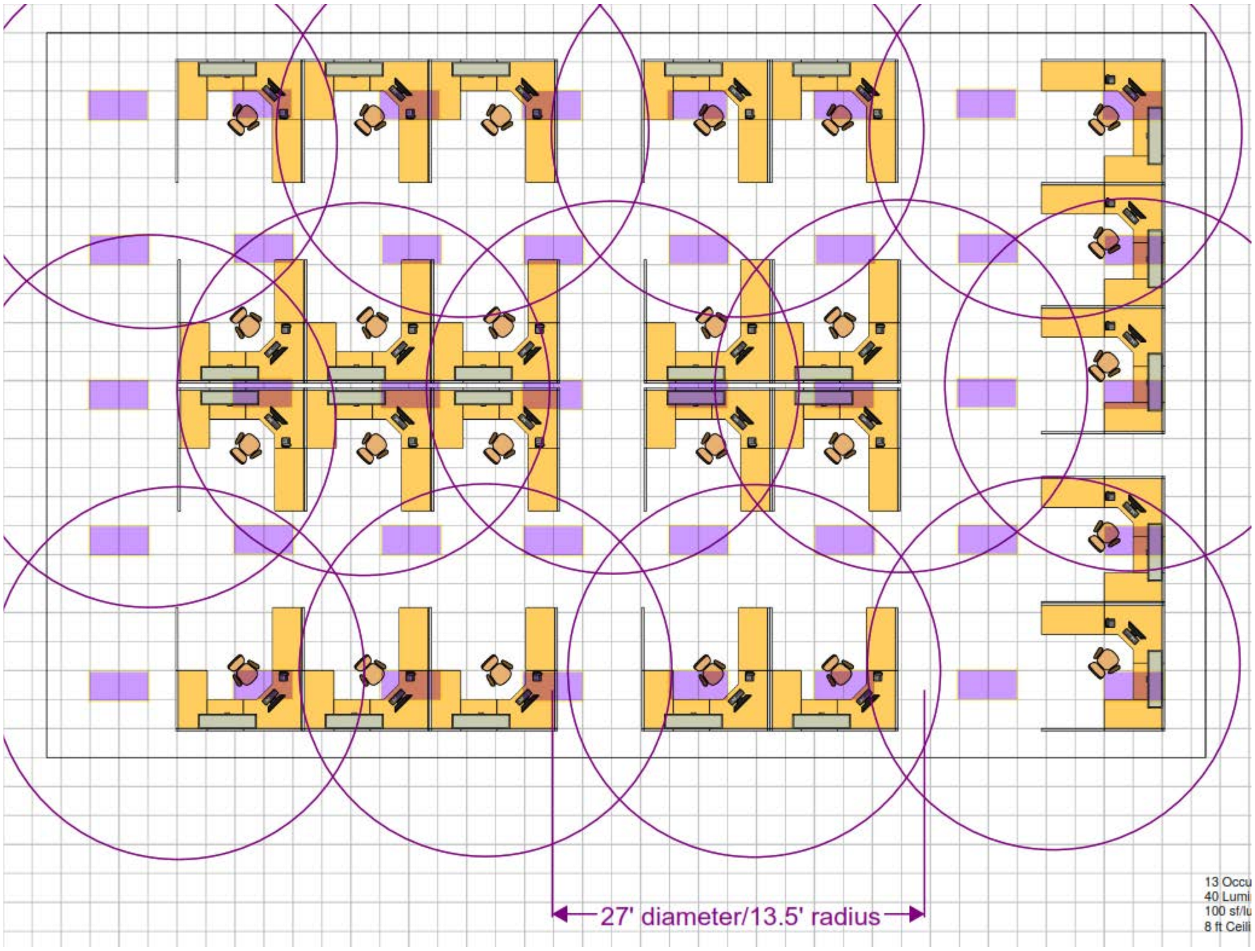


Figure 19: Floor plan of Model Office B.

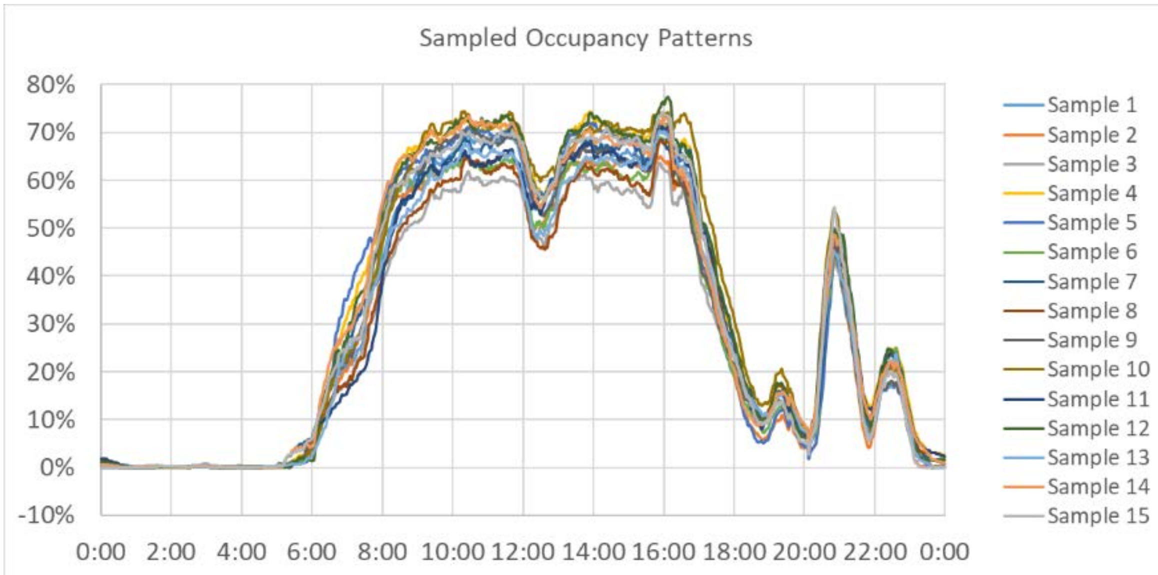


Figure 20: Average daily occupancy pattern of 15 random samples of 25 occupants.

Table 97: Per-unit energy savings of the sample runs in Model Office B.

Per-unit Energy Savings (kW/ft^2/yr)		
Sample Run	**Best** Case	**Worst** Case
Sample Run 1	0.965	0.442
Sample Run 2	1.174	0.674
Sample Run 3	1.065	0.483
Sample Run 4	1.035	0.507
Sample Run 5	0.967	0.482
Sample Run 6	1.123	0.591
Sample Run 7	1.155	0.630
Sample Run 8	1.200	0.650
Sample Run 9	1.010	0.495
Sample Run 10	1.126	0.619
Sample Run 11	1.162	0.644
Sample Run 12	0.873	0.363
Sample Run 13	1.170	0.639
Sample Run 14	1.046	0.516
Sample Run 15	0.897	0.392
Average of all Sample Runs	**1.065**	**0.542**

H.1.3. Model Office C

Figure 21 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 40W 2’-by-4’ luminaires, the pink rectangular, are installed in a 10’-by-10’ grid. Each purple circle represents the coverage area, i.e. the control zone, of an occupancy sensor, and the center of the circle is the location of the occupancy sensor.

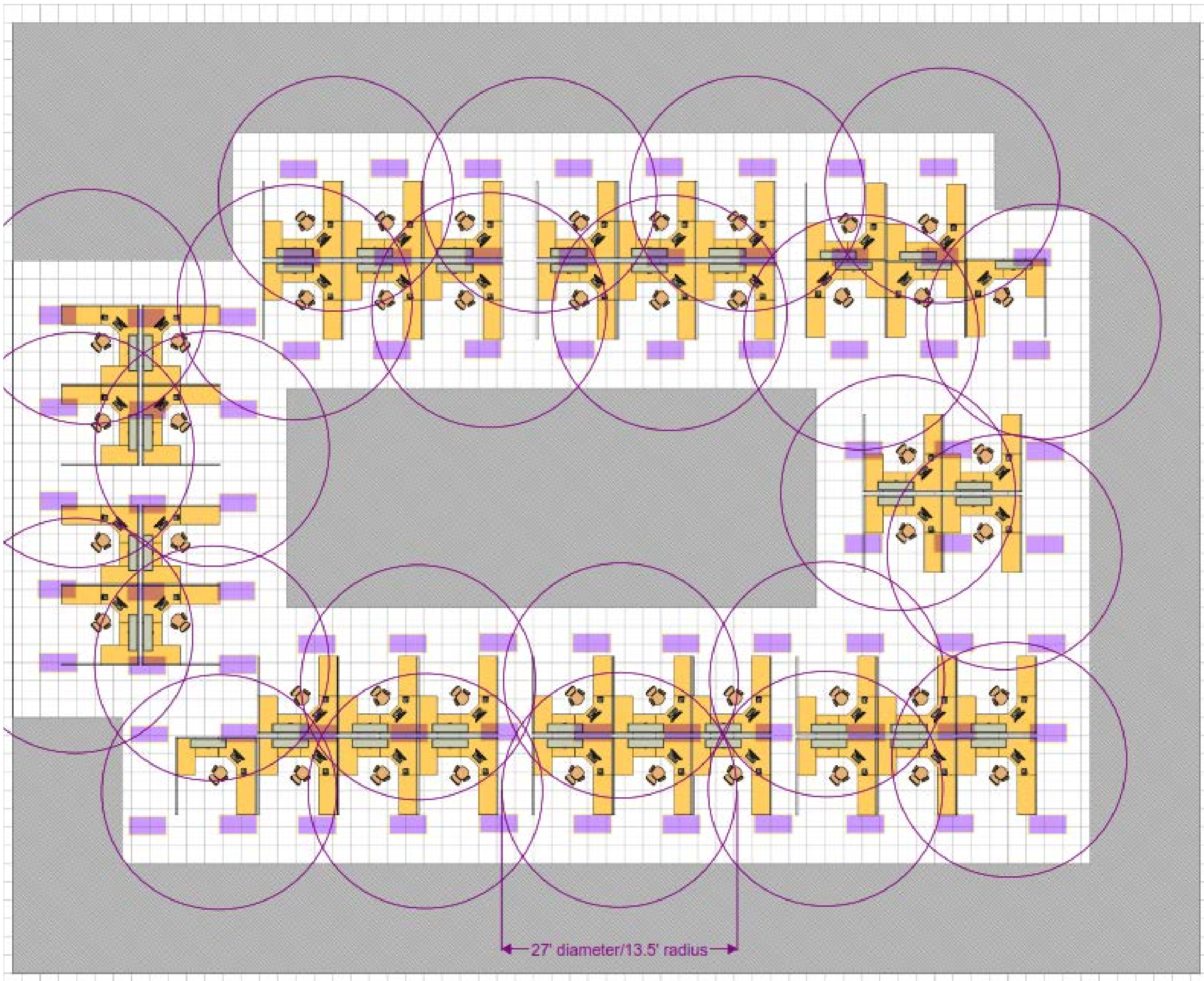


Figure 21: Floor plan of Model Office C for a large open-plan office area.

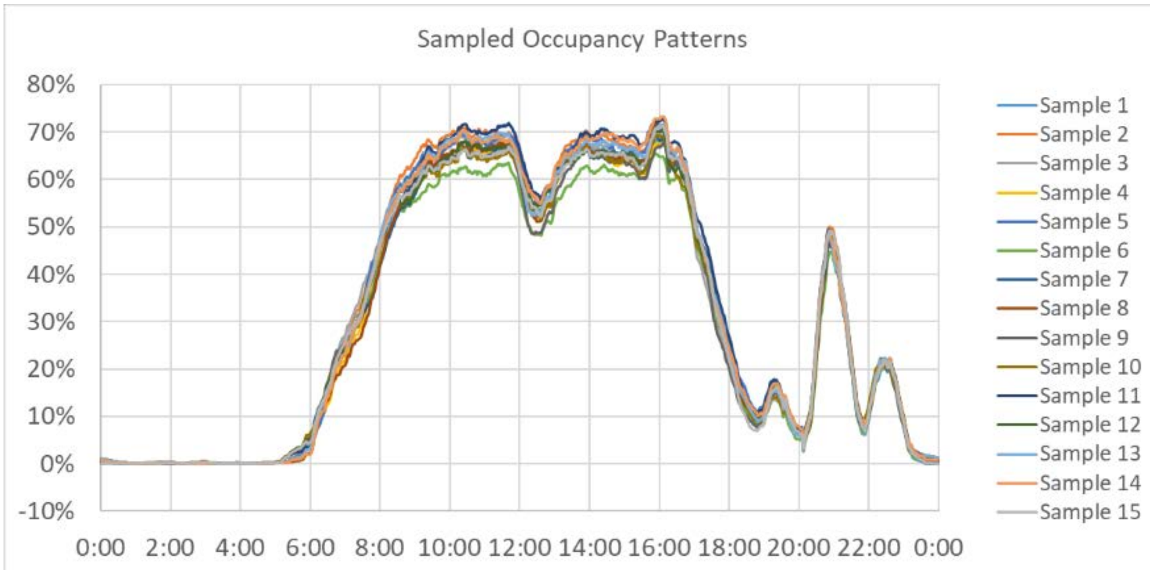


Figure 22: Average daily occupancy pattern of 15 random samples of 48 occupants.

Table 98: Per-unit energy savings of the sample runs in the Model Office C.

Per-unit Energy Savings (kW/ft²/yr)		
Sample Run	**Best Case**	**Worst Case**
Sample Run 1	1.284	0.713
Sample Run 2	1.267	0.703
Sample Run 3	1.251	0.689
Sample Run 4	1.214	0.639
Sample Run 5	1.267	0.699
Sample Run 6	1.331	0.733
Sample Run 7	1.132	0.546
Sample Run 8	1.213	0.642
Sample Run 9	1.298	0.720
Sample Run 10	1.294	0.709
Sample Run 11	1.263	0.695
Sample Run 12	1.282	0.701
Sample Run 13	1.275	0.713
Sample Run 14	1.058	0.494
Sample Run 15	1.124	0.552
Average of all Sample Runs	**1.237**	**0.663**

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 99: 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	N/A	7000 or more	3000 and less
CvO - Cove light omnidir	Not Used	N/A	N/A
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	N/A	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
SLl - 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 100: 2x2 and 2x4 Troffers

Manufacturer	2 X 2 Low/High Lumen Output (lumens)	Lumens per Watt	2 X 2 Low/High Lumen Output (lumens)	Lumens per Watt	Comments/Remarks/Notes
Manufacturer A[a]	2,000 to 4,800	109 to 130	3,000 to 12,000	112 to 137	Sampling of 8 different product types – Lensed & Basket (not all have full range)
Manufacturer B[b]	1,400 to 4,800	111 to 143	2,400 to 9,200	118 to 147	Sampling of 8 different product types – Lensed & Basket (not all have full range)
Manufacturer C	2,000 to 6,500	102 to 129	3,400 to 13,000	106 to 136	Sampling of 4 different product types – Lensed & Basket (not all have this full range)
Manufacturer D[c]	1,000 to 6,000	86 to 156	2,000 to 12,000	99 to 178	Sampling of 6 different product types – Lensed & Basket (not all have full range)
Manufacturer E	2,300 to 4,500	94 to 130	3,200 to 7,800	97 to 135	Sampling of 8 different product types – Lensed & Basket (not all have full range)
Manufacturer F[d]	3,400 to 6,500	66 to 94	3,900 to 9,200	66 to 122	Sampling of 4 different product types – Lensed & Basket (not all have full range)
Average of 5 Manufacturers[d]	1,740 to 5,320	100 to 138	2,800 to 10,800	98 to 142	Sampling of 38 different product types (not all have full range)
Max. Range 5 Manufacturers[d]	1,000 to 6,500	86 to 156	2,000 to 13,000	97 to 178	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 115 lumens per watt (LPW) / 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 101 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 101: 2022 Lumen Method Model Lighting Foot-candle Levels, Fraction of Area Illuminated and Referenced Standards

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (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 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (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

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (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
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

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
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
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

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
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
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

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (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 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (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)

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
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
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

2022 T24 Combined Name	Circulation (fc)	Circulation IES Ref	Task Horizontal (fc)	Task IES Ref	Suppl horiz (fc)	Suppl. IES Ref	Wall Wash Vertical (fc)	Wall Wash IES Ref Vertical (fc)
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
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

Documents referenced in the table above: (Illuminating Engineering Society 2017) (Illuminating Engineering Society 2017) (Illuminating Engineering Society 2015) (Illuminating Engineering Society 2017) (Illuminating Engineering Society 2017) (Illuminating Engineering Society 2016) (Illuminating Engineering Society 2017) (Illuminating Engineering Society 2015) (Illuminating Engineering Society 2013) (Illuminating Engineering Society 2013) (Illuminating Engineering Society 2018) (Illuminating Engineering Society 2012) (Illuminating Engineering Society 2011) (Heschong and McHugh 2000)

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 102: Prototypical Primary Function Area: Dimensions, RCR and Reflectances

Primary Function Area	Ht.	Width (ft)	Length (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 Area	11	15	30	2.5	4.3	70%	50%	20%
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%

Primary Function Area	Ht.	Width (ft)	Length (ft)	Work Plane ht (ft)	Nom. RCR	Ceil. Ref	Wall Ref	Floor Ref
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%	44%	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%
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	20	12	30	0.0	11.7	70%	50%	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%

Primary Function Area	Ht.	Width (ft)	Length (ft)	Work Plane ht (ft)	Nom. RCR	Ceil. Ref	Wall Ref	Floor Ref
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 Room	12	40	30	3.0	2.6	80%	50%	20%
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 103 shows 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 (shown in Table 104). 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 103: 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 104: 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 105 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 105: 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 106 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 106: 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.

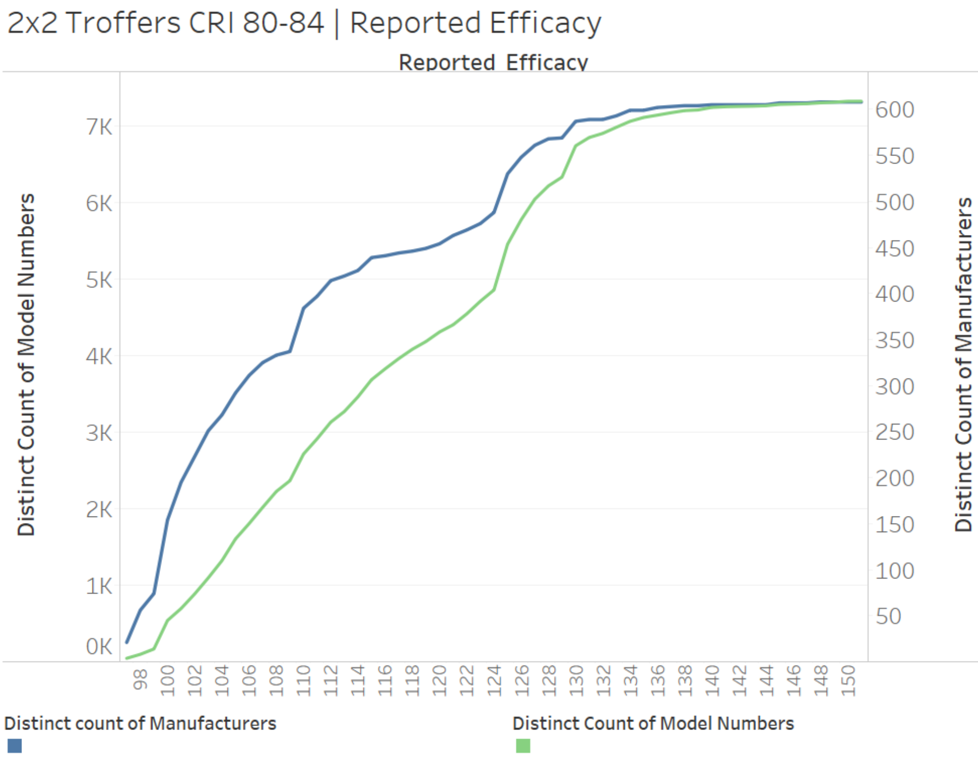


Figure 23: Reported efficacy for 2x2 troffers with CRI 80-84.

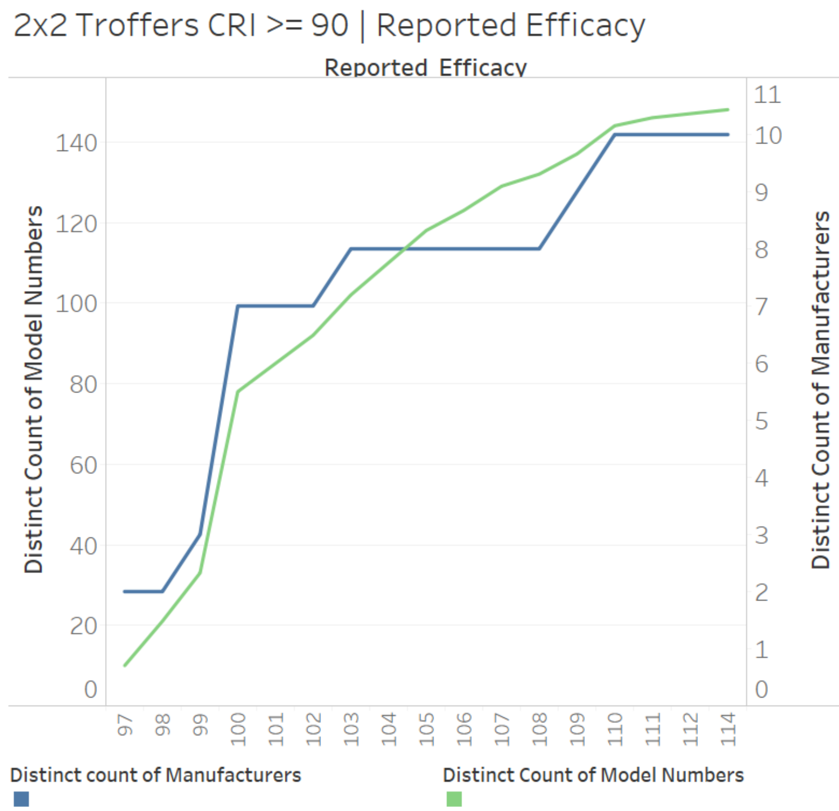


Figure 24: Reported Efficacy for 2x2 troffers with CRI greater than or equal to 90.

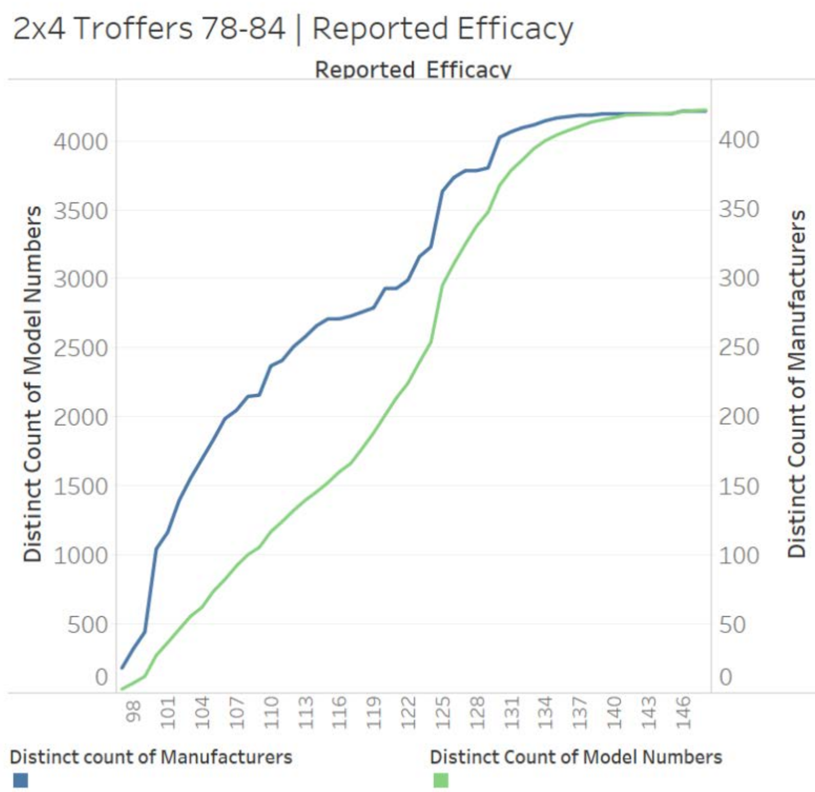


Figure 25: Reported efficacy for 2x4 troffers (78-84).

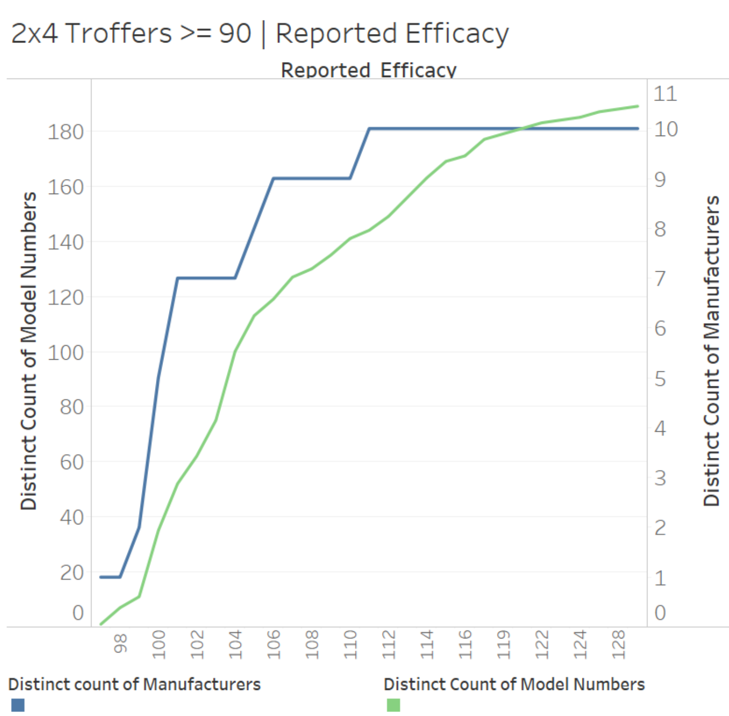


Figure 26: Reported efficacy for 2x4 troffers (greater than or equal to 90).

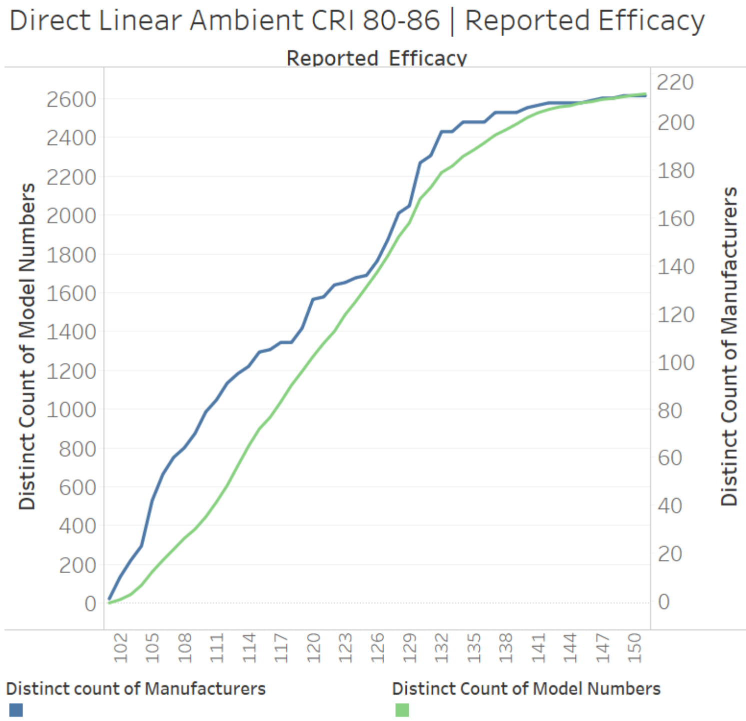


Figure 27: Reported efficacy for direct linear ambient CRI 80-86.

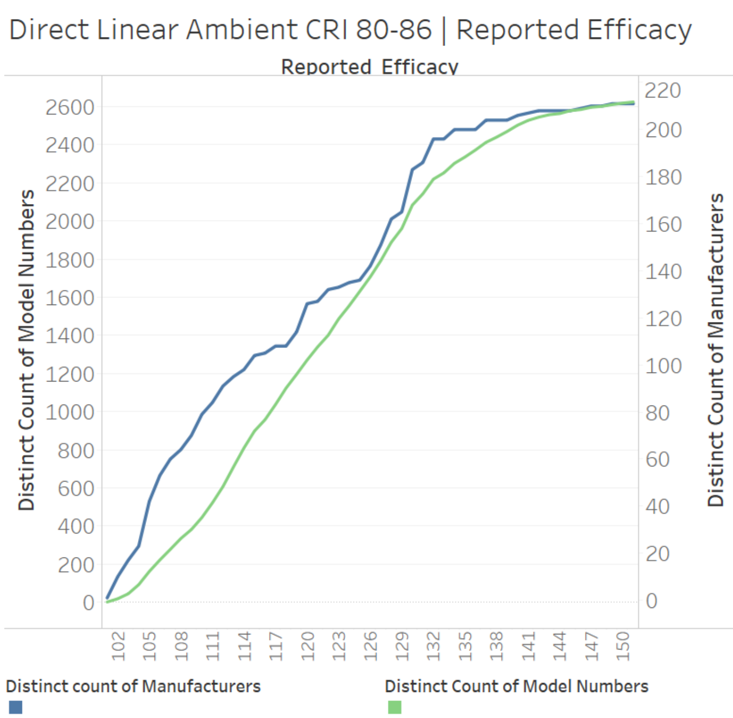


Figure 28: Reported efficacy for direct linear ambient CRI 80-86.

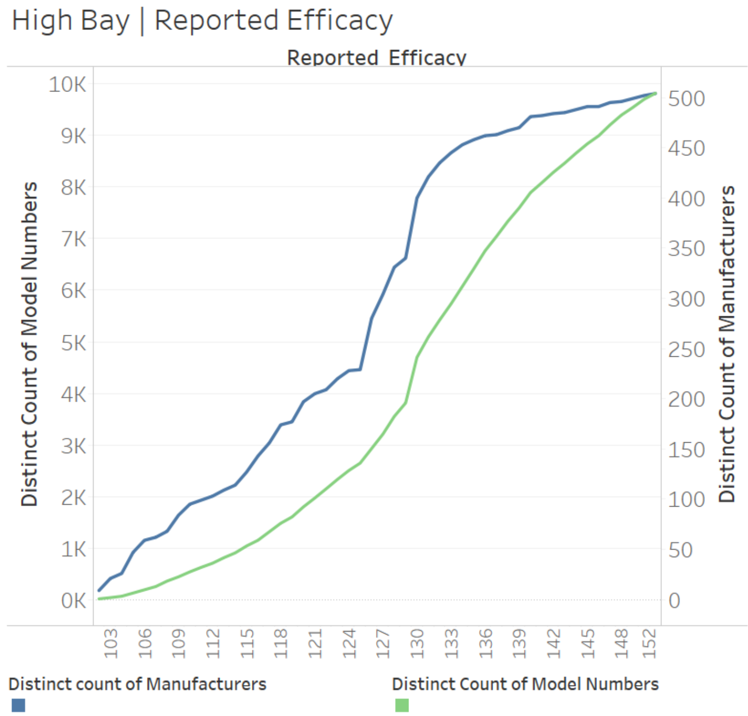


Figure 29: Reported efficacy for high bay.

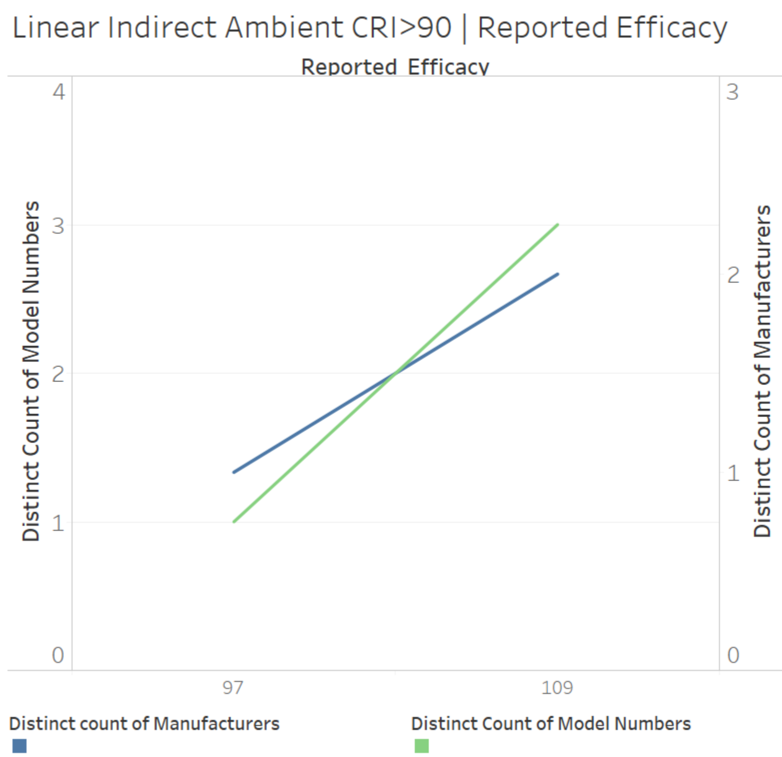


Figure 30: Reported efficacy for linear indirect ambient (CRI greater than 90).

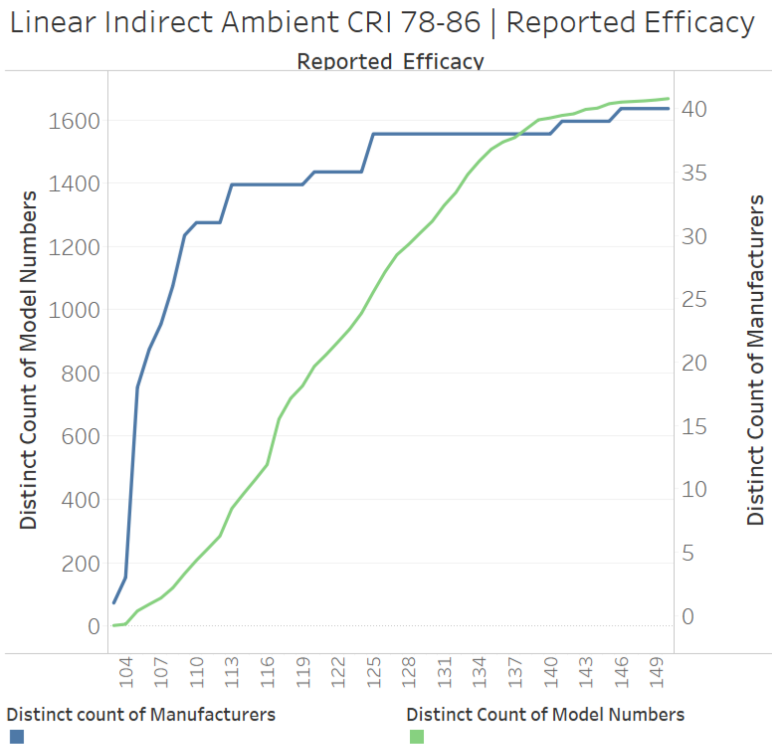


Figure 31: Reported efficacy for linear indirect ambient (CRI 78-86).

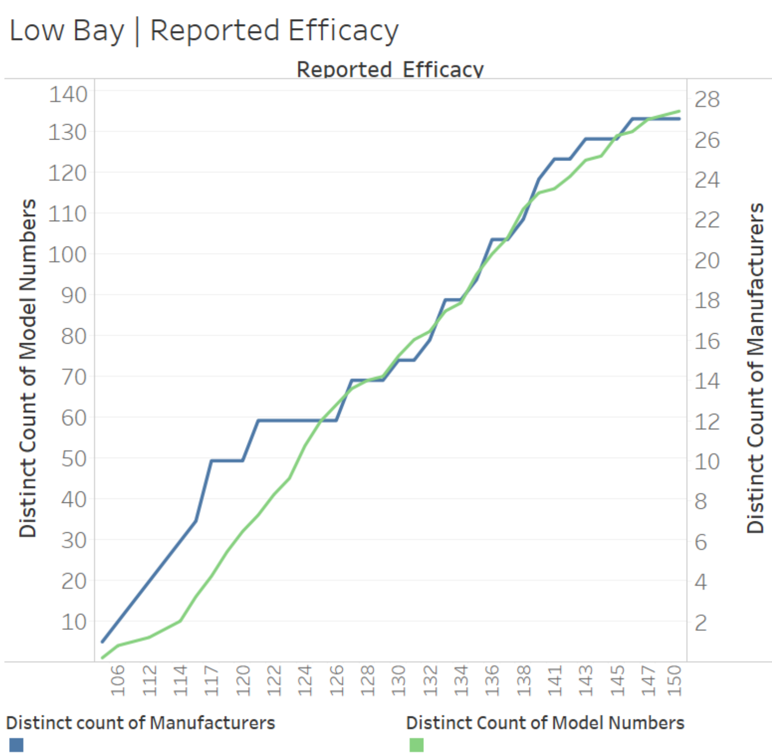


Figure 32: Report efficacy for low bay.

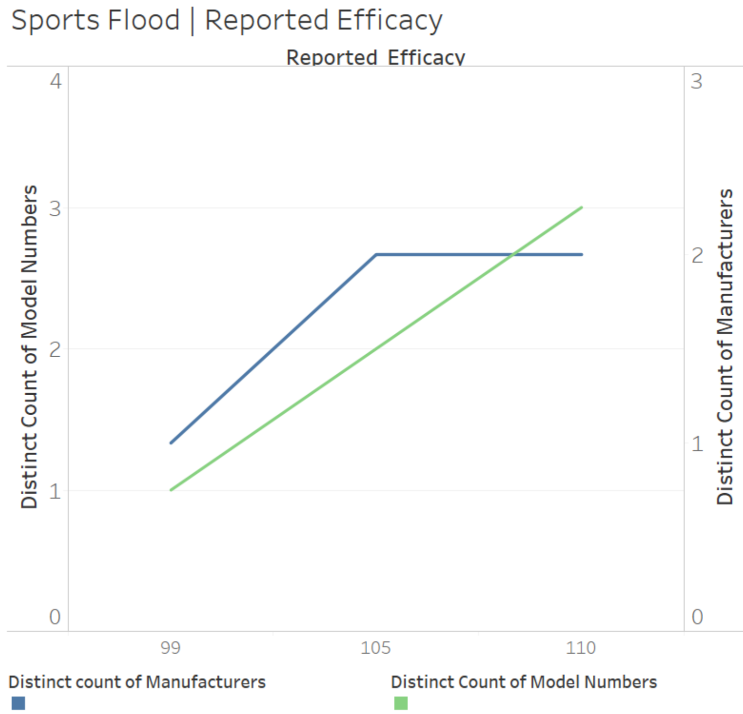


Figure 33: Reported efficacy for sports flood.

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.

M.1. Multi-Zone Occupancy in Large Offices Nominal TDV Energy Cost Savings

Table 107. 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 Nominal TDV Electricity Cost Savings (Nominal $)	15-Year Nominal TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year Nominal TDV Energy Cost Savings (Nominal $)
Model Office A ($2,584\ ft^2$)	All	$3.40	$0.01	$3.41
Model Office B ($4,000\ ft^2$)	All	$3.43	$0.01	$3.44
Model Office C ($7,540\ ft^2$)	All	$3.98	$0.01	$3.99
Average	All	$3.60	$0.01	$3.61

Table 108: 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 Nominal TDV Electricity Cost Savings (Nominal $)	15-Year Nominal TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year Nominal TDV Energy Cost Savings (Nominal $)
Small Office	All	$1.29	$0.00	$1.29
Large Office	All	$1.66	$0.00	$1.66
Retail	All	$0.13	$0.00	$0.13
Non-Refrigerated Warehouse	All	$0.13	$0.00	$0.13
Refrigerated Warehouse	All	$0.09	$0.00	$0.09
Schools	All	$0.20	$0.00	$0.20
Colleges	All	$0.16	$0.00	$0.16
Hospitals	All	$0.10	$0.00	$0.10

M.2. Lighting Power Densities Nominal TDV Energy Cost Savings

Table 109: Statewide Nominal Energy Cost Savings Over 15-Year Period of Analysis

Primary Function Area	Statewide New Construction (Million ft²/yr)	New Construction Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nominal $)	1st Yr Statewide Alterations (Million ft²/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nominal $)
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	0.0	$0.0	14.8	0.0	$0.0
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
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

Primary Function Area	Statewide New Construction (Million ft^2/yr)	New Construction Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nominal $)	1st Yr Statewide Alterations (Million ft^2/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nominal $)
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	0.0	$0.0	17.2	0.0	$0.0
Office Area: Open plan office > xxx sf	7.4	-0.9	-$2.7	22.2	-2.6	-$8.1
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

Primary Function Area	Statewide New Construction (Million ft²/yr)	New Construction Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nominal $)	1st Yr Statewide Alterations (Million ft²/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nominal $)
Restrooms	5.5	0.0	$0.0	17.3	0.0	$0.0
Stairwell	2.3	-0.5	-$1.7	7.0	-1.6	-$5.2
Theater Area: Motion picture	0.9	0.4	$1.5	2.6	1.3	$4.6
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	-$0.1
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
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

Primary Function Area	Statewide New Construction (Million ft^2/yr)	New Construction Energy Savings (GWh/yr)	Nominal Energy Cost Savings (Million Nominal $)	1st Yr Statewide Alterations (Million ft^2/yr)	Alteration Energy Savings (GWh/yr)	Alterations Nominal Cost Savings (Million Nominal $)
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 Facility	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
Sports Arena – Playing Area: Class IV Facility	0.0	0.0	$0.0	0.0	0.0	$0.0
Statewide Totals	**162.7**	**23.4**	**$80.2**	**506.5**	**72.4**	**$247.4**

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 110 and provide a summary of the analysis.

Table 110: 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 111: 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	N/A	8 ft^2
Case Top LPD	5.75 W	N/A	5.00 W

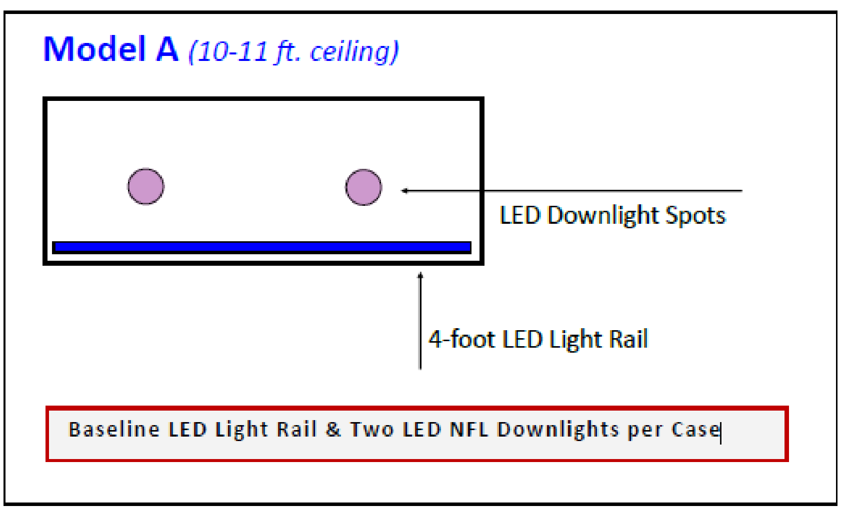


Figure 34: Model A (10' to 11' ceiling) used for updating very valuable display lighting power densities.

Table 112: 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	N/A	8 ft^2
Case Top LPD	9.75 W	N/A	8.50 W

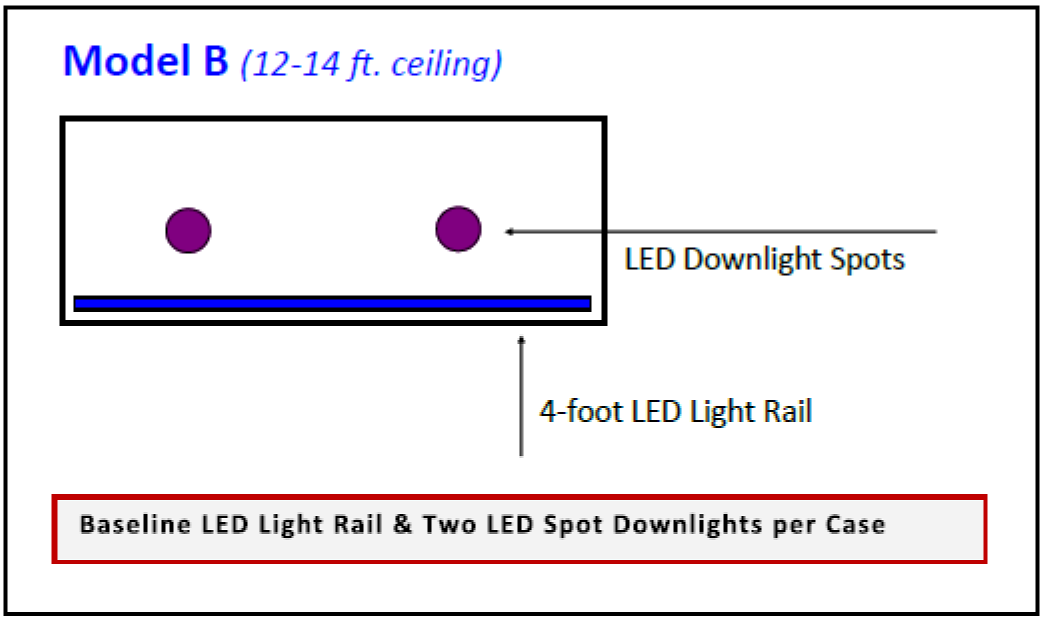


Figure 35: Model B (12’ to 14’ ceiling) used for updating very valuable display lighting power densities.

Table 113: 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	N/A	4 ft^2
Case Top LPD	8.00 W	N/A	7.00 W

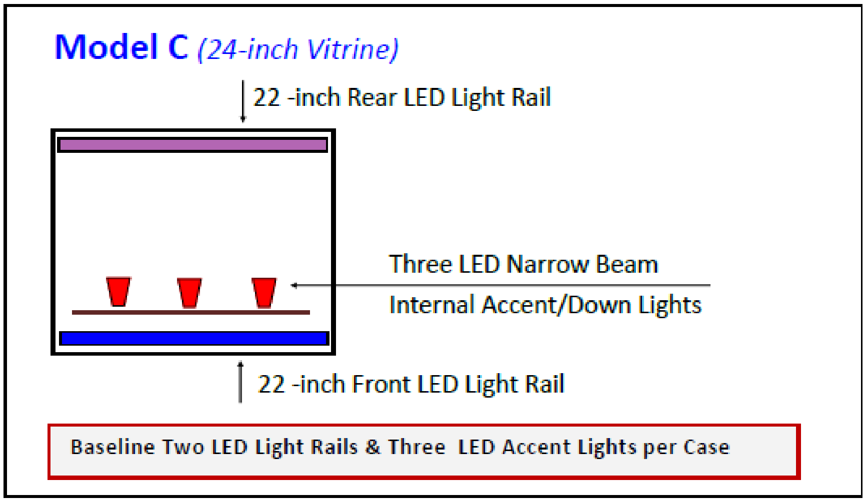


Figure 36: Model C (24" vitrine) used for updating very valuable display lighting power densities.

Table 114: 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

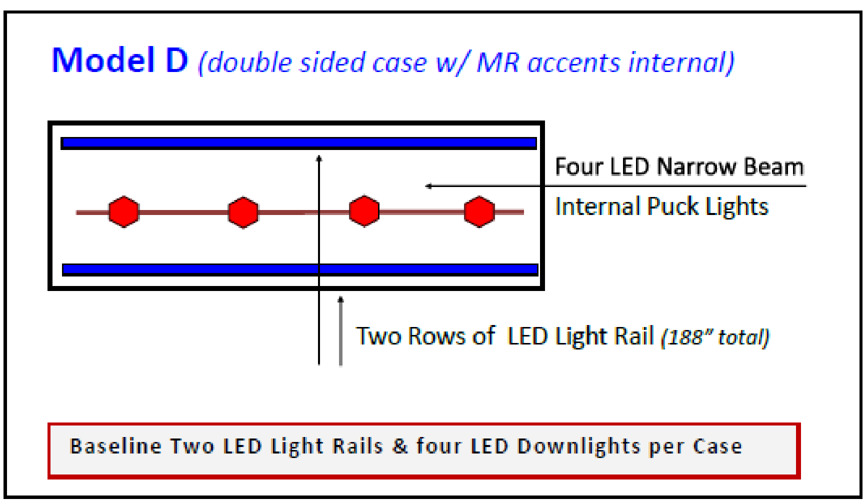


Figure 37: Model D (double sided case with internal multifaceted reflector lamps) used for updating very valuable display lighting power densities.

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 115: 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	N/A	N/A	N/A	N/A	N/A	**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 116: 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 117: 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" diameter 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 foot-candles (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/ft^2.

Table 118: 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 38 and Table 119 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 119 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 percent gain for Floor display and 3 percent 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. 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 LPDs 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 38: Tailored method floor, accent, and display lighting power density calculations on a square foot basis.

Table 119: 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 39, Figure 40, Figure 41 and Table 120, 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 120 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 39: 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 40: Chandelier Models

4-foot X 10-foot Model

Title 24 2011-2016		Title 24 2019 Proposed		Title 24 2022 Model
142 W	100% LED 80CRI	136 W	100% LED 90CRI	
		12 to 14 W	95+-CRI	120 W 90+CRI
				120 W Ave
		136 2019 Baseline		FACTOR: 0.88

Figure 41: Luminous Wall Panel Model

Table 120: 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 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 71 primary function areas, 10 increase their LPDs, 30 decrease their LPDs and 31 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)

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~~ Display/Decorative	~~0.30~~ 0.25
Auditorium Area	0.70	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.45
		~~Accent, display and feature[3]~~	~~0.20~~
Auto Repair / Maintenance Area	0.55	Detailed Task Work[7]	0.20
Barber, Beauty Salon, Spa Area	~~0.80~~ 0.65	Detailed Task Work[7]	0.20
		~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Civic Meeting Place Area	~~1.00~~ 0.90	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Classroom, Lecture, Training, Vocational Area	~~0.70~~ 0.60	White or Chalk Board[1]	~~4.50~~ 7 W/ft

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)
Concourse and Atria Area		~~0.90~~ 0.60	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Convention, Conference, Multipurpose and Meeting Area		~~0.85~~ 0.75	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Copy Room		0.50	-	-
Corridor Area		~~0.60~~ 0.40	~~Ornamental~~ Display/Decorative	0.25
Dining Area	Bar/Lounge and Fine Dining	~~0.55~~ 0.45	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.35
	Cafeteria/Fast Food	~~0.40~~ 0.45	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
	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~~ Display/Decorative	~~0.30~~ 0.25
Hotel Function Area		0.85	~~Ornamental~~ Display/Decorative	~~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~~ Display/Decorative	~~0.30~~ 0.25
	Stacks Area	~~1.10~~ 1.00	-	-
~~Main Entry~~ Lobby, Main Entry		~~0.85~~ 0.70	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Locker Room		0.45	-	-
Lounge, Breakroom, or Waiting Area		~~0.65~~ 0.55	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25

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)
~~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] Display/Decorative	~~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	Display/Decorative and 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

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)
Retail Sales Area	Grocery Sales	~~1.05~~ 1.00	~~Accent, display and feature[3]~~	~~0.20~~
			Display/Decorative	~~0.15~~ 0.35
	Retail Merchandise Sales	~~1.00~~ 0.95	~~Accent, display and feature[3]~~	~~0.20~~
			Display/Decorative	~~0.15~~ 0.35
	Fitting Room	0.60	External Illuminated Mirror[5]	40 W/ea
			Internal Illuminated Mirror[5]	120 W/ea
Religious Worship Area		0.95	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
Restrooms		0.65	~~Accent, display and feature[3]~~	~~0.20~~
			Display/Decorative[4]	~~0.15~~ 0.35
Stairwell		~~0.5~~ 0.60	~~Accent, display and feature[3]~~	~~0.20~~
			Display/Decorative[4]	~~0.15~~ 0.35
Storage, Commercial/Industrial ~~Storage~~	Warehouse	~~0.45~~ 0.40	-	-
	Shipping & Handling	0.60	-	-
Theater Area	Motion picture	~~0.60~~ 0.50	~~Ornamental~~ Display/Decorative	~~0.30~~ 0.25
	Performance	~~1.00~~ 0.80		
Transportation Function	Baggage Area	0.40	-	-
	Ticketing Area	0.45	~~Accent, display and feature[3]~~ Display/Decorative	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	Display/Decorative[4]	~~0.15~~ 0.30
	Dining	0.80	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	Lounge/Waiting Area	~~0.75~~ 0.80	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	~~Main Entry~~ Lobby, Main Entry	0.85	~~Ornamental~~ Display/Decorative	0.30
			Transition Lighting OFF at night[12]	0.95
			Tunable white or dim-to-warm[10]	0.10
	Multipurpose Room	~~0.95~~ 0.85	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	Religious Worship Area	1.00	~~Ornamental~~ Display/Decorative	0.30
			Tunable white or dim-to-warm[10]	0.10
	Restroom	~~0.80~~ 1.00	~~Accent, display and feature[3]~~ Display/Decorative	0.20
	Stairwell	0.80	Display/Decorative	0.30
Healthcare Facility and Hospitals	Exam/Treatment Room	1.15	-	-
	Imaging Room	~~1.00~~ 0.60	Display/Decorative	0.20
			Tunable white or dim-to-warm[10]	0.10
	Medical Supply Room	0.55	-	-

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)
	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	Display/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	-	-
All other		0.40	-	-

The following commentary supports the recommendations to adjust the primary function areas LPDs. The following commentary supports the recommendations to adjust the primary function areas LPDs.

- **Auditorium, Hotel Function Area, Library: Reading Area, Museum Area: Exhibition/Display and Religious Worship Area:** For all of these areas, the additional allowed wattage allowance is proposed to be reduced by 0.05 W/sf. This reduction reflects the increased efficacy of high CRI sources. In the time period between the development of the 2019 Title 24, Part 6 proposed LPDs and this proposal for the 2022 Title 24, Part 6 LPDs, overall LED efficacies have not increased appreciably, but the efficacies for high CRI sources used in modeling ornamental lighting have increased by an average of 12 percent. A 0.883 factor was applied to the 0.30 W/sf 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.

- **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, a decision was made to provide some added design leeway. This resulted in 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. The model projects that this space could be illuminated to IES recommended levels for around 0.25 W/ft^2. Therefore, the allowed 0.40 W/sf has a significant margin of error. It is worth noting that ASHRAE 90.1-2019 similarly has a 0.40 W/sf general lighting allowance for corridors.
- **Corridor Area:** Small increase in allowed lighting, however allowed lighting is less for corridors without any ornamental lighting. 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. This reflects that circulation in the corridor has a base allowance that would allow 10 maintained foot-candles and five 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, the 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/Leisure):** Family/Leisure allowed LPD dropped 19 percent. These targets are based on results of the updated (more detailed 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.

- **Lobby, Main Entry:** Besides the drop in allowed power for ornamental lighting from 0.30 to 0.25 W/sf as described for other applications, the 18 percent drop in general lighting power allowance is the result of aligning with the recommended illuminances from DG-25 (10 fc for lobby circulation, 15 fc for desktop and general reading and 50 fc for more difficult reading and writing tasks). The model design was based on large and small diameter downlights and a high CRI aperture wall washer providing 10 fc average on half of the walls. The model design required 0.59 W/sf. This is conservative as often in lobbies the higher illuminance reading tasks are provided by exempt portable lighting. The 2019 lobby LPD was based on a model that used a less efficient indirect pendant lighting system with twice as much design illuminance for the entire space supplemented by downlights and a wall washing system.
- **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 six 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 AGi32 modeling conducted in 2019 for open plan offices. For the 2022 standards, the primary function areas, “open plan office” and “office area > 250 square feet” were combined into office areas > 250 square feet as there was no definitive agreed upon meaning of the “open plan” terminology. Common architectural parlance included opposite interpretation of whether open plan offices have interior partitions associated with system furniture.

  In addition, the lumen model calculated an LPD for a 600 ft^2 space that was around 0.4 W/ft^2 or 30 percent lower than the proposed allowance. In response to designer comments, the Statewide CASE Team left the LPD at 0.60 W/ft^2 to accommodate special issues such as converted buildings that might want to leave exposed brick or other legacy features that have low surface reflectances. This proposed LPD is the same as the 2019 LPD for “open plan office” but 0.05 W/ft^2 less than the 2019 LPD for offices > 250 ft^2.

However, the most significant change in this proposal for offices is the change to the 0.20 W/ft^2 additional lighting power allowance for “portable lighting for office areas.” Originally this was allowed only for portable lighting that was included on the plans. The primary use of this allowance was for undercabinet lighting attached to system furniture. Similar to other portions of this proposal that provide more flexibility for the use of additional lighting power allowance, for office lighting it is proposed that the 0.20 W/sf be allowed for both “display/decorative” and “portable lighting.” Thus, this allowance can be used for non-general lighting to highlight walls and artwork or used for undercabinet lighting or some combination of the two.

- **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 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 and similar objects 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 power 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 enhancing the visual environment of the space. The general lighting model was calculated to be less than 0.50 W/ft^2 thus the 0.60 W/ ft^2 proposed general lighting power density included a 20 percent safety factor. This was calculated with a 10 fc design illuminance for 70 percent of the area based on the RP-29 recommended illuminance for "Imaging -booth/general" and a 30 fc design illuminance of 30 fc for the rest of the space associated with the RP-29 recommended task illuminance for "Imaging -Diagnostic/reading." Additionally, when revisiting this design the light sources used to provide general lighting were updated from lensed downlights to basket troffers which have higher luminous efficacy. It should be noted that the 0.60 W/ ft^2 proposed LPD (20 percent safety factor) allows for the designer to use downlights for general illumination as

opposed to the basket troffers used in the model.

- **Healthcare Facility and Hospitals: Nursery:** The general lighting power was reduced by 16 percent based on aligning the design illuminances with those recommended in IES RP-29. The 2019 model was based on a design illuminance of 50 fc for the entire space whereas the 2022 model was calculated with 80 percent of the space illuminated to 30 fc according to the nursery "observation" task and 20 percent of the space illuminated to 50 fc for the nursery "treatment" task. The 2022 model calculated LPD was 0.6 W/ ft^2, and used high (90+) CRI lighting, thus the allowed 0.80 W/sf provides an added 33 percent leeway above the calculated value. As is the case with other medical spaces, "examination and surgical lights, low-ambient night-lights, and lighting integral to medical equipment," are exempted.
- **Healthcare Facility and Hospitals: Nurse's Station:** Overall lighting power increased 35 percent to account for improved definitions of what tasks are likely to need illumination at nurses' stations. The revised model included wall washing behind nurses' stations 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 lower the LPDs for six of the building types. Most categories decline by 0.05 W/sf. Motion picture theaters is proposed to be reduced by 0.10 W/ ft^2. The area weighting factors are provided in Table 121.

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 121: 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. In all of the lines that are shaded grey, 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 122: General Lighting System Proposed 2022 and 2019 Base Costs

Primary Function Area	2022 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 Output	32,000	305	90	57	5.33	$182	16,000	811	PAR downlight flood	306	71	27	11	$158	$1,796	$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	39,600	734	135	32	23.02		120,000	838	Linear Industrial (repl FL)	1,965	131	59	33		$0	$0
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)	501	106	48	10	$122	$1,280	$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	40,698	800	Linear Rec Hi Perf Lensed (repl I	483	119	41	12	$129	$1,531	$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		63,000	838	Linear Industrial (repl FL)	1,032	131	59	17		$0	$0
Concourse and Atria Area	Linear light slot 4" or more 80CRI	96,000	1,315	104	33	39.34	$320	288,000	851	PAR downlight flood	5,933	71	27	221	$158	$34,847	$12,590
Convention, Conference, Multipurpose and Meeting Are	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	$0
Corridor Area	Linear light slot 4" or more 80CRI	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 Warm	2,700	49	69	36	1.38	$162	18,000	811	PAR downlight flood	284	71	27	11	$158	$1,670	$223
Dining Area: Cafeteria/Fast Food	Troffer Lensed 80CRI	7,200	108	110	38	2.85		12,000	831	Narrow Linear (repl FL)	178	87	25	7		$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)	297	106	48	6		$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)	1,100	105	42	26		$0	$0
Financial Transaction Area	Troffer Basket 80CRI	4,320	41	116	38	1.07	$146	21,600	831	Narrow Linear (repl FL)	428	87	25	17	$341	$5,958	$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: Precisio	High Bay 80CRI	32,400	460	128	175	2.63		206,400	869	Industrial Super High Bay	3,505	118	376	9		$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)	143	77	124	1	$514	$591	$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)	470	106	48	10		$0	$0
Library : Reading Area	Troffer Basket 80CRI	36,000	482	116	38	12.77	$146	21,600	835	Linear Dir/Ind (repl FL)	330	105	42	8	$372	$2,910	$1,864
Library : Stacks Area	Linear light slot 4" or more 80CRI	2,880	92	104	33	2.76	$320	7,200	831	Narrow Linear (repl FL)	126	87	25	5	$341	$1,751	$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)	69	106	48	1		$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 Warm Lo	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 90CRI	560	13	101	41	0.32	$196	2,800	800	Linear Rec Hi Perf Lensed (repl I	60	119	41	1	$129	$190	$63
Office Area: > 250 square feet	Troffer Basket 90CRI	2,400	34	101	41	0.82	$196	12,000	835	Linear Dir/Ind (repl FL)	163	105	42	4	$372	$1,437	$161
~~Open plan office~~ > 250 sf	Pendant direct/indirect 80CRI	7,200	119	97	50	2.39		48,000	835	Linear Dir/Ind (repl FL)	652	105	42	15		$0	$0

Primary Function Area	2022 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 Hi Ou	99,000	1,910	112	70	27.32	$300	9,900	859-3	Parking structure luminaire	990	112	55	18	$300	$5,395	$8,195
Pharmacy Area	Troffer Basket 80CRI	19,200	273	116	38	7.24	$146	28,800	830	Linear Direct Lensed (repl FL)	476	106	48	10	$94	$935	$1,057
Retail Sales Area: Grocery Sales	Linear light slot 4" or more 80CRI	19,200	224	104	33	6.71	$320	96,000	800	Linear Rec Hi Perf Lensed (repl I	939	119	41	23	$129	$2,975	$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)	1,007	87	25	41	$341	$14,004	$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)	12	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		1,440	804	Wall Mount LED Linear	24	94	33	1		$0	$0
Stairwell	Industrial strip 80CRI	7,200	213	135	32	6.69	$81	3,600	831	Narrow Linear (repl FL)	0	87	25	0	$130	$0	$542
Theater Area: Motion picture	Downlight 4" and less 80CRI	7,800	194	76	32	6.00	$162	46,800	811	PAR downlight flood	958	71	27	36	$158	$5,628	$973
Theater Area: Performance	#N/A	0	0		#N/A		$0	80,000	811	PAR downlight flood	657	71	27	24	$158	$3,860	$0
Transportation Function : Baggage Area	Troffer Basket 80CRI	37,800	463	116	38	12.27		27,000	830	Linear Direct Lensed (repl FL)	247	106	48	5		$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)	272	87	25	11		$0	$0
Videoconferencing Studio																	
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)	888	105	42	21		$0	$0
Aging Eye/Low-vision: Stairwell	Downlight large 6"+ 90CRI	4,800	109	78	36	2.99	$162	1,600	831	Narrow Linear (repl FL)	11	87	25	0	$341	$156	$485
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		32,000	851	PAR downlight flood	611	71	27	23		$0	$0
Aging Eye/Low-vision: Restroom	Cove light assymetric 80CRI	2,592	79	91	40	1.99	$380	4,320	804	Wall Mount LED Linear	78	94	33	2	$256	$615	$757
Healthcare Facility and Hospitals: Exam/Treatment Roo	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 Roo	Troffer Basket 90CRI	12,000	180	101	41	4.35		36,000	830	Linear Direct Lensed (repl FL)	594	106	48	12		$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	346	119	41	8	$129	$1,095	$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)	58	105	42	1	$372	$514	$277
Healthcare Facility and Hospitals: Operating Room	Troffer Basket 90CRI	72,000	1,021	101	41	24.64		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)	37	105	42	1	$372	$329	$61
Healthcare Facility and Hospitals: Physical Therapy Rc	Troffer Basket 80CRI	19,200	167	116	38	4.41	$146	24,000	835	Linear Dir/Ind (repl FL)	466	105	42	11	$372	$4,111	$644
Healthcare Facility and Hospitals: Recovery Room	#N/A	0	0		#N/A			7,488	800-1	Linear Rec Hi Perf Lensed (repl I	123	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
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
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
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

Table 123: 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	56,000	811	PAR downlight flood	1,259	71	27	46.8	$158.00	$7,395.47	$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	Industrial strip 80CRI	144,000	2,500	135	32	78.4		24,000	839	Task (repl FL)	571	67	7	77.4		$0.00	$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	4,150	801	Downlight open (repl INC)	70	86	46	1.5	$157.00	$240.20	$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	$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				$0.00	$0.00
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	$0.00	$4,304.25
Convention, Conference, Multipurpose and Meeting Are	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						$0.00	$0.00
Corridor Area	#N/A	0	0		#N/A	0.0	$0	0	0	NA	0	0			$0.00	$0.00	$0.00
Dining Area: Bar/Lounge and Fine Dining	Downlight 4" and less 80CRI Lo Output	24,300	801	62	15	53.6	$136	4,500	803	Linear WW Open (repl FL	82	84	28	3.0	$318.00	$940.32	$7,291.61
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		$0.00	$0.00
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		$0.00	$0.00
Electrical, Mechanical, Telephone Rooms	#N/A	0	0		#N/A	0.0		7,200	839	Task (repl FL)	207	67	7	28.0		$0.00	$0.00
Exercise/Fitness Center and Gymnasium Area	#N/A	0	0		#N/A	0.0		0	0	NA	0	0				$0.00	$0.00
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	$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				$0.00	$0.00
General/Commercial & Industrial Work Area: High Bay	Industrial strip 80CRI	108,000	1,530	135	32	48.0		0	0	NA	0	0				$0.00	$0.00
General/Commercial & Industrial Work Area: Precision	Industrial strip 80CRI	360,000	4,835	135	32	151.6		0	0	NA	0	0				$0.00	$0.00
Hotel Function Area	Downlight 4" and less 90CRI	11,340	201	83	29	7.0	$162	5,400	801	Downlight open (repl INC)	92	86	46	2.0	$157.00	$312.58	$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	Troffer Basket 80CRI	4,800	56	116	38	1.5		0	0	NA	0	0				$0.00	$0.00
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	11,520	803	Linear WW Open (repl FL	209	84	28	7.6	$318.00	$2,407.21	$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		$0.00	$0.00
Lounge, Breakroom, or Waiting Area	Downlight large 6"+ 90CRI	1,440	27	78	36	0.7	$162	0	0	NA	0	0			$0.00	$0.00	$120.15
Museum Area: Exhibition/Display	#N/A	0	0		#N/A	0.0		0	0	NA	0	0				$0.00	$0.00
Museum Area: Restoration Room	#N/A	0	0		#N/A	0.0	$0	27,000	830	Linear Direct Lensed (repl	446	106	48	9.3	$122.00	$1,137.74	$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	Troffer Basket 90CRI	10,800	201	101	41	4.9	$196	5,400	839	Task (repl FL)	129	67	7	17.4	$45.00	$783.31	$952.28
~~Open plan office~~ > 250 sf	Pendant direct/indirect 80CRI	67,200	1,129	97	50	22.8		21,600	839	Task (repl FL)	514	67	7	69.6		$0.00	$0.00

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				$0.00	$0.00
Parking Garage Area: Dedicated Ramps	Parking garage luminaire 70CRI	0	0	111	42	0.0	$300	0	0	NA	0	0			$0.00	$0.00	$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			$0.00	$0.00	$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	63	106	48	1.3	$122.00	$161.81	$442.99
Retail Sales Area: Grocery Sales	Downlight large 6"+ 90CRI	218,880	3,524	78	36	96.7	$162	100,800	841	Downlight open (repl MH)	1,761	86	46	38.3	$157.00	$6,016.03	$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	$158.00	$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	15	106	48	0.3		$0.00	$0.00
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	$360.00	$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 CF	27	77	30	0.9		$0.00	$0.00
Stairwell	#N/A	0	0	#N/A	#N/A	0.0	#N/A	0	0	NA	0	0			$0.00	$0.00	$0.00
Theater Area: Motion picture	Troffer Basket 80CRI	23,400	419	116	38	11.1	$146	0	0	NA	0	0			$0.00	$0.00	$1,618.65
Theater Area: Performance	Downlight 4" and less 90CRI Warm	320,000	6,473	69	36	181.1	$162	280,000	811	PAR downlight flood	6,901	71	27	256.5	$158.00	$40,532.88	$29,345.13
Transportation Function : Baggage Area	Downlight large 6"+ 80CRI	32,400	643	82	33	19.6		27,000	835	Linear Dir/Ind (repl FL)	412	105	42	9.8		$0.00	$0.00
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		$0.00	$0.00
Videoconferencing Studio																	
Aging Eye/Low-vision: Main Entry Lobby	#N/A	0	0		#N/A	0.0		0	801	Downlight open (repl INC)	0	86	46			$0.00	$0.00
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	$157.00	$132.50	$0.00
Aging Eye/Low-vision: Corridor Area	#N/A	0	0		#N/A	0.0	$0	0	0	NA	0	0			$0.00	$0.00	$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	$158.00	$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	$158.00	$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				$0.00	$0.00
Aging Eye/Low-vision: Dining	Downlight 4" and less 90CRI	48,000	833	83	29	28.7		19,200	823	Indirect Pendant (repl CF)	810	77	124	6.5		$0.00	$0.00
Aging Eye/Low-vision: Restroom	Downlight 4" and less 90CRI	4,320	89	83	29	3.1	$162	1,944	820	Downlight Lensed (repl CF	52	77	30	1.7	$162.00	$282.54	$500.23
Healthcare Facility and Hospitals: Exam/Treatment Roo	Troffer Basket 90CRI	1,800	55	101	41	1.3		0	0	NA	0	0				$0.00	$0.00
Healthcare Facility and Hospitals: Imaging Room	Downlight large 6"+ 80CRI	3,360	69	82	33	2.1	$162	1,120	820	Downlight Lensed (repl CF	26	77	30	0.9	$162.00	$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				$0.00	$0.00
Healthcare Facility and Hospitals: Nursery	Troffer Basket 80CRI	19,200	240	116	38	6.4	$146	4,800	800	Linear Rec Hi Perf Lensed	86	119	41	2.1	$129.00	$273.70	$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	36,000	649	101	41	15.7		0	0	NA	0	0				$0.00	$0.00
Healthcare Facility and Hospitals: Patient Room	Troffer Basket 90CRI	4,608	117	101	41	2.8	$196	2,400	830	Linear Direct Lensed (repl	40	106	48	0.8	$122.00	$101.13	$555.56
Healthcare Facility and Hospitals: Physical Therapy Ro	Downlight large 6"+ 80CRI	12,000	193	82	33	5.9	$162	24,000	835	Linear Dir/Ind (repl FL)	466	105	42	11.1	$372.00	$4,111.18	$953.15
Healthcare Facility and Hospitals: Recovery Room	Troffer Basket 90CRI	4,608	117	101	41	2.8		0	0	NA	0	0				$0.00	$0.00
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				$0.00	$0.00
Sports Arena – Playing Area: Class II Facility	High Bay 80CRI	500,000	9,119	128	175	52.1		0	0	NA	0	0				$0.00	$0.00
Sports Arena – Playing Area: Class III Facility	Low bay 80CRI	375,000	5,702	145	112	51.1		0	0	NA	0	0				$0.00	$0.00
Sports Arena – Playing Area: Class IV Facility	Low bay 80CRI	250,000	3,801	145	112	34.0		0	0	NA	0	0				$0.00	$0.00

Table 124: Supplemental Lighting System Proposed 2022 and 2019 Base Costs

Primary Function Area	2022 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 Out	24,000	389	122	59	7		0	0	NA	0.00	0		0.00		$0.00	$0.00
Barber, Beauty Salon and Spa Area	Downlight 4" and less 90CRI	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		$0.00	$0.00
Concourse and Atria Area	#N/A	0	0	0	#N/A		$0.00	120,000	834-1	Linear Wall Cove (	3573.63	81	26	136.20	$360	$49,033.08	$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						$0.00	$0.00
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		$0.00	$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 Out	13,500	361	115	67	5		0	0	NA	0.00	0		0.00		$0.00	$0.00
Electrical, Mechanical, Telephone Rooms	#N/A	0	0	0	#N/A			0	0	NA	0.00	0		0.00		$0.00	$0.00
Exercise/Fitness Center and Gymnasium Area	#N/A	0	0	0	#N/A			0	0	NA	0.00	0		0.00		$0.00	$0.00
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 H	48,000	1,223	76	15	82		0	0	NA	0.00	0		0.00		$0.00	$0.00
General/Commercial & Industrial Work Area: High Bay	Strip Under cabinet 80CRI H	120,000	2,978	76	15	199		0	0	NA	0.00	0		0.00		$0.00	$0.00
General/Commercial & Industrial Work Area: Precisio	Industrial strip 80CRI Hi Out	72,000	855	122	59	14		0	0	NA	0.00	0		0.00		$0.00	$0.00
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 H	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	0	NA	0.00	0		0.00		$0.00	$0.00
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	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		$0.00	$0.00
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		$0.00	$0.00
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	Strip Under cabinet 80CRI	0	0	63	9		$40.00	0	0	NA	0.00	0		0.00	$0	$0.00	$0.00
~~Open plan office~~ > 250 sf	Strip Under cabinet 80CRI	0	0	63	9			0	0	NA	0.00	0		0.00		$0.00	$0.00

Primary Function Area	2022 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		$0.00	$0.00
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 F	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	0	0	NA	0.00	0	Zero Field (	0.00	$0	$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	0	NA	0.00	0				$0.00	$0.00
Religious Worship Area	Downlight 4" and less 90CRI	120,000	2,023	83	29	70	$162.00	84,000	811	PAR downlight flo	1719.70	71	27	63.93	$158	$10,100.84	$11,315.18
Restrooms	#N/A	0	0	0	#N/A			0	0	NA	0.00	0				$0.00	$0.00
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	0	NA	0.00	0				$0.00	$0.00
Transportation Function : Ticketing Area	#N/A	0	0	0	#N/A			0	0	NA	0.00	0				$0.00	$0.00
Videoconferencing Studio																	
Aging Eye/Low-vision: Main Entry Lobby	#N/A	0	0	0	#N/A			0	0	NA	0.00	0				$0.00	$0.00
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			12,096	801	Downlight open (re	205.00	86	46			$0.00	$0.00
Aging Eye/Low-vision: Dining	#N/A	0	0	0	#N/A			0	0	NA	0.00	0				$0.00	$0.00
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 Roo	Downlight large 6"+ 90CRI	3,600	79	78	36	2		0	0	NA	0.00	0				$0.00	$0.00
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				$0.00	$0.00
Healthcare Facility and Hospitals: Nursery	Downlight large 6"+ 90CRI	8,000	138	78	36	4	$162.00	1,600	800	Linear Rec Hi Perf	28.80	119	41	0.71	$129	$91.23	$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	0	0	0	#N/A			0	0	NA	0.00	0				$0.00	$0.00
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 Ro	#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	3,840	72	69	36	2		0	0	NA	0.00	0	0	0.00		$0.00	$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		$0.00	$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		$0.00	$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		$0.00	$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		$0.00	$0.00

Table 125: 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	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 WW Luminaire Ref No.	2019 WW Luminaire Description	2019 Wall Washer System Watts	2019 Vertical delivered efficacy	2019 Avg Watts/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	17.6	$380.00	906	WW - Aperture HC	153.81	31.21	52.0	3.0	$282.00	$834.13	$6,696.33	$10,026	$8,716
Auditorium Area	Hi CRI Linear WW HO 70/50/20	2,281	35.4	37.0	61.7	$410.00	902	Wall Graze - Aperture	2,048	29	24	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		0	N/A	0	N/A	N/A	0.0		$0.00	$0.00	$0	$0
Barber, Beauty Salon and Spa Area	Hi CRI Aperture WW 70/50/20	177	37.5	23.4	7.6	$228.00	902	Wall Graze - Aperture	236	29	24	9.8	$282.00	$2,772.77	$1,728.59	$5,616	$7,585
Civic Meeting Place Area	Hi CRI Aperture WW 70/50/20	141	37.5	23.4	6.0	$228.00	952	CRI-Wall Graze - Aperture	92	23	34	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	4.1	$356.00	905	Wall Wash - Linear	207	34	18	11.5	$320.00	$3,674.91	$1,458.37	$5,446	$2,752
Commercial/Industrial Storage: Warehouse	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$483	$514
Commercial/Industrial Storage: Shipping & Handling	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Concourse and Atria Area	Linear Wall Grazer HO 70/30/20	3,355	30.7	47.0	71.4	$380.00	906	WW - Aperture HC	0	31	52	0.0	$282.00	$0.00	$27,122.99	$83,880	$44,017
Convention, Conference, Multipurpose and Meeting Are	Hi CRI Linear WW 70/50/20	171	38.7	27.0	6.3	$228.00	954	CRI-Wall Wash - Aperture	170	35	34	5.0	$282.00	$1,413.05	$1,440.00	$9,214	$3,390
Copy Room	0	0	38.7	27.0	0.0		#N/A	No copy room model in 2019				0.0				$0	$0
Corridor Area	Forward throw WW corridor 70/50/20	59	69.8	27.0	2.2	$360.00	901	Forward WW - Linear	292	22	18	16.2	$320.00	$5,196.21	$790.32	$5,196	$1,804
Dining Area: Bar/Lounge and Fine Dining	Hi CRI Linear Wall Grazer HO 70/50/20	201	28.3	36.8	5.5	$444.00	952	CRI-Wall Graze - Aperture	307	23	34	9.0	$282.00	$2,548.50	$2,420.65	$5,812	$10,221
Dining Area: Cafeteria/Fast Food	Linear WW 70/50/20	129	43.0	27.0	4.8		905	Wall Wash - Linear	105	34	18	5.8				$0	$0
Dining Area: Family and Leisure	Linear WW 70/50/20	90	43.0	27.0	3.3	$356.00	905	Wall Wash - Linear	280	34	18	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		0	N/A	0	N/A	N/A	0.0				$0	$0
Electrical, Mechanical, Telephone Rooms	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Exercise/Fitness Center and Gymnasium Area	0	0	#N/A	#N/A	#N/A		901	Forward WW - Linear	0	22	18	0.0				$0	$0
Financial Transaction Area	Linear Wall Grazer 70/50/20	177	37.5	27.0	6.6	$356.00	903	Wall Graze - Linear	87	31	18	4.8	$360.00	$1,736.20	$2,340.31	$7,694	$4,084
General/Commercial & Industrial Work Area: Low Bay	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
General/Commercial & Industrial Work Area: High Bay	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
General/Commercial & Industrial Work Area: Precision	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Hotel Function Area	Hi CRI Aperture WW 70/50/20	141	37.5	23.4	6.0	$228.00	904	Wall Wash - Aperture	41	44	24	1.7	$228.00	$388.44	$1,371.90	$1,292	$2,910
Scientific Laboratory Area	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$8,327	$958
Laundry Area	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Library : Reading Area	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$3,981	$1,864
Library : Stacks Area	0	0	#N/A	#N/A	#N/A	#N/A	901	Forward WW - Linear	0	22	18	0.0	$320.00	$0.00	$0.00	$4,158	$2,493
Main Entry Lobby	Hi CRI Aperture WW HO 70/40/20	497	36.3	50.0	9.9	$282.00	906	WW - Aperture HC	385	31	52	7.4	$282.00	$2,085.32	$2,800.55	$6,512	$5,313
Locker Room	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Lounge, Breakroom, or Waiting Area	Hi CRI Linear Wall Grazer 70/50/20	150	22.1	18.3	8.2	$406.00	953	CRI-Wall Graze - Linear	258	25	28	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		0	N/A	0	N/A	N/A	0.0				$0	$0
Museum Area: Restoration Room	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$4,917	$8,995
Office Area: ≤ 250 square feet	Linear WW 70/50/20	0	43.0	27.0	0.0	$356.00	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$404	$310
Office Area: > 250 square feet	Forward throw WW 70/50/20	68	51.6	28.0	2.4	$360.00	905	Wall Wash - Linear	52	34	18	2.9	$320.00	$932.54	$872.58	$3,153	$1,986
~~Open plan office~~ > 250 sf	Aperture WW HO 70/30/20	189	42.3	50.0	3.8		905	Wall Wash - Linear	210	34	18	11.7		$0.00	$0.00	$0	$0

Primary Function Area	2022 Wall Washer Description	2022 Wall Washer System Watts	2022 Vertical Delivered Efficacy	2022 Avg Watts/luminaire	2022 Number of Luminaires	2022 Cost Per Luminaire	2019 WW Luminaire Ref No.	2019 WW Luminaire Description	2019 Wall Washer System Watts	2019 Vertical delivered efficacy	2019 Avg Watts/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		0	N/A	0	N/A	N/A	0.0				$0	$0
Parking Garage Area: Dedicated Ramps	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#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	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$5,395	$8,195
Pharmacy Area	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$1,097	$1,721
Retail Sales Area: Grocery Sales	Hi CRI Linear WW 70/50/20	286	38.7	27.0	10.6	$228.00	905	Wall Wash - Linear	3,730	34	18	207.2	$320.00	$66,314.09	$2,419.20	$75,305	$24,333
Retail Sales Area: Retail Merchandise Sales	Hi CRI Aperture WW 70/50/20	887	37.5	23.4	37.9	$228.00	904	Wall Wash - Aperture	1,308	44	24	54.5	$228.00	$12,430.04	$8,642.95	$42,596	$29,300
Retail Sales Area: Fitting Room	Hi CRI Aperture WW 70/50/20	71	37.5	23.4	3.1		0	N/A	0	N/A	N/A	0.0				$0	$0
Religious Worship Area	Hi CRI Linear Wall Grazer HO 70/30/20	758	25.7	36.8	20.6	$444.00	952	CRI-Wall Graze - Aperture	2,276	23	34	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	0.8		903	Wall Graze - Linear	86	31	18	4.8				$0	$0
Stairwell	Linear WW 70/50/20	0	43.0	27.0	0.0	$356.00	901	Forward WW - Linear	329	22	18	18.3	$320.00	$5,845.74	$0.00	$5,846	$542
Theater Area: Motion picture	Linear Wall Grazer 70/30/20	0	36.0	27.0	0.0	$356.00	903	Wall Graze - Linear	0	31	18	0.0	$360.00	$0.00	$0.00	$5,628	$2,591
Theater Area: Performance	Hi CRI Linear Wall Grazer HO 70/30/20	5,027	25.7	36.8	136.6	$444.00	952	CRI-Wall Graze - Aperture	9,104	23	34	267.8	$282.00	$75,511.03	$60,654.92	$119,904	$90,000
Transportation Function : Baggage Area	Forward throw WW 70/50/20	244	51.6	28.0	8.7		902	Wall Graze - Aperture	1,106	29	24	46.1				$0	$0
Transportation Function : Ticketing Area	Linear WW 70/50/20	235	43.0	27.0	8.7		905	Wall Wash - Linear	175	34	18	9.7				$0	$0
Videoconferencing Studio																$0	$0
Aging Eye/Low-vision: Main Entry Lobby	Linear Wall Grazer 70/50/20	560	37.5	27.0	20.8		903	Wall Graze - Linear	78	31	18	4.3				$0	$0
Aging Eye/Low-vision: Stairwell	Forward throw WW 70/50/20	37	51.6	28.0	1.3	$360.00	903	Wall Graze - Linear	103	31	18	5.7	$360.00	$2,066.91	$474.68	$2,355	$959
Aging Eye/Low-vision: Corridor Area	Hi CRI Forward throw WW corridor 70/5	287	55.1	27.0	10.6	$410.00	902	Wall Graze - Aperture	437	29	24	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	17.1	$228.00	903	Wall Graze - Linear	194	31	18	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	7.5	$228.00	903	Wall Graze - Linear	174	31	18	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	24.6		903	Wall Graze - Linear	109	31	18	6.0				$0	$0
Aging Eye/Low-vision: Dining	Hi CRI Linear Wall Grazer 70/50/20	606	22.1	18.3	33.1		903	Wall Graze - Linear	207	31	18	11.5				$0	$0
Aging Eye/Low-vision: Restroom	Forward throw WW 70/50/20	81	51.6	28.0	2.9	$360.00	903	Wall Graze - Linear	93	31	18	5.2	$360.00	$1,860.22	$1,047.09	$2,758	$2,304
Healthcare Facility and Hospitals: Exam/Treatment Roo	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Healthcare Facility and Hospitals: Imaging Room	0	0	#N/A	#N/A	#N/A	#N/A	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$1,190	$458
Healthcare Facility and Hospitals: Medical Supply Roo	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Healthcare Facility and Hospitals: Nursery	0	0	#N/A	#N/A	#N/A	#N/A	905	Wall Wash - Linear	0	34	18	0.0	$320.00	$0.00	$0.00	$1,460	$1,540
Healthcare Facility and Hospitals: Nurse’s Station	Hi CRI Linear Wall Grazer 70/50/20	102	22.1	18.3	5.6	$406.00	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$2,255.11	$1,038	$2,778
Healthcare Facility and Hospitals: Operating Room	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Healthcare Facility and Hospitals: Patient Room	Hi CRI Aperture WW 70/50/20	0	37.5	23.4	0.0	$228.00	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$0.00	$447	$751
Healthcare Facility and Hospitals: Physical Therapy Rc	Linear Wall Grazer 70/50/20	411	37.5	27.0	15.2	$356.00	0	N/A	0	N/A	N/A	0.0	#N/A	$0.00	$5,417.39	$8,222	$7,014
Healthcare Facility and Hospitals: Recovery Room	Hi CRI Linear WW 70/50/20	26	38.7	27.0	1.0		955	CRI-Wall Wash - Linear	47	27	28	1.7				$0	$0
Sports Arena – Playing Area: Class I Facility	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Sports Arena – Playing Area: Class II Facility	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Sports Arena – Playing Area: Class III Facility	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0
Sports Arena – Playing Area: Class IV Facility	0	0	#N/A	#N/A	#N/A		0	N/A	0	N/A	N/A	0.0				$0	$0

Salmon-colored rows 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.

These costs are summarized in Table 53 and are compared against the energy cost savings to determine the B/C ratio for each primary application area. A similar effort was conducted, but instead of calculating the values for each prototypical space, the results were calculated relative to the statewide new construction square footage added each year. This is summarized in Table 56. Overall, the proposed LPDs for each year’s new construction would save $290 million in first costs, 24 GWh/yr in electricity consumption, and reduce operating expenditure on energy costs by $60 Million/yr.

Appendix T: Large Office Detailed Radiosity Method Models

This section documents the analysis conducted to address comments from lighting designers that thought the 2019 LPD standards were achievable under most circumstances; however, there are some circumstances where this is difficult. One example was presented where a brick manufacturing building was being repurposed as an office building and the designer wished to expose the brick and highlight this as a design feature. Brick has a very low reflectance (around 10 percent) and as a result, absorbs more light than light colored walls with effective reflectances of 50 percent. Office spaces with system furniture have more nooks and crannies, with a variety of tasks that render them harder to simulate with the inverse lumen method. Though task/ambient lighting is more energy efficient, many offices have large monitors with some applications having multiple large monitors per desk. As a result, undercabinet lighting is blocked by these large monitors and in some cases, there is not much desktop area for portable lighting. Additionally, office spaces are a significant application type with more statewide area than any other space type, so it is prudent to spend more resources to characterize these spaces well as the lighting power densities selected for these space types have a large statewide energy impact. Large office spaces were simulated in 2019 using detailed radiosity method tools (AGI32), and these models were revisited and updated to investigate the specific issue of whether the proposed 2022 large office LPDs were robust enough to accommodate several design approaches and different wall and ceiling reflectances.

T.1. Title 24 2019 Design A (Pendant Task/Ambient Design)

Plan A is a large office design sometimes called “open plan” with systems furniture and cubicles. This is a task/ambient design with circulation and general lighting light levels provided by ceiling mounted but with task lamps and undercabinet lighting providing the higher illumination levels required for detailed tasks.

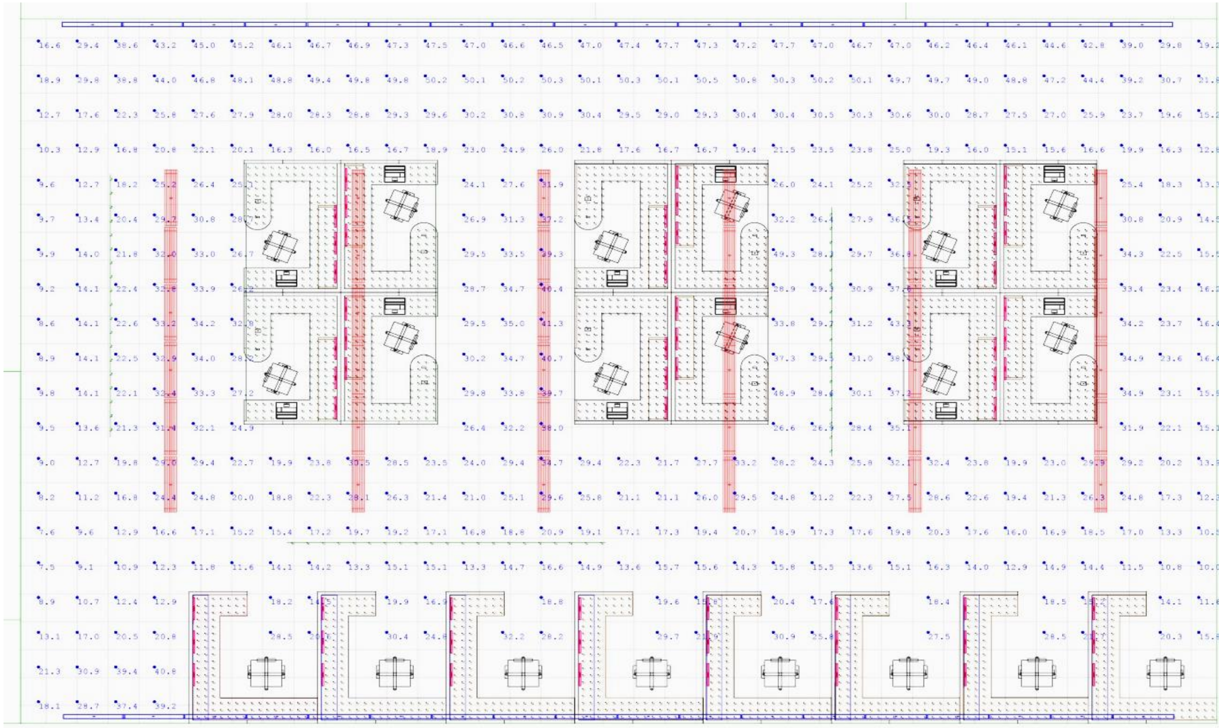


Figure 42: Plan View 2019 Design A (Direct Indirect Pendants, Task Ambient Lighting)

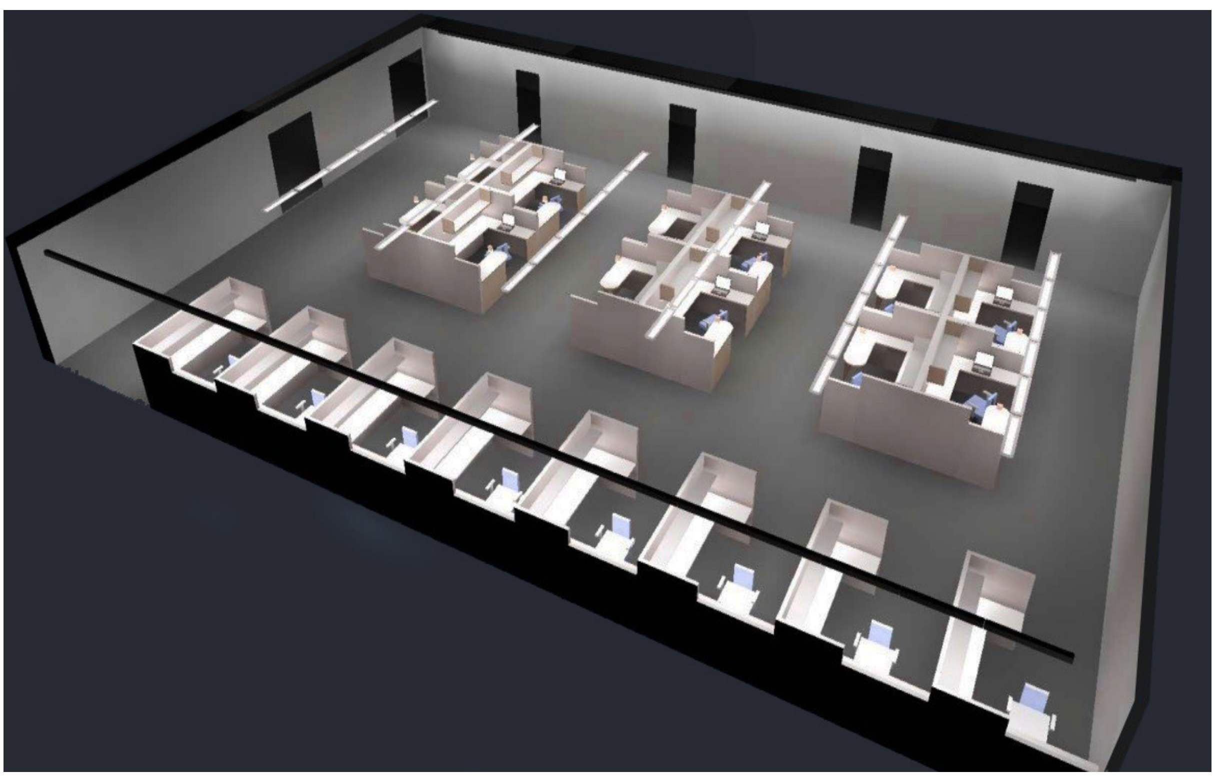


Figure 43: Perspective View 2019 Plan A

This task/ambient design makes use of direct/indirect LED pendant luminaires for general illumination. Wall-washers on the long wall opposite center room cubicles brighten wall surfaces as do wall-grazers on long wall adjacent to wall cubicles. Some of the spill light from the wall grazers also increase illuminance in the adjacent cubicles. Task lighting (under shelf and desk lamps) for high level; illuminance on desktops within the cubicles. Refer to Table 126 for performance details such as space geometry, reflectances, foot-candle target, luminaire distribution and color quality. Space dimensions are the same across all models and are not repeated in tables for the other design models.

The lighting power density for Model A is **0.456 W/sf.**

Table 126: Design Summary - 2019 T-24 Model A: Original Model – Task/Ambient with Pendant Lighting

Surface	Refl	Dimensions	Illuminance Targets	FC	Luminaire Type	Distribution	CCT / CRI
Ceiling	80	78.0' L X 50.1' W X 9.0' H	Circulation (average)	26	Circulation	Direct/Indirect Linear Pendants	3500/80
Wall 1	50	50.1' L X 9.0' H	Center Cubicle Tasks	42-46	Wall-Washer	Asymmetrical Recessed LED	3500/84
Wall 2	50	78.0' L X 9.0' H	Wall Cubicle Tasks	37-46	Wall Grazer	Asymmetrical Recessed LED	3500/80
Wall 3	50	50.1' L X 9.0' H	Focal zones (desk top)	71-93	Undercounter	Linear LED Shelf Mount Task	3500/87
Wall 4	50	78.0' L X 9.0' H	Wall-Washer (vertical)	21	Desk Lamp	LED Table Task Lamp	3500/87
Floor	20	78.0' L X 50.1' W	Wall Grazer (vertical)	19			

T.2. Title 24 2019 Design B (Recessed Troffer Task/Ambient Design)

Plan B is a large office task/ambient design with circulation and general lighting light levels provided by LED basket troffers and with task lamps and undercabinet lighting providing the higher illumination levels required for detailed tasks. The primary difference between 2019 Design A and 2019 Design B is that general lighting in Design B is provided with recessed basket troffers.

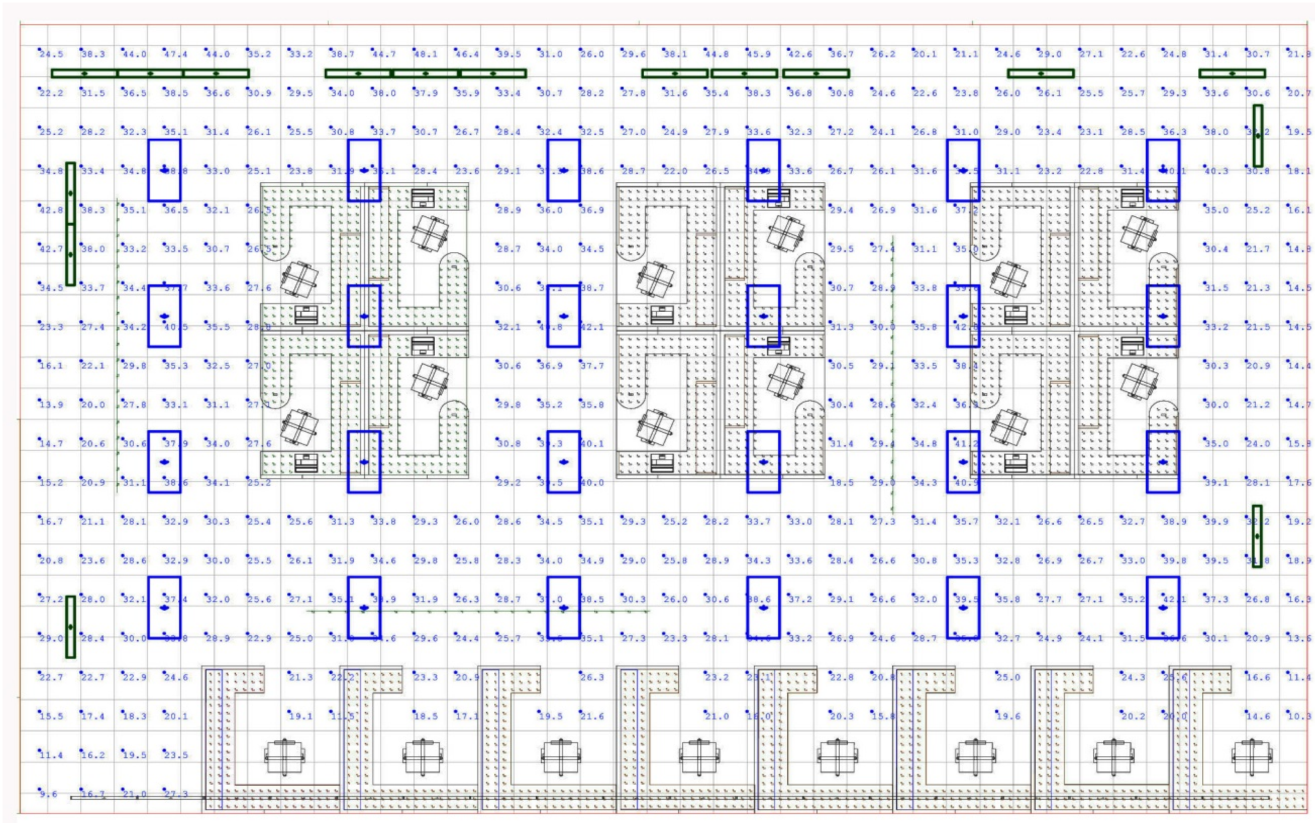


Figure 44: Plan View 2019 Design B (Recessed LED Basket Troffers Task Ambient Lighting)

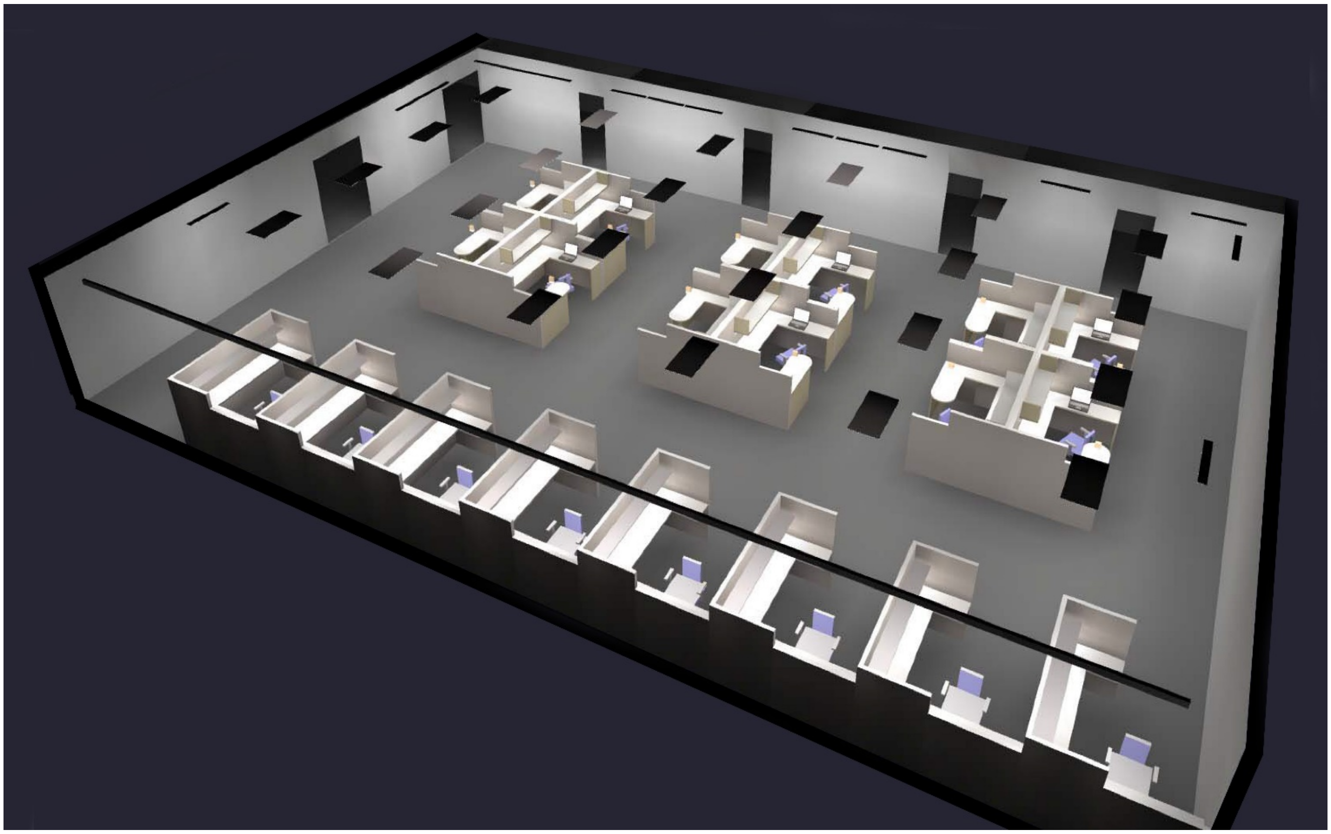


Figure 45: Perspective View 2019 Plan B

General illumination is provided by twenty-four 2’ X 4’ recessed basket LED troffer luminaires. Wall-washers on the long wall opposite center room cubicles and several additional wall-washers on two short walls provide wall brightness or highlight art. Wall-grazers on the long wall adjacent to wall cubicles brighten the wall and spill lights provides some task illuminance in the adjacent cubicles. Task lighting (under shelf and desk lamps) provide high levels of illuminance on desktops within the cubicles. Refer to Table 127 for performance details such as foot-candle targets, luminaire types and light source quality.

The lighting power density for Model B is **0.491 W/sf.**

Table 127: Design Summary - 2019 T-24 Model B: Original Model – Task/Ambient with Recessed Basket Troffers

Surface	Refl	Illuminance Targets	FC	Luminaire Type	Distribution	CCT / CRI
Ceiling	80	Circulation (average)	31	Circulation	2 X 4 LED Basket Troffer	3500/80
Wall 1	50	Center Cubicle Tasks	46-50	Wall-Washer	Asymmetrical Recessed LED	3500/84
Wall 2	50	Wall Cubicle Tasks	31-38	Wall Grazer	Asymmetrical Recessed LED	3500/80
Wall 3	50	Focal zones (desk top)	63-87	Undercounter	Linear LED Shelf Mount Task	3500/87
Wall 4	50	Wall-Washer (vertical)	28	Desk Lamp	LED Table Task Lamp	3500/87
Floor	20	Wall Grazer (vertical)	19			

T.3. Title 24 2022 Design A1 (Pendant Task/Ambient Lighting, Low Wall Reflectance)

Design A1 is a large office design with pendent lighting wall washing and undercabinet task lighting similar to Design A, except that Design A1 has one of the long walls being modelled with a reflectance of 10 percent to represent a brick wall. As a result, higher wattage wall washers were aimed at the wall so the luminance of the wall would not drop as much relative to the original design.

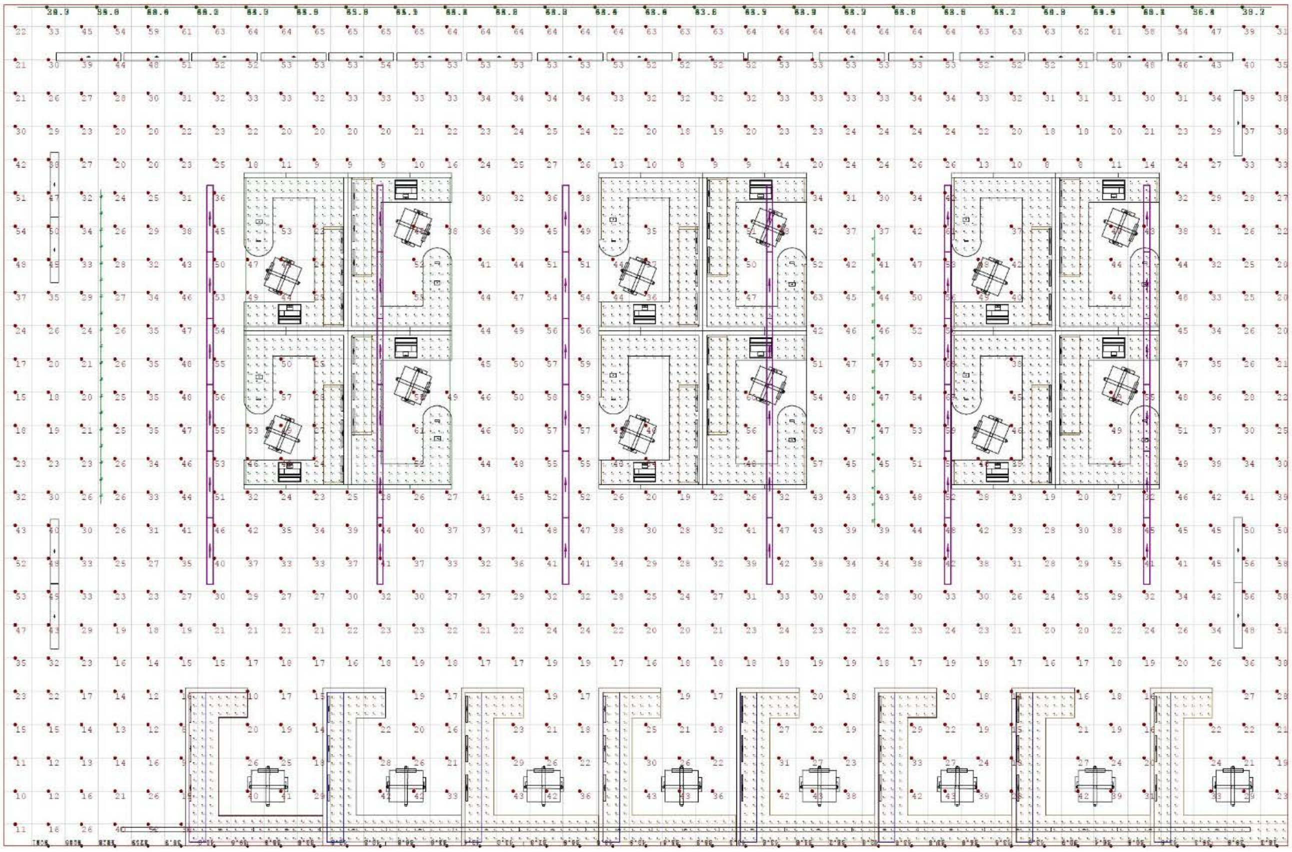


Figure 46: Plan View 2022 Design A1 (Pendant + Task Lighting).

Figure 47: Perspective View 2022 Design A1 Pendant + Undercabinet Lighting with Brick Wall.

Open plan office design with addition of "Dark Brick" wall (10% reflectance) and enhanced wall-washers for illumination of wall as well as several additional wall-washers for art/graphics on the two short walls. Direct/indirect LED pendant luminaires for general illumination. Wall-grazer on long wall adjacent to wall cubicles. Task lighting (under shelf and desk lamps) for high level illuminance on desktops withing the in cubicles.

To offset the absorbed light on the brick wall, wall washing was increased and as a result the projected overall lighting power density for Model A1 increased to **0.542 W/sf.**

Table 128: Design Summary – 2022 T-24 Model A1: Pendant Task/Ambient System and Brick (low reflectance) Wall

Surface	Refl	Dimensions	Illuminance Targets	FC	Luminaire Type	Distribution	CCT / CRI
Ceiling	80	78.0' L X 50.1' W X 9.0' H	Circulation (average)	34	Circulation	Direct/Indirect Linear Pendants	3500/80
Wall 1	50	50.1' L X 9.0' H	Center Cubicle Tasks	42-52	Wall-Washer	Asymmetrical Recessed LED	3500/84
Wall 2	50	78.0' L X 9.0' H	Wall Cubicle Tasks	38-46	Wall Grazer	Asymmetrical Recessed LED	3500/80
Wall 3	50	50.1' L X 9.0' H	Focal zones (desk top)	71-93	Undercounter	Linear LED Shelf Mount Task	3500/87
Wall 4	50	78.0' L X 9.0' H	Wall-Washer (vertical)	49	Desk Lamp	LED Table Task Lamp	3500/87
Floor	20	78.0' L X 50.1' W	Wall Grazer (vertical)	19			

T.4. Title 24 2022 Design A2 (Pendant no Task Lighting, Low Wall Reflectance)

Design A2 is a large office design with systems furniture and cubicles but is not a task/ambient system. This design is less efficient for two reasons: 1) the direct/indirect lighting has a lower optical efficiency as uplight leaving the fixture bounces off the ceiling with some absorptance losses, 2) this design contains a brick wall with 10% reflectivity. The direct/indirect provides great uniformity and a bright ceiling surface but is not great for providing high light levels needed for tasks. The low reflectance wall absorbs light and requires added light to provide a moderate luminance. The Statewide CASE Team is looking at this as a worst-case scenario, but some designs might use this approach.

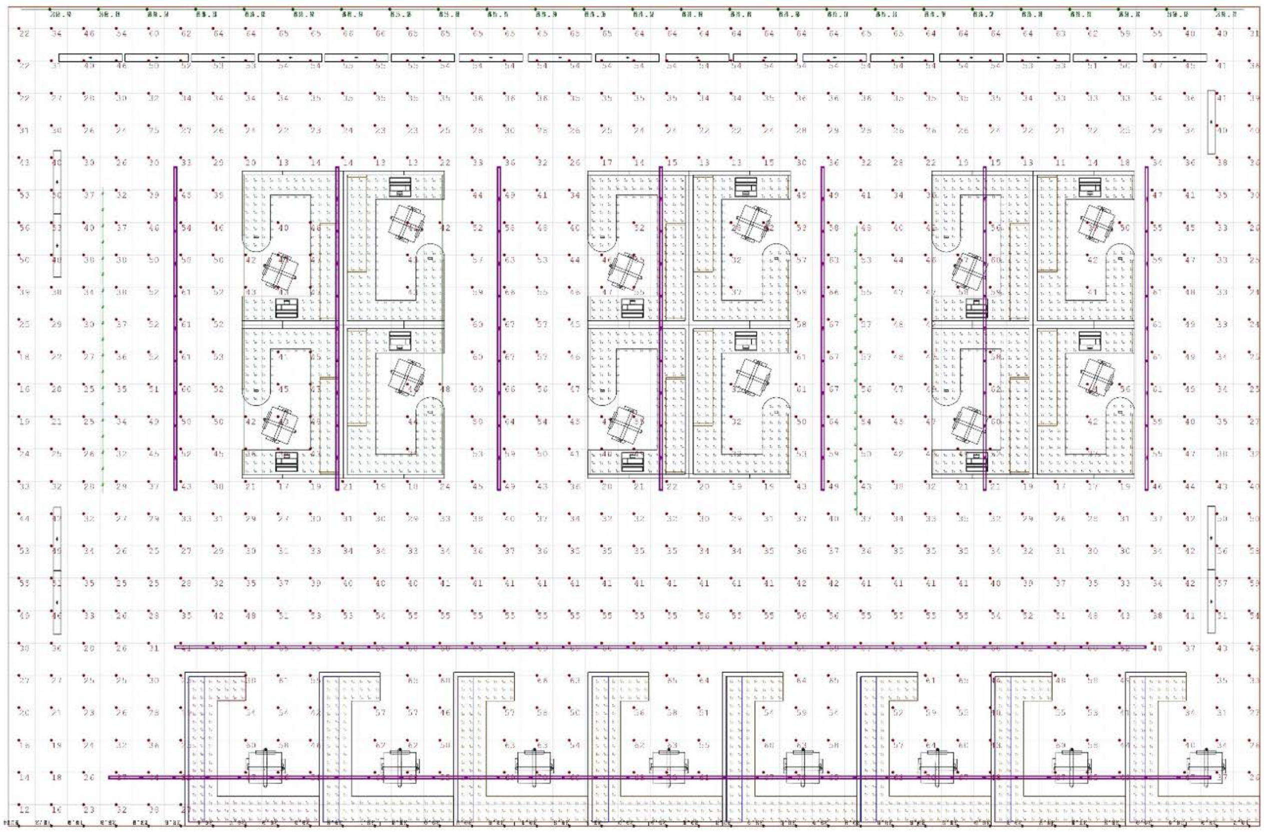


Figure 48: Plan View 2022 Design A2 (Direct Indirect Pendant Lighting Providing Task and General Lighting).

Carefully examing the rendering of Design A2 in Figure 49 without task lighting and compare that to the rendering of Design A1 with task lighting in Figure 47, shows that the task surfaces are brighter in Design A1 and with less power required. This helps highlight how task ambient design is an effective efficiency measure that saves energy and increases the amount of light where it is needed.

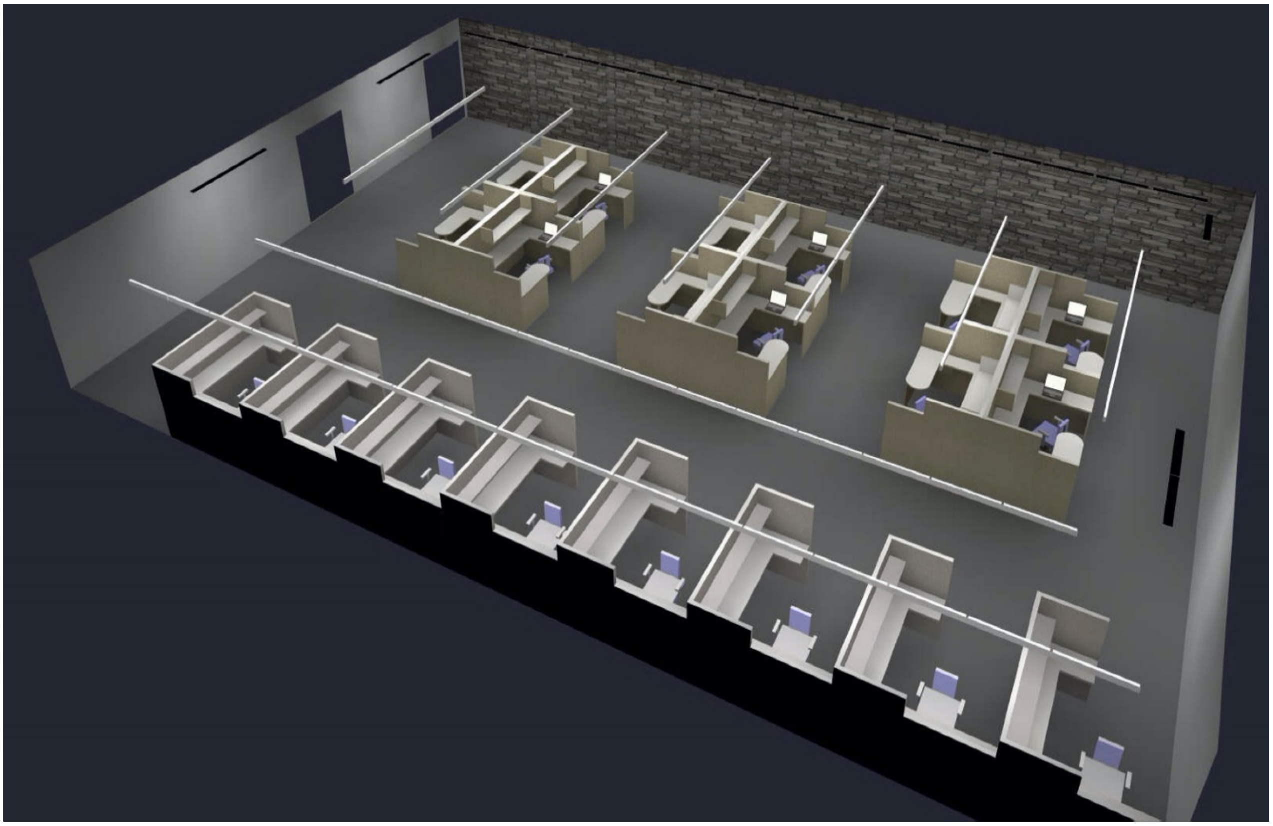


Figure 49: Perspective View 2022 Design A2 Pendant Lighting and No Task Lighting with Brick Wall.

Open plan office design with addition of “Dark Brick” wall *(10% reflectance)* and enhanced wall-washers for illumination of wall as well as several additional wall-washers for art/graphics on the two short walls. To achieve the design objective relatively efficiently wall using only ceiling mounted lighting, included deletion of task lighting *(under shelf and desk lamps*) within the cubicles and deletion of wall-grazers on long wall adjacent to wall cubicles. More direct/indirect LED pendant luminaires (with increased lumen output) were added to accommodate both general and task illumination. Table 129 summarizes changes in the design and results. The two primary changes are the reflectance of Wall 4 (dropped from 50% to 10% reflectance) and the overall workplan average illuminance increased. This work plane illuminance serves both circulation and tasks (see the asterisk in the table). Note that the cubicle task illuminances are slightly lower than the average work plane illuminance due to some absorption of light by the systems furniture partitions.

To offset the absorbed light on the brick wall, wall washing was increased. To provide reasonable task illuminances without dedicated tasks lights, the pendant general lighting system power was increased. As a result, the overall lighting power density for Model A2 increased to **0.737 W/sf.**

Table 129: Design Summary - 2022 T-24 Model A2: Pendant Lighting with Brick Wall (Pendants Providing Task and General Lighting)

Surface	Refl	Illuminance Targets	FC	Luminaire Type	Distribution	CCT / CRI
Ceiling	70	Circulation (average)*	43	Circulation	Increased Output Direct/Indirect	3500/80
Wall 1	50	Center cubicle Tasks	32-38	Wall-Washer	High Output Asymmetrical LED	3500/84
Wall 2	50	Wall cubicle Tasks	26-41	Wall Grazer	NA	NA
Wall 3	50	Focal zones (desk top)	42-54	Undercounter	NA	NA
Wall 4	10	Wall-Washer (vertical)	49	Desk Lamp	NA	NA
Floor	20	Wall Grazer (vertical)	NA			
*Work plane average for design without task lighting component						

T.5. 2022 Title 24 Design B1 (Recessed Basket Troffers, Low Wall Reflectance Task/Ambient Design)

This design is the same as the 2019 Title 24 Design B except for one of the long walls being modelled with a reflectance of 10 percent to represent a brick wall. As a result, higher wattage wall washers were aimed at the wall so the luminance of the wall would not drop as much relative to the original basket troffer design.

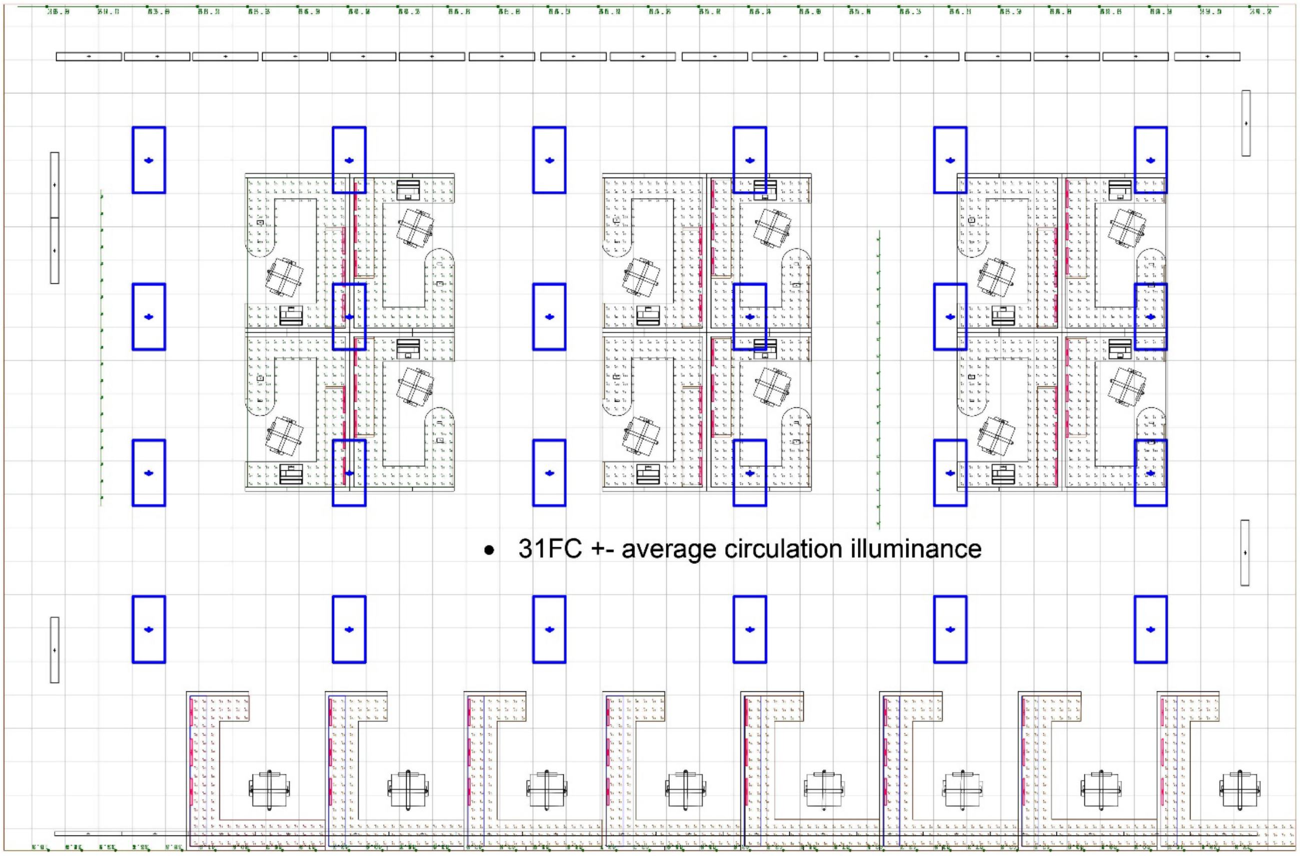


Figure 50: Plan View 2022 Design B1 (Troffer Lighting + Task Lighting).

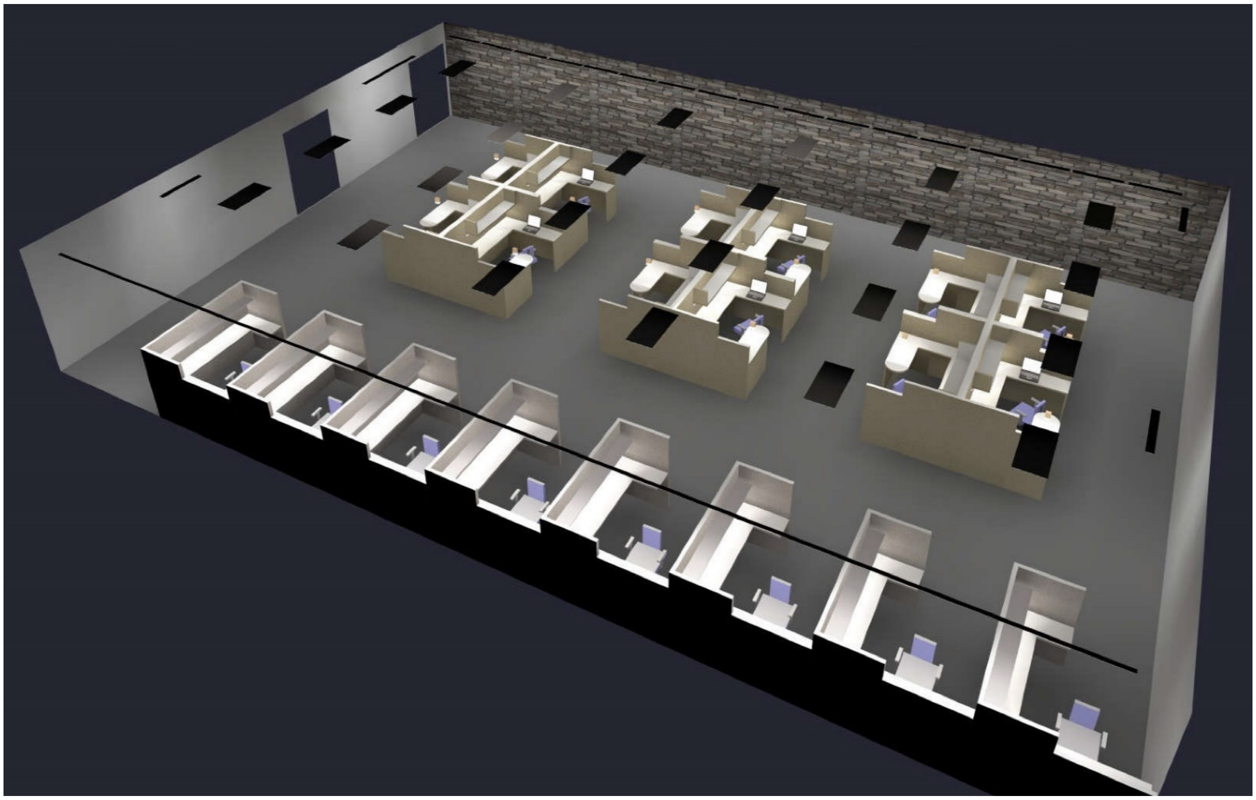


Figure 51: Perspective View 2022 Design B1 Troffer + Undercabinet Lighting with Brick Wall.

Open plan office design with addition of “Dark Brick” wall (10% reflectance) and enhanced wall-washers for illumination of wall as well as several additional wall-washers for art/graphics on the two short walls. The same twenty-four 2’ X 4’ recessed basket LED troffer luminaires were used for general illumination as in the original 2019 Model design. This design also retained the wall-grazers on long wall adjacent to wall cubicles. Task lighting (under shelf and desk lamps) for high level illuminance on desktops within the cubicles. Table 130 summarizes that the main change in the design is that wall 4 which had a 50 percent reflectance in Model B has now a reflectance of 10 percent in Model B1.

To offset the absorbed light on the brick wall, wall washing was increased and as a result the overall lighting power density for Model B1 increased to **0.608 W/sf.**

Table 130: Design Summary – 2022 T-24 Model B1: Recessed Basket Troffer Task/Ambient System and Brick (low reflectance) Wall

Surface	Refl	Illuminance Targets	FC	Luminaire Type	Distribution	CCT / CRI
Ceiling	70	Circulation (average)	31	Circulation	2 X 4 LED Basket Troffer	3500/80
Wall 1	50	Center cubicle Tasks	46-50	Wall-Washer	High Output Asymmetrical LED	3500/84
Wall 2	50	Wall cubicle Tasks	31-38	Wall Grazer	Asymmetrical Recessed LED	3500/80
Wall 3	50	Focal zones (desk top)	63-87	Undercounter	Linear LED Shelf Mount Task	3500/87
Wall 4	10	Wall-Washer (vertical)	41	Desk Lamp	LED Table Task Lamp	3500/87
Floor	20	Wall Grazer (vertical)	39			

T.6. 2022 Title 24 Design B2 (Recessed Basket Troffers, Low Wall Reflectance Task Lighting Provided by General Lighting System)

Design B2 is the same Design B1 except that undercabinet and task lighting has been removed. In its place, eleven more recessed troffers are placed in the ceiling to make up the difference in task lighting. As a result, this is not a task ambient system and is less efficient as the light source is no longer placed close to the task. However, the basket troffers are a very efficient light source. Additionally, the Statewide CASE Team is evaluating this design with one wall having a brick finish with 10 percent reflectivity. The Statewide CASE Team is looking at this as a less than optimal scenario but some designs might use this approach.

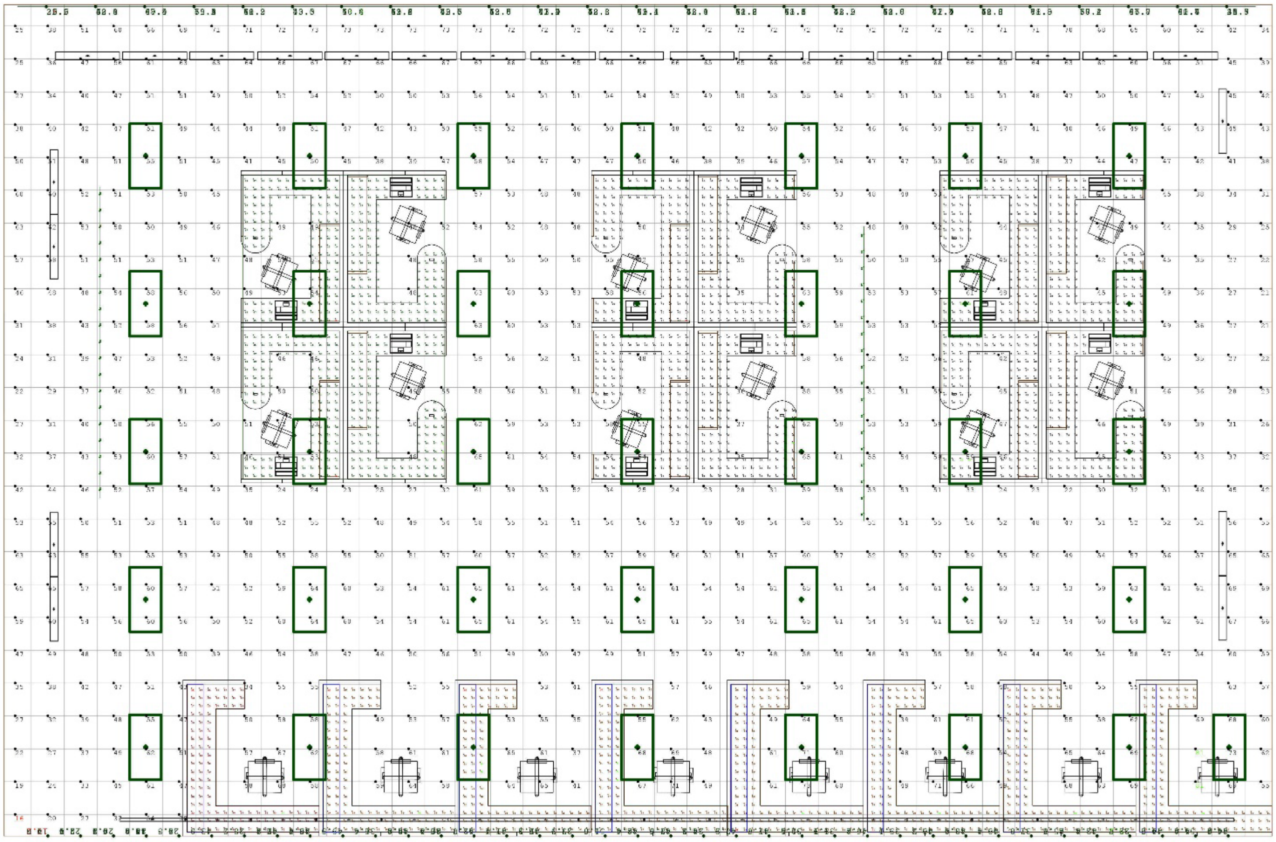


Figure 52: Plan View 2022 Design B2 (Troffer Lighting Providing Task and General Lighting).

Carefully examining the rendering of Design B2 in Figure 53 without task lighting and comparing that to the rendering of Design B1 with task lighting in Figure 51, shows that the task surfaces are brighter in Design B1 and with less power required. This helps highlight how task ambient design is an effective efficiency measure that saves energy and increases the amount of light where it is needed.

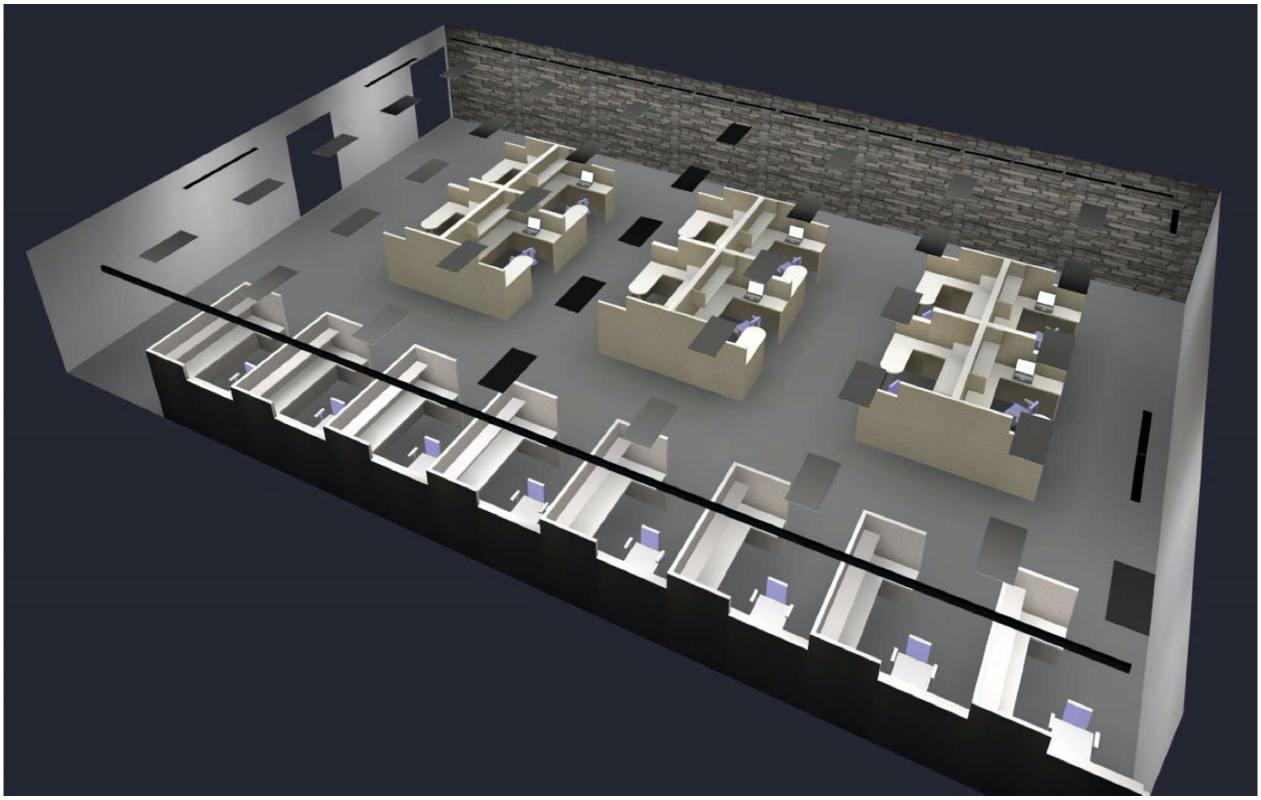


Figure 53: Perspective View 2022 Design B2 Troffers (Undercabinet Lighting Removed) with Brick Wall.

Open plan office design with addition of “Dark Brick” wall (10 percent reflectance) and enhanced wall-washers for illumination of wall as well as several additional wall-washers for art/graphics on the two short walls. Task lighting (under shelf and desk lamps) for high level illuminance on desktops within the cubicles was deleted. To increase the ambient light levels to also provide task lighting the number of troffers were increased from 24 to 35 troffers, and each troffer had a higher light output. This closer spacing allowed a troffer to be placed over each work surface while maintaining a regularly spaced grid of luminaires.

Wall-grazers on long wall adjacent to wall cubicles were retained in this design. Table 131 summarizes changes in the design and results. The two primary changes are 1) the reflectance of Wall 4 (dropped from 50 percent to 10 percent reflectance) and 2) the overall work plane average illuminance increased to provide task illuminance (see the asterisk in the table). Note that the cubicle tasks are slightly lower than the average work plane illuminance due to some absorption of light by the systems furniture partitions.

To offset the absorbed light on the brick wall, wall washing was increased. To provide reasonable task illuminances without dedicated tasks lights, general lighting was increased. As a result, the overall lighting power density for Model B2 increased to **0.675 W/sf.**

Table 131: Design Summary – 2022 T-24 Model B2: Recessed Basket Troffer Providing General and Task Lighting in Space with Brick (low reflectance) Wall

Surface	Refl	Illuminance Targets	FC	Luminaire Type	Distribution	CCT / CRI
Ceiling	70	Circulation (average)*	52	Circulation	Increased Output Basket Troffer	3500/80
Wall 1	50	Center cubicle Tasks	46-50	Wall-Washer	High Output Asymmetrical LED	3500/84
Wall 2	50	Wall cubicle Tasks	31-38	Wall Grazer	Asymmetrical Recessed LED	3500/80
Wall 3	50	Focal zones (desk top)	44-60	Undercounter	NA	NA
Wall 4	10	Wall-Washer (vertical)	41	Desk Lamp	NA	NA
Floor	20	Wall Grazer (vertical)	39			
*Work plane average for design without task lighting component						

T.7. Large Office Lighting Summary Analysis

The table below compiles the lighting power density data together in one table so the patterns from the detailed radiosity method simulations can be seen. The term Task/Ambient in this context refers to placing task lighting sources close to the task with higher illuminance needs, in this case placing undercabinet and task lights on the desktops for use for detailed reading tasks. Normally monolithic lighting designs refer to designs where a single lighting system is providing general lighting, task lighting and accent lighting. In this case it is shorthand for not providing task lighting and to provide task lighting levels via ceiling mounted lighting. The designs call monolithic are not monolithic in their purest sense as the designs without task lighting still have accent lighting to highlight and brighten the walls.

In summary, lower wall reflectances result in more lighting power being required to provide equivalent brightness ins the space and capabilities to meet IES task illuminances The use of monolithic designs that make use of ceiling mounted lighting to provide detail task illuminance on the desktop require even more power than the task/ambient designs. A task/ambient design even with low reflectances can be designed to meet the needs of the occupants within the constraints of the current LPD proposal. If a monolithic design approach is taken to meet the occupant needs in a room geometry with some low reflectance walls, this would be difficult to achieve without the use of additional trade-offs or the use of lighting Power Adjustment Factors.

Table 132: AGI32 Model Open Office Summary Information

Model	General Lighting Luminaires	Design Type	Wall Reflectance	General Lighting LPD	Display/ Decorative LPD	Portable/ Undercabinet Task LPD	Total LPD
Model A	Direct/Indirect Pendants	Task/ Ambient	All Medium	0.183	0.156	0.117	0.456
Model B	Recessed Basket Troffers	Task/ Ambient	All Medium	0.202	0.156	0.117	0.475
Model A1	Direct/Indirect Pendants	Task/ Ambient	One wall low	0.183	0.242	0.117	0.542
Model A2	Direct/Indirect Pendants	Monolithic	One wall low	0.484	0.253	0.000	0.737
Model B1	Recessed Basket Troffers	Task/ Ambient	One wall low	0.238	0.253	0.117	0.608
Model B2	Recessed Basket Troffers	Monolithic	One wall low	0.422	0.253	0.000	0.675