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

Nonresidential High Performance Envelope

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FINAL CASE Report

Prepared by Energy Solutions and Determinant

Please submit comments to info@title24stakeholders.com.

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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 – Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison – and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this CASE Report is to present a package of cost-effective code changes that will improve the envelope performance in nonresidential buildings. The Statewide CASE Team aimed to maintain flexibility in how envelope performance is achieved. The submeasures (high performance windows, opaque envelope, roof alterations, and cool roofs) work interactively and the proposed code changes would achieve improved energy performance for both new construction and building alterations.

Collaborating with stakeholders who may be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts when developing code change proposals. Appendix F: in this report summarizes the stakeholder engagement activities the Statewide CASE Team conducted around each submeasure to identify and address associated issues. Stakeholder feedback from the Draft CASE Report informed several adjustments to the proposed code modifications, which are described below.

The Statewide CASE Team was investigating a proposed change to prescriptive cool roof requirements for low-sloped roofs. After hearing stakeholders' concerns about product availability, costs, moisture accumulation, and potential impacts on the market, The Statewide CASE Team will be recommending more stringent requirements as a voluntary requirement in Title 24, Part 11 (CALGreen) instead of a prescriptive requirement in Title 24, Part 6. This report presents all information the Statewide CASE Team developed for a possible low-sloped cool roof code change to provide transparency. This information could be leveraged if a low-sloped code change is considered as part of future code cycles or if a local jurisdiction is interested in pursuing a reach code that includes more reflective roofs. It will also be used when considering a package of code change recommendations for CALGreen.

The recommended insulation requirements for roof alterations proposed in the Draft CASE Report have been modified to simplify compliance and adjust to stakeholder feedback on market impacts. The revised proposal, which is not as stringent as the recommendations presented in the Draft CASE Report, would still result in significant cost-effective energy savings.

For high performance windows, the Statewide CASE Team worked with stakeholders to develop a cost-effective, technically feasible and market-ready proposal. This includes recommendations for curtain wall/storefront fenestration that vary by climate zone, and updates to the formula used to calculate net solar heat gain of fenestration using a credit for horizontal slats or overhangs. Code language was included in the Draft CASE Report that would have updated maximum thermal transmittance values (U-factor) for fenestration along the performance path of compliance. After listening to stakeholder feedback, the Statewide CASE Team recommends that the Energy Commission consider the proposal outlined in Appendix N: for Title 24, Part 11 (CALGreen) or the next code change cycle.

The following sections summarize key components of this report: measure background and proposed changes to submeasures, market analysis and cost effectiveness, impacts on energy, water and greenhouse gas emissions, and recommendations for compliance and enforcement.

Measure Description

Background Information

The building envelope is a critical system for ensuring building longevity and energy efficiency. The envelope separates the building's conditioned space from the exterior and includes walls, windows, roofs, floors, and the foundation. The building envelope has a longer lifetime than lighting or mechanical systems and its operation is not tunable, so it is especially important to optimize performance during installation.

The proposed code changes address conditions in the various California climate zones and provide alternative pathways that permit flexibility in building design and renovation.

Cool Roofs

The cool roofs code change proposal recommends increasing the required reflectance levels and thermal emittance levels of steep-sloped roofs for nonresidential buildings. Changes to the reflectance levels in Title 24, Part 11 CALGreen are being considered for low-sloped roofs rather than Title 24, Part 6 due to feedback from stakeholders as to product availability and potential market impacts. Cool roofs achieve energy savings by reflecting solar energy back into the atmosphere and radiating absorbed heat away from the building. This reduces heat transferred from the roof into the building, which in turn reduces the need for air conditioning during cooling seasons. Cool roofs are particularly effective in hot, dry climate zones. There are three metrics that quantify energy efficiency of roofing: aged solar reflectance, thermal emittance, and the Solar Reflectance Index (SRI). In determining the proposed prescriptive standards, all three ratings were evaluated and updated. This Final CASE Report also includes updated insulation values that can be used to trade off cool roof requirements.

Three of these submeasures affect nonresidential roofs: cool roofs, roof alterations, and opaque envelope. Opaque envelope was updated most recently in the 2016 code cycle, while cool roofs focuses on updating requirements that were last modified in the 2013 code cycle, and the roof alterations submeasure would update requirements that have not been changed since the 2008 code cycle.

Roof Alterations

The roof alterations code change proposal recommends increasing the required insulation levels for roof replacements to be closer to the requirements for new construction, adding a requirement that all roofs have at least R-10 insulation above deck regardless of existing conditions, and adding insulation requirements for roof recovers. The Statewide CASE Team is also proposing changes to the existing exceptions for roof replacements; see Section 3.6.2 for the proposed language.

In 2018, it became possible to fully deduct the expense of roof replacements in the year completed, rather than over a 39-year period, which makes it significantly more affordable to replace roofs and add insulation. Adequate insulation levels increase the effectiveness of the building envelope and reduce the energy required to maintain the temperature in conditioned space. Adding insulation during a roof alteration is the most cost-effective time to do so and is a key avenue to achieving California’s carbon reduction goals.

High Performance Windows

The high performance windows code change proposal updates window characteristics in nonresidential buildings to improve envelope efficiency. This includes the prescriptive requirements for solar heat gain coefficient (SHGC), U-factor, and visible transmittance (VT), as well as the calculation for relative solar heat gain coefficient (RSHGC) to account for impact of overhangs and horizontal slats.

Opaque Envelope

The opaque envelope code change proposal focuses on walls and roofs. This submeasure reevaluates existing assembly U-factor requirements using the latest cost parameters to determine if cost-effective reductions in U-factor are justified in all climate zones. When cost-effective, the maximum prescriptive U-factor value was decreased to further increase the effectiveness of the envelope to maintain constant, comfortable temperature within the building.

Proposed Code Change

Cool Roofs

The cool roof submeasure proposes updates to the existing solar reflectance and thermal emittance requirements for nonresidential buildings with both steep-sloped[1] roofs (proposed changes to Title 24, Part 6) and low-sloped[2] roofs (considering revisions for Title 24, Part 11 / CALGreen) in climate zones where doing so is cost effective. The proposed code changes would impact new construction, additions, and alterations with exceptions noted below.

For steep-sloped roofs in Climate Zones 2 and 4 through 16 the minimum aged solar reflectance would be increased from 0.20 to 0.25, the minimum thermal emittance would be increased from 0.75 to 0.80, and the Solar Reflectance Index (SRI) from 16 to 23. There are no proposed changes to the steep-sloped cool roof requirements for Climate Zones 1 and 3. All nonresidential buildings with steep-sloped roofs are impacted by the proposal, including relocatable public school buildings and healthcare facilities. Newly constructed healthcare facilities and additions to healthcare facilities would need to meet the updated cool roof requirements. Alterations to healthcare facilities do not need to comply with the cool roof or any envelope requirements.

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[1] Section 100.1(b) Definitions of Title 24, Part 6 defines a steep-sloped roof as “a roof that has a ration of rise to run of greater than or equal to 2:12 (9.5 degrees from horizontal).

[2] Section 100.1(b) Definitions of Title 24, Part 6 defines a low-sloped roof as “a roof that has a ration of rise to run of less than 2:12 (9.5 degrees from horizontal).

For the potential low-sloped roofs proposal in CALGreen, in Climate Zones 4, and 6 through 15, the minimum aged solar reflectance would be increased to 0.70, and SRI would be increased to 85. There are no proposed changes to the low-sloped cool roof requirements for Climate Zones 1, 2, 3, 5, and 16. The proposed requirements for low-sloped roofs would impact all nonresidential building types (including relocatable public school buildings) except warehouses, retail buildings, and grocery stores.

This proposal would revise the Title 24, Part 6 prescriptive alternative available for low-sloped roofs that allows for less stringent cool roof requirements in combination with additional roof/ceiling insulation. The updated insulation requirements for this alternative would be updated to achieve similar energy performance as applying the revised prescriptive cool roof requirements in combination with the updated insulation requirements proposed in the opaque envelope and roof alterations submeasures.

Currently, hotel/motel buildings are subject to two different sets of envelope requirements. Requirements in Table 140.3-B apply to nonresidential spaces and requirements in Table 140.3-C apply to guestroom spaces. This proposal would simplify requirements for hotel/motel by removing requirements that only apply to guestroom space. Requirements in Table 140.3-B, which would be updated by this proposal, would apply to the entire hotel/motel building. See Appendix M: for recommendations for hotel / motel.

The proposed code changes for the roof alterations, which require all buildings to have a minimum of R-10 above-deck after a roof replacements and roof recovers, are relevant to the existing cool roof requirements for low-sloped roofs. Requiring insulation on roof replacements and recovers would keep the roof deck warm, minimizing risk of moisture accumulation. Moisture accumulation is discussed in Section 2.2.2.6.

Roof Alterations

This proposed submeasure would update the existing prescriptive requirements for roof replacements[3] and add new requirements for roof recovers.[4] The proposed changes would increase the stringency of insulation requirements that must be met when roofs are replaced. Depending on climate zone, roofs would be required to have either R-17 or R-23. The proposal would remove the exception that states that if the existing roof has R-7 insulation, insulation does not need to be added or replaced.

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[3] The California Building Code (Title 24, Part 2) and California Existing Building Code, Title 24 Part 10 define roof replacement as follows, “Roof Replacement. The process of removing the existing roof covering, repairing any damaged substrate and installing a new roof covering.”

[4] The California Building Code (Title 24, Part 2) and the California Existing Building Code (Title 24 Part 10) define roof recover as follows, “Roof Recover. The process of installing an additional roof covering over a prepared existing roof covering without removing the existing roof covering.”

For roof recovers, the proposed changes would establish a requirement that a minimum of R-10 insulation be added during roof recovers or meet the insulation requirements for roof replacements, whichever is less.

In addition to increasing the stringency of insulation requirements, the proposed code change would update existing exceptions and recommend revisions to improve the compliance verification process. With the proposed revisions, all buildings even those that qualify for the revised exceptions would be required to have R-10 above-deck insulation upon completion of a roof replacement or roof recovers alteration. Existing above deck insulation counts towards the required R-10 insulation levels. Specific changes to the exceptions would:

- Completely remove the exception that states that if the existing roof has R-7 insulation, insulation does not need to be added or replaced.
- Completely remove the exception that states that insulation is not required to be added if doing so would reduce the base flashing height to less than eight inches at penthouse and parapet walls. Stakeholders provided feedback that having to raise base flashing heights at penthouse or parapet walls does not add significant complexity or costs to projects. This change would reduce complexity of the code and remove an exception that stakeholders have said is unnecessary.
- Modify the exception for limited base flashing height of mechanical equipment so that at least R-10 must be installed above deck regardless of base flashing height. The language for the exception is also changed to reference manufacturers' instructions rather than a height of eight inches.
- Add a performance option for third-party inspection of existing conditions that can be used to count existing insulation towards meeting the proposed requirements.
- Add a field inspection requirement to verify insulation is installed.
- Add a requirement that insulation installers complete a progress report, contingent on a forthcoming nonresidential registry. This allows building officials to more easily follow the progress of projects and schedule inspections.

The proposed code changes would not require any significant software changes. The proposed changes would apply to all nonresidential buildings, including guestrooms of hotel/motels, but not including hospitals. The Statewide CASE Team is proposing that the entire roof of hotels/motels comply with the requirements above. Healthcare facilities are excluded from all requirements in Section 141.0 of Title 24, Part 6.

Currently, hotel/motel buildings are subject to two different sets of envelope requirements. Requirements in Table 141.0-C have separate requirements for nonresidential spaces and guestroom spaces. This proposal would simplify requirements for hotel/motel building by removing requirements that only apply to guestroom space. See Appendix M: for recommendations for hotels/motels.

High Performance Windows

The structural, thermal, and optical characteristics of windows (also known as vertical fenestration) have a large impact on a building's energy performance as well as occupant comfort. This submeasure applies to new nonresidential construction only. Requirements for high-rise residential would move to the forthcoming multifamily code, which would be separate for the 2022 code cycle. The requirements for hotel/motel guestrooms would no longer be separated from the overall hotel/motel requirements.

The Statewide CASE Team considered updates to three requirements for windows to optimize performance across the 16 California climate zones: U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT). U-factor measures the rate of heat transfer, specifically conductive and convective, with lower U-factors indicating better window insulation. SHGC is the fraction of solar radiation transmitted directly through the window, with lower SHGC indicating lower transmittance. VT is the fraction of visible light that is transmitted through the window. Both SHGC and VT reflect percentage values, while U-factor is measured in Btu/(hr/ft^2/°F). After stakeholder feedback, the proposed update would reflect more stringent U-factor and SHGC values while VT would remain the same. Current code specifies a single value for each window characteristic across all climate zones. This submeasure would update the reference table to include values that vary across climate zones to account for climate-specific needs for fixed windows. Exceptions for site-built fenestration would be removed, as supported by stakeholder feedback.

The submeasure also revises the relative solar heat gain coefficient (RSHGC) formula. This formula currently calculates the RSHGC for a given combination of fenestration SHGC, orientation and overhang, effectively lowering the net solar heat gain of fenestration through an overhang credit. The revision updates the formula to adjust TDV values and add horizontal slats to the credit.

Opaque Envelope

The opaque envelope of a building refers to all aspects of the envelope that are not transparent. This submeasure proposes increasing existing insulation requirements for walls and roofs. Cool roofs and roof alterations have their own proposed standards (see Sections 2 and 3 of this report). Increased insulation reduces demand on HVAC equipment and improves comfort, with zero or minimal impact to building aesthetics.

The rate of heat transfer though the envelope is determined by its U-factor. This proposal would lower existing U-factor requirements, taking climate zone into account to ensure cost effectiveness. Like the existing requirements, these new requirements would be prescriptive and impact nonresidential new construction, additions, and alterations. This proposal would not add or modify field verification or acceptance tests or require any technology not previously regulated. for a summary of the proposed scope. It would require a software update to account for the new standard design.

Currently, hotel/motel buildings are subject to two different sets of envelope requirements. Requirements in Table 140.3-B apply to nonresidential spaces and requirements in Table 140.3-C apply to guestroom spaces. This proposal would simplify requirements for hotel/motel by removing requirements that only apply to guestroom space. Requirements in Table 140.3-B, which would be updated by this proposal, would apply to the entire hotel/motel building. See Appendix M: for recommendations for hotel/motel.

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 would be modified to reflect the proposed changes.

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)
Cool Roofs	Prescriptive	140.3(a)1.A, 141.0(b)2.B	N/A	Yes	NRCC-ENV-E
Roof Alterations	Prescriptive	141.0(b)2.B.iii 141.0(b)3.C	Reference Appendix JA4	Yes	NRCC-ENV-E
High Performance Windows	Prescriptive	100.1, 110.6, 130.1, 140.3	Reference Appendix NA7.4.5	Yes	NRCC-ENV-E
Opaque Envelope	Prescriptive	140.0, 140.3	N/A	Yes	N/A

Market Analysis and Regulatory Assessment

Cool Roofs

The cool roof market is comprised of many types of roofing products. For steep-sloped nonresidential roofs, metal, asphalt, and tile products are the most common. For low-sloped roofs, reflective coatings and single-ply roofs, such as thermoplastic polyolefin (TPO) or polyvinyl chloride (PVC) roofs, are the most popular. There are hundreds of rated products that can meet the proposed standards for both steep- and low-sloped roofs. Since the current Title 24, Part 6 code already requires cool roofs for nonresidential buildings in the state, there would be no significant changes in the types of products used in roofing projects.

Roof Alterations

Existing buildings make up approximately three quarters of the roofing market and low-sloped roofs make up close to 90 percent of nonresidential roofs. Roof replacements are the most cost-effective time to improve roof insulation, and in 2018 the United States (U.S.) tax code was reformed to make up to $1 million from a roof replacement tax deductible in the year of completion, rather than over 39 years.

Polyisocyanurate is the most popular insulation type for reroofing projects, with a 77 percent market share in the Pacific region. Current technologies and design strategies meet the requirements to comply with the code change, but certain complexities must be considered during a roof replacement that would not be relevant to new construction. Equipment may have to be lifted or flashing at penthouse and parapet walls adjusted and cladding removed and refinished to make room for the added insulation.

High Performance Windows

The high performance fenestration market is well established. Well-insulating windows are currently considered best practice for new construction and major renovations and are becoming standard practice, due in part to recent advancements in glazing and frame technology.

The current nonresidential fenestration market is composed of a wide range of market actors including project designers and architects, component manufacturers (glazing, frame, spacers, etc.), window system manufacturers and designers, installers/contractors, certification officials, and commissioning representatives. The proposed revisions of prescriptive requirements for vertical fenestration would have impacts on all these market actors to varying degrees. Current technologies include gas-filled, advanced low-e, thermally broken frames, and triple-pane glazing. All are readily available and allow for a wide range of lower U-factors in whole-window assembly.

The horizontal slat market includes various manufacturers who typically supply an entire horizontal slat assembly directly to the contractor. The manufacturer typically makes the horizontal slats to the specifications given by the architect. Interviews and surveys of manufacturers and architects consistently demonstrated that exterior horizontal slats have also grown in popularity. Exterior horizontal slats are available from many manufacturers, such as Airolite, Alcoa, EFCO, Arcadia, ASCA, Construction Specialties, Industrial Louvers, LouvreTec, and Unicel. There are no foreseen impediments to supplying these products.

Opaque Envelope

The building opaque envelope market is also well established. Different construction techniques, such as wood-framed, metal-framed, and mass walls, have differing insulating potential and U-factor values, and therefore separate requirements and best practices of installation and maintenance. Current technologies and design strategies commonly meet the requirements to comply with the proposed code change. The nonresidential building envelope market contains many market actors in a variety of roles such as designers, architects, component manufacturers (shell, insulation, etc.), installers, construction companies, and certification/compliance specialists. All market actors would be impacted to some extent by this submeasure.

Cost Effectiveness

The above proposed code changes are cost effective for all climate zones where they would be required. The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater is considered cost effective by Energy Commission standards. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratio for each envelope submeasure varies based on the climate zones and building types. See Table 2 and Table 3 for a summary of B/C ratios by climate zone, calculated and weighted by impacted construction forecast using the following equation where BCR is the B/C ratio, CF is the impacted construction forecast, and *i* is the building prototype:

$$B/C\ Ratio_{Climate\ Zone} = \sum \frac{BCR_{building\ prototype(i),Climate\ Zone} * CF_{building\ prototype(i),Climate\ Zone}}{CF_{Climate\ Zone}}$$

The methodology, assumptions, and results for each submeasure are presented in Section 2.4 (cool roofs), 3.4 (roof alterations) 0 (high performance windows) and 5.4 (opaque envelope). The analysis periods are 30 years for all submeasures.

Table 2: Construction-weighted Benefit-to-Cost Ratios Across All Climate Zones – New Construction

Climate Zone	Cool Roofs – Low-Sloped[a]	Cool Roofs – Steep-Slope	High Performance Windows - Fixed)	High Performance Windows - Curtain Wall and Storefront	Opaque Envelope
1	N/A	N/A	N/A	1.10	1.74
2	N/A	3.40	0.74	N/A	1.41
3	N/A	N/A	N/A	N/A	1.34
4	1.82	3.99	N/A	N/A	1.00
5	N/A	2.55	0.66	N/A	1.00
6	1.71	6.12	0.76	N/A	1.12
7	2.28	5.32	0.84	1.11	0.82
8	2.05	8.56	0.73	N/A	1.30
9	1.98	5.77	1.32	N/A	1.81
10	1.98	5.23	N/A	N/A	1.01
11	4.12	5.71	1.29	N/A	1.38
12	1.11	4.54	1.00	N/A	1.51
13	1.52	5.23	1.42	N/A	1.62
14	2.48	3.65	1.12	N/A	1.60
15	2.14	8.79	1.58	N/A	1.31
16	N/A	1.90	N/A	0.91	1.80
Average, Weighted by Construction Forecast	**1.90**	**5.54**	**1.04**	**1.08**	**1.37**

a. Potential CALGreen proposal

Table 3: Construction-weighted Benefit-to-Cost Ratios Across All Climate Zones – Alterations

Climate Zone	Cool Roofs – Low-Sloped[a]	Cool Roofs – Steep-Slope	Roof Replacements	Roof Recovers
1	N/A	N/A	3.27	3.86
2	N/A	7.74	1.67	1.38
3	N/A	N/A	1.93	2.41
4	3.24	16.16	2.12	2.69
5	N/A	12.02	1.98	2.47
6	4.42	20.51	1.53	1.62
7	2.44	22.16	1.51	1.48
8	6.76	19.22	2.02	2.25
9	5.25	13.25	1.83	2.47
10	3.34	12.30	1.31	0.95
11	3.09	11.63	1.85	1.51
12	2.04	11.63	1.66	1.32
13	3.63	13.88	1.73	1.44
14	2.75	10.36	1.59	1.37
15	5.10	28.94	1.16	1.00
16	N/A	6.36	2.58	1.95
Average, Weighted by Construction Forecast	**4.20**	**16.15**	**1.74**	**1.87**

a. Potential CALGreen proposal

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

Table 4 presents the estimated energy and demand impacts of the proposed code change that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Sections 2.5 (cool roofs), 3.5 (roof alterations), 4.5 (high performance windows), and 5.5 (opaque envelope) for the methodology, assumptions, and results for statewide impacts for each submeasure. See Sections 2.3 (cool roofs), 3.3 (roof alterations, 4.3 (high performance windows), and 5.3 (opaque envelope) for details on methodology, assumptions, and results for energy impacts per prototypical building. Numbers that are red and in parenthesis are negative values. Please note that the below table models each submeasure individually and does not take interactive effects into account.

Table 4: First-Year Statewide Energy and Impacts

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (million therms/yr)	TDV Energy Savings (TDV million kBtu/yr)
Cool Roofs	**5.7**	**0.5**	**(0.1)**	**124.1**
New Construction- Steep-Sloped	0.8	0.1	0.0	16.1
Alterations- Steep-Sloped	4.9	0.4	(0.1)	108.0
Roof Alterations	**37.2**	**3.1**	**8.0**	**3,669.3**
Roof Recovers	19.3	1.7	3.9	1,796.2
Roof Replacements	17.8	1.4	4.1	1,873.1
High Performance Windows	**4.2**	**0.2**	**0.0**	**106.6**
New Construction – Fixed	4.2	0.2	0.0	106.3
New Construction – Curtain wall/Storefront	0.0	0.0	0.0	0.3
Opaque Envelope	**3.5**	**0.2**	**0.5**	**243.0**
Total	**50.6**	**4.0**	**8.4**	**4,143.3**

The largest energy and TDV savings and peak demand reductions come from the roof alterations submeasure. The current proposal, which would significantly increase the insulation requirements for roof replacements and add requirements for roof recovers, is projected to save 8 MMTherms/year, with several conservative assumptions. The primary conservative assumption is a baseline insulation level of R-11 for roof recovers in Climate Zones 2, 10-16 since there is no insulation requirement for recovers and the Statewide CASE Team heard from stakeholders that even if there is existing insulation below deck, it often is not as effective after 15 years – when the roof would be replaced or recovered. The other conservative assumption is that the models used meet the 2019 new construction requirements except for the roof insulation and so energy consumption is under-estimated significantly compared to and older building that would actually have its roof replaced. This is discussed in more detail in Section 3. The electricity savings of the cool roofs submeasure outweigh small increases in natural gas usage due to a heating penalty.

Although the proposed code changes for this CASE Report will apply to the food, small school, and public assembly building categories, the Statewide CASE Team did not simulate energy impacts from the associated prototypical buildings and for this analysis no savings were attributed to these building types. In reality, there will be savings from these building types, so the statewide energy savings are likely understated for all submeasures.

Table 5 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO_2e). Assumptions used in developing the GHG savings are provided in Sections 2.5.2, 3.5.2, 4.5.2, 5.5.2 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 5: First-Year Statewide GHG Emissions Impacts

Measure	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Cool Roofs- Steep-Sloped	848	$89,983
Roof Alterations	52,529	$5,578,598
High Performance Windows	790	$83,814
Opaque Envelope	3,330	$353,642
Total	**57,497**	**$6,106,037**

Water and Water Quality Impacts

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

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Sections 2.1.5, 3.1.5, 4.1.5, and 5.1.5 for each submeasure. Impacts on market actors are described in the second section of each submeasure, and in Appendix E:.

The proposed changes would increase the stringency of existing requirements that have established compliance verification processes. The only proposal that would change the compliance verification process is the roof alterations submeasure. The submeasure is proposing to add inspections as described in the next section. The key issues related to compliance and enforcement are summarized below:

- **Roof alterations:** To receive a permit, a Nonresidential Code Compliance Envelope (NRCC-ENV-E) form for roof replacements must be filled out, but currently the insulation requirements are not always triggered when they should be due to user error. The Statewide CASE Team has heard from stakeholders that building departments do not have the capacity to carry out necessary inspections to support compliance and enforcement and so is proposing third-party inspections of the insulation.

- **High performance windows:** Stakeholders have indicated that many windows manufacturers do not provide National Fenestration Rating Council ratings for products specified in designs. Stakeholders have also indicated that many building departments are not enforcing windows requirements. Representatives from the Compliance Improvement Team receive questions about compliance with the nonresidential windows requirements frequently. The Statewide CASE Team is considering opportunities to improve the compliance verification process, though feedback suggests that the compliance verification process is clear, but the requirements are not being enforced. The proposed changes would eliminate the under 200 ft^2 exception for site-built fenestration, which stakeholders have recommended as a path to ease compliance.
- **Cool roofs:** Roofing contractors need to be aware of the updated above deck insulation requirements roof alteration proposal.

Field Verification and Acceptance Testing

Cool Roofs

No new field verification or acceptance testing is proposed in this submeasure.

Roof Alterations

Table 141.0 – E in 2019 Title 24, Part 6 has a column titled "Standard Design With Third-party Verification of Existing Conditions Shall be Based On" and has a row for roof/ceiling insulation. However, the inspection does not provide any credit and so there is no reason for it to occur. The Statewide CASE Team is proposing two new inspections: a third-party performance option before the start of the project to assess existing below and/or above deck insulation if the contractor would like to use it toward meeting the requirements insulation requirements as well as verifying that a project qualifies for an exception, and a second, required inspection before the roof cover is installed to verify the quality and amount of the newly installed insulation.

High Performance Windows

No new field verification or acceptance testing is proposed for this submeasure. The Statewide CASE Team is continuing to work with the Compliance Improvement Team for this submeasure.

Opaque Envelope

No new field verification or acceptance testing is proposed in this submeasure.

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 CASE Report is to present a package of cost-effective code changes that will improve the envelope performance in nonresidential buildings. The Statewide CASE Team aimed to maintain flexibility in how envelope performance is achieved. The submeasures (high performance windows, opaque envelope, roof alterations, and cool roofs) work interactively and the proposed code changes would achieve improved energy performance for both new construction and building alterations.

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, architects, contractors, national laboratories, building scientists, and others involved in the code compliance process. The proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on October 24, 2019, and April 23, 2020 along with feedback received in written comments and through direct communications with stakeholders. Collaborating with stakeholders who may be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts when developing code change proposals. Appendix F: in this report summarizes the stakeholder engagement activities the Statewide CASE Team conducted around each submeasure to identify and address associated issues. Stakeholder feedback from the Draft CASE Report informed several adjustments to the proposed code modifications, which are described below.

The Statewide CASE Team was investigating a proposed change to prescriptive cool roof requirements for low-sloped roofs. After hearing stakeholders' concerns about product availability, costs, moisture accumulation, and potential impacts on the market, The Statewide CASE Team will be recommending more stringent requirements as a voluntary requirement in Title 24, Part 11 (CALGreen) instead of a prescriptive requirement in Title 24, Part 6. This report presents all information the Statewide CASE Team developed for a possible low-sloped cool roof code change to provide transparency. This information could be leveraged if a low-sloped code change is considered as part of future code cycles or if a local jurisdiction is interested in pursuing a reach code that includes more reflective roofs. It will also be used when considering a package of code change recommendations for CALGreen.

The recommended insulation requirements for roof alterations proposed in the Draft CASE Report have been modified to simplify compliance and adjust to stakeholder feedback on market impacts. The revised proposal, which is not as stringent as the recommendations presented in the Draft CASE Report would still result in significant cost-effective energy savings.

For high performance windows, the Statewide CASE Team worked with stakeholders to develop a cost-effective, technically feasible and market-ready proposal. This includes recommendations for curtain wall/storefront fenestration that vary by climate zone, and updates to the formula used to calculate net solar heat gain of fenestration using a credit for horizontal slats or overhangs. Code language was included in the Draft CASE Report that would have updated maximum thermal transmittance values (U-factor) for fenestration along the performance path of compliance. After listening to stakeholder feedback, the Statewide CASE Team recommends that the Energy Commission consider the proposal outlined in Appendix N: for Title 24, Part 11 (CALGreen) or the next code change cycle.

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

- Section 2 – Cool Roofs presents a proposal and associated cost and energy savings for prescriptive updates to the aged solar reflectance, thermal emittance, and Solar Reflectance Index (SRI) for both low- and steep-sloped roofs of nonresidential buildings.

- Section 3 – Roof Alterations presents a proposal and associated cost and energy savings for updates to the prescriptive requirements for insulation in roof replacements. The update would increase the insulation requirements for roof replacements and add insulation requirements for roof recovers.
- Section 4 – High Performance Windows presents a proposal and associated cost and energy savings for prescriptive updates to the U-factor, relative solar heat gain coefficient (RSHGC), and visible transmittance (VT) for windows of nonresidential buildings. The update applies to new construction, additions, and alterations.
- Section 5 – Opaque Envelope presents a proposal and associated cost and energy savings for prescriptive updates to the U-factor of nonresidential building envelope. The update applies to new construction, additions, and alterations.
- Section 6 – 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. There are no on-site water savings associated with this proposal.
- Appendix C:Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on greenhouse gas (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:Cool Roof Surveys describes the surveys that the Statewide CASE Team conducted to collect information to inform proposals.
- Appendix I: Cool Roof Moisture Accumulation Background Information discusses moisture accumulation associated with cool roofs.

- Appendix J:Combined Energy Savings and Cost Effectiveness of Cool Roof and Roof/Ceiling Insulation contains preliminary results for the Large Office and Secondary School building types.
- Appendix K:Energy Cost Savings in Nominal Dollars includes energy cost savings in nominal dollars for all climate zones and all building prototypes.
- Appendix L:Answers to Frequently Asked Questions - includes a list of key questions and answers regarding the envelope proposal.
- Appendix M:Recommended Simplifications for Hotel / Motel Envelope Requirements presents recommendations to harmonize requirements for hotel/motel so there are no longer different requirements that apply to nonresidential spaces and guestroom spaces.
- Appendix N:Fenestration U-Factor Maximum includes stakeholder feedback and recommendations for a window U-factor backstop in Title 24, Part 6.
- Appendix O:: Roof Alterations Costs includes the insulation and labor costs for every climate zone.
- Appendix P:: Mark-Up Standards Language for All Envelope Measures includes the combined code language from all 2022 nonresidential envelope measures discussed in this Final CASE Report.

The following is a brief summary of the subsections within Sections 2 through 5 of this report:

- Submeasure description describes the submeasure 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.
- The Market Analysis section includes a review of the current market structure. The Market Analysis subsections describe the feasibility issues associated with the code change, including whether the proposed submeasure 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.
- Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Cost and Cost Effectiveness section includes a discussion and presents analysis of the materials and labor required to implement the submeasure 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.

- First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the state of California. Statewide water consumption impacts are also reported in this section.
- Proposed Revisions to Code Language concludes each report section 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.

2. Cool Roofs

2.1 Submeasure Description

2.1.1 Measure Overview

The cool roof submeasure proposes updates to the existing solar reflectance and thermal emittance requirements for nonresidential buildings with both steep-sloped[5] roofs (proposed changes to Title 24, Part 6) and low-sloped[6] roofs (considering revisions for Title 24, Part 11 / CALGreen) in climate zones where doing so is cost effective. The proposed code changes would impact new construction, additions, and alterations with exceptions noted below.

For steep-sloped roofs in Climate Zones 2 and 4 through 16 the minimum aged solar reflectance would be increased from 0.20 to 0.25, the minimum thermal emittance would be increased from 0.75 to 0.80, and the Solar Reflectance Index (SRI) from 16 to 23. There are no proposed changes to the steep-sloped cool roof requirements for Climate Zones 1 and 3. All nonresidential buildings with steep-sloped roofs are impacted by the proposal, including relocatable public school buildings and healthcare facilities. Newly constructed healthcare facilities and additions to healthcare facilities would need to meet the updated cool roof requirements. Alterations to healthcare facilities do not need to comply with the cool roof or any envelope requirements.

For the potential low-sloped roofs proposal in CALGreen, in Climate Zones 4, and 6 through 15, the minimum aged solar reflectance would be increased to 0.70, and SRI would be increased to 85. There are no proposed changes to the low-sloped cool roof requirements for Climate Zones 1, 2, 3, 5, and 16. The proposed requirements for low-sloped roofs would impact all nonresidential building types (including relocatable public school buildings) except warehouses, retail buildings, and grocery stores.

This proposal would revise the Title 24, Part 6 prescriptive alternative available for low-sloped roofs that allows for less stringent cool roof requirements in combination with additional roof/ceiling insulation. The updated insulation requirements for this alternative would be updated to achieve similar energy performance as applying the revised prescriptive cool roof requirements in combination with the updated insulation requirements proposed in the opaque envelope and roof alterations submeasures.

[5] Section 100.1(b) Definitions of Title 24, Part 6 defines a steep-sloped roof as “a roof that has a ration of rise to run of greater than or equal to 2:12 (9.5 degrees from horizontal).

[6] Section 100.1(b) Definitions of Title 24, Part 6 defines a low-sloped roof as “a roof that has a ration of rise to run of less than 2:12 (9.5 degrees from horizontal).

Currently, hotel/motel buildings are subject to two different sets of envelope requirements. Requirements in Table 140.3-B apply to nonresidential spaces and requirements in Table 140.3-C apply to guestroom spaces. This proposal would simplify requirements for hotel/motel by removing requirements that only apply to guestroom space. Requirements in Table 140.3-B, which would be updated by this proposal, would apply to the entire hotel/motel building. See Appendix M: for recommendations for hotel / motel.

The proposed code changes for the roof alterations, which require all buildings to have a minimum of R-10 above-deck after a roof replacements and roof recovers, are relevant to the proposed cool roof requirements for low-sloped roofs. Stakeholders have noted that R-10 above deck insulation will eliminate moisture issues in the vast majority of situations. As discussed in the roof alterations section of this report, stakeholders have also indicated that R-10, which is about 1.75 inches thick, can be installed on existing roofs without necessitating major changes such as the lifting of equipment. This change would keep the roof deck warm, minimizing risk of moisture accumulation. Moisture accumulation is discussed in Section 2.2.2.6.

Table 6 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 changes.

Table 6: Scope of Code Change Proposal – Cool Roofs

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)
Cool Roofs	Prescriptive	140.3(a)1.A, 141.0(b)2.B	N/A	Yes	NRCC-ENV-E

2.1.2 Measure History

Cool roofs achieve energy savings by reflecting solar energy back into the atmosphere and radiating absorbed heat. The ability to reflect solar energy is called solar reflectance, and the ability to radiate solar heat is called thermal emittance. These metrics are both measured on a scale of zero to one, with one being the most efficient level. Aged solar reflectance is the reflectance of the roof surface after three years of weathering and dirt accumulation. Per Title 24, Part 6, the SRI is calculated by weighing the aged solar reflectance and thermal emittance. Roofing products must either comply by meeting both the aged solar reflectance and thermal emittance requirements or the

SRI requirement. Higher solar reflectance and thermal emittance correspond to higher SRI. Generally, the higher the SRI, the better the roofing materials ability to reduce heat transfer into the building. The Lawrence Berkeley National Laboratory and California Energy Commission maintain publicly available calculators that can be used to calculate the SRI based on the solar reflectance and thermal emittance values (Lawrence Berkeley Lab n.d.) (California Energy Commission n.d.).

Cool roofs reduce the amount of heat a building absorbs, reducing the need for air conditioning, which is responsible for an estimated 5 to 10 percent of urban peak electricity demand (Akbari 2001). Cool roofs are particularly effective in hot, dry climate zones, but in the heating season there is a penalty since less heat is absorbed into the building. However, studies consistently show that the heating penalty in the winter months is much less than the benefit in the summer months since roofs do not typically receive much sunlight during the winter, and there is not much of a heat gain to lose (Levinson and Akbari 2009, Ramamurthy 2015). Though there are some heating losses, this proposal leads to savings in select building types and climate zones, as discussed in Section 2.5.

In 1998, the Cool Roof Rating Council (CRRC) was established to create test procedures and labels that could accurately measure the radiative properties of roofing products. CRRC members include roofing industry members, government representatives, and academic researchers. The CRRC was created to provide a widely approved procedure to rate the solar radiative properties of roofs (Akbari and Levinson 2008). The CRRC still plays an essential role in Title 24, Part 6. As per Section 10-113, roofing products used to comply with the prescriptive requirements must be rated and labeled by the CRRC.

Cool roof standards have been in place in model codes for over two decades. The 1999 edition of American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 90.1 (ASHRAE 90.1) included both prescriptive and performance credit options for cool roof requirements. In the 1999 code, a cool roof was considered a roof with minimum initial solar reflectance of 0.70 and minimum thermal emittance of 0.75. These compliance options were chosen after a cool roof study group was formed in 1997. In 2001, California followed and adopted compliance credits for cool roofs which had the same definition as that of ASHRAE 90.1 1999 (Akbari and Levinson 2008). In 2005, California became the first state in the country to adopt prescriptive cool roof requirements. Minimum solar radiative properties for low-sloped nonresidential buildings were added to Title 24, Part 6, and the evolution of these standards over past code cycles is depicted in Table 7. With no change in the cool roof standards in nearly a decade, warmer temperatures and availability of highly reflective products necessitate the proposed changes of this submeasure.

As noted above, the ASHRAE 90.1 1999 and 2005 Title 24, Part 6 Standards were based on initial solar reflectance values, which is a measure of performance of the products without any weathering. For the 2008 code cycle, the initial solar reflectance metric was replaced with an aged measurement since the aged solar reflectance provides more accurate estimates that account for weathering and dirt accumulation. After the implementation of the 2008 Title 24, Part 6 Standards, products had the option to reach compliance by meeting both the aged solar reflectance and thermal emittance standards, or the SRI standard. The SRI calculation is designed to allow products to comply with the standard if the product has a slightly lower aged solar reflectance than the standard requires but a high thermal emittance, or vice versa.

Table 7: Historical and Proposed Title 24, Part 6 Cool Roof Requirements for Nonresidential Buildings Except High-rise Residential and Guestrooms of Hotel/Motel

Criteria	Definition	Low-sloped 2001 Compliance Option	Low-sloped 2005 Code	Low-sloped 2008 Code	Low-sloped 2013 Code	Steep-sloped 2008 Code	Steep-sloped 2013 Code	Steep-sloped 2022 Code (proposed)[a]
Initial Solar Reflectance	Ability to reflect sunlight	0.70	0.75	N/A	N/A	N/A	N/A	N/A
Aged Solar Reflectance (ASR)	Ability to reflect sunlight after a 3-year period of weathering	N/A	N/A	0.55	0.63	0.20	0.20	0.25
Thermal Emittance (TE)	The ability of a roof to radiate absorbed heat	0.75	0.75	0.75	0.75	0.75	0.75	0.80
Aged Solar Reflective Index (SRI)	Measure of a roof's ability to reject solar heat using ASR and aged TE values	N/A	N/A	64	75	16	16	23

Note: Low-sloped roofs have a pitch less than 2:12. Steep-sloped roofs have a pitch greater than or equal to 2:12.

a. The proposed requirements for steep-sloped roofs would apply to climate zones 2 and 4 through 16. The requirements that have been in place since the 2013 code would remain for climate zones 1 and 3.

2.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, 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 sections of Title 24, Part 6 shown below. See Section 2.6.2 of this report for marked-up code language.

— **SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES**

- **Section 140.3(a) – Envelope Component Requirements:** The purpose of this change is to update the minimum aged solar reflectance, thermal emittance, and SRI levels for applicable climate zones. Additionally, Table 140.3 would be modified with the revised roof/ceiling insulation tradeoff levels. Tables 140.3-B, -C, and -D would also be modified with the updated cool roof values. These changes are necessary to present the updated cool roof standards for non-residential roofs.

— **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**

- **Section 141.0(b)2B:** This change is necessary to modify the cool roof requirements for roof alterations. Table 141.0-B would be updated with the revised low-sloped roof/ceiling insulation tradeoff values for aged solar reflectance of roof alterations. These changes are necessary to present the updated cool roof standards for non-residential roof alterations.

2.1.3.2 Summary of Changes to the Reference Appendices

There would be no changes to the Nonresidential Reference Appendices.

The proposed code change would not modify the ACM Reference Manual. The ACM Reference Manual refers to the solar reflectance requirements in Table 140.3-B, Table 140.3-C, and 140.3-D for new construction and the values in Section 141.0 for alterations, so revising code language is sufficient. The current ACM Reference Manual states the thermal emittance for the Standard Design shall be 0.85 for all climate zones.

2.1.3.3 Summary of Changes to the Nonresidential Compliance Manual

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

- Table 3-2: Prescriptive Criteria for Roofing Products for Nonresidential Buildings
- Table 3-5: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance
- Section 3.2.4.2
- Section 3.6.2.2(C) Roofs
- Table 3-23: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance

See Section 2.6.5 of this report for more detail on proposed revisions to the text of the compliance manual.

2.1.3.4 Summary of Changes to Compliance Documents

NRCI-ENV-01-E would be updated to show the updated reflectance values.

2.1.4 Regulatory Context

2.1.4.1 Existing Requirements in the Title 24, Part 6

To comply with the prescriptive cool roof requirements, a roof must either meet both the minimum aged solar reflectance requirements and minimum thermal emittance level or meet the SRI. Existing cool roof requirements apply to new construction, additions, and alterations for all nonresidential buildings including relocatable public school buildings and healthcare facilities. Table 8 presents the existing solar radiative requirements for all nonresidential buildings. Guestroom spaces in hotels and motels must meet the same solar radiative properties as multifamily buildings, and these requirements are slightly less stringent than the nonresidential requirements due to the increased internal heating loads in these types of consistently occupied buildings.

Table 8: Current Cool Roof Requirements

Building Type	Sloped	Climate Zones	Aged Solar Reflectance	Thermal Emittance	SRI
Nonresidential Buildings Except High-rise Residential and Guestrooms of Hotel/Motel	Low	All	0.63	0.75	75
High-rise Residential and Guestrooms of Hotel/Motel	Low	9–11 and 13–15	0.55	0.75	64
High-rise Residential and Guestrooms of Hotel/Motel	Low	1–8, 12, 16	No requirement	No requirement	No requirement
High-rise Residential and Guestrooms of Hotel/Motel	Steep	2–15	0.20	0.55	16
Nonresidential Buildings Except High-rise Residential and Guestrooms of Hotel/Motel	Steep	All	0.20	0.75	16

There are four exceptions to the prescriptive nonresidential cool roof requirements. The first exception, which applies to both low- and steep-sloped roofs, exempts roof area covered by building integrated solar photovoltaic panels or building integrated solar thermal panels. There is no proposed change to this exception. Emerging research shows that highly reflective roofs improve the efficiency of rooftop solar panels (Altan 2019, Magallanes 2011). In addition, roof-mounted solar photovoltaic systems often cover only a small portion of the roof.

A second exception states that low-sloped roofs do not need to meet the prescriptive cool roof requirements if they meet less stringent solar reflectance requirements in combination with more stringent roof/ceiling insulation levels as specified in Table 140.3 for new construction or Table 141.0-B for alterations. Increasing insulation levels, particularly above the roof deck, decreases the amount of heat that is absorbed into the building. The revised roof/ceiling tradeoff values are presented in Section 2.6.2 below. As noted in Section 2.5.5, using this tradeoff would not mitigate urban heat island as effectively as the products with an aged solar reflectance of 0.70. However, added insulation above the deck, does have the added benefit of mitigating moisture accumulation as discussed in Section 2.2.2.6.

The third exception states that wood-framed roofs in Climate Zones 3 and 5 with U-factor of 0.034 or below are exempted from meeting the low-sloped prescriptive requirements. This requirement is slightly less stringent than the values in Table 140.3 due to the cooler marine climate of Climate Zones 3 and 5. There is no proposed change to this exception since there is no proposed change to the cool roof requirements for these climate zones.

In the fourth exception, low-sloped roofs with a weight of at least 25 pounds per square foot (lbs/ft^2) are exempt from the requirements, because a high thermal mass also reduces the heat absorbed by the building. There is no proposed revision to this exception. A roof with stone ballast atop a single-ply membrane is an example of a roofing system that may qualify for this exception.

Roofing products used to comply with Title 24, Part 6 using the prescriptive requirements must be rated by the CRRC and are listed in the CRRC Rated Product Directory. Other roofing products available in the market can be used if the building uses the performance approach. If using the performance approach, designers can opt to meet the required energy budget using the CRRC rated properties or the default aged solar reflectance and thermal emittance values listed in Exception 1 to Section 110.8(i)1 for unrated products. The default aged solar reflectance and thermal emittance for asphalt shingles is 0.08 and 0.75, respectively, and for all other products, the default values are 0.10 and 0.75, respectively.

There are no existing requirements in Title 24, Part 6 for documenting moisture content of wood decks or for installing minimum levels of above deck insulation.

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

There are relevant requirements for cool roofs in the California Green Building Standards (Title 24, Part 11, CALGreen). Tier 2 of CALGreen in Section A5.106.11 has solar reflectance standards that are noted below in Table 9.

Section 1202.3 of the California Building Code (Title 24, Part 2) includes insulation requirements for condensate control that apply to unvented enclosed wood frame assemblies. These existing requirements are relevant to the proposal to require above deck insulation when cool roofs are installed on buildings with wood decks to address , stakeholders' concerns that highly reflective roofs can lead to moisture accumulation in the roof deck (see Section 2.2.2.6 and Appendix I:).

2.1.4.3 Relationship to Local, State, or Federal Laws

Multiple jurisdictions within the state of California have established reach codes that are more stringent than the current Title 24, Part 6, cool roof standards. They are shown in Table 9.

Table 9: Relevant Local Cool Roof Standards

Jurisdiction	Sloped	Aged Solar Reflectance	Thermal Emittance	SRI
State of California	Low	0.63	0.75	75
State of California	Steep	0.20	0.75	16
State of California (CALGreen)	Low	0.68	0.85	82
State of California (CALGreen)	Steep	0.28	0.85	27
Brisbane, California	Low	0.70	0.85	85
San Mateo, California	Low	0.70	0.85	85
County of Los Angeles	Low	0.68	0.85	82
County of Los Angeles	Steep	0.28	0.85	27

2.1.4.4 Relationship to Industry Standards

ASHRAE 90.1-2019 has a minimum aged solar reflectance standard of 0.55 and minimum thermal emittance of 0.75 for low-sloped roofs in national Climate Zones 1, 2, 3, and 4a and 4b. These climate zones represent the warm-humid climate zones of the country. The majority of California is in national Climate Zone 3. There are no requirements for steep-sloped roofs in ASHRAE 90.1. Roofs that are at least 75 percent covered by solar photovoltaic arrays do not need to meet ASHRAE 90.1's roof reflectance standards. The 2018 edition of the International Energy Conservation Code (IECC) also has an aged solar reflectance requirement of 0.55 and aged thermal emittance requirement of 0.75 for low-sloped roofs in national Climate Zones 1, 2, and 3.

Solar reflective properties of roofing products are determined by American National Standards Institute (ANSI)/CRRC S100- “Standard Test Methods for Determining Radiative Properties of Materials” (CRRC 2016). The procedure was formerly called CRRC-1 Standard.

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 negative impacts on market actors who are involved in the process could be mitigated or reduced. 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:** Building designers first determine whether they would comply with the cool roof requirements in the prescriptive pathway or the roof/ceiling insulation tradeoff requirements. If choosing the cool roof method, they would choose the specifications of the CRRC-rated roofing material for the alteration or new construction. If using the roof/ceiling insulation tradeoff, designers would determine where to install the insulation and what type to use. The designers complete the Nonresidential Code Compliance Envelope (NRCC-ENV-E) form. Both contractors and building designers would have to comply with either the proposed cool roof standards or the roof/ceiling insulation tradeoff. If during a roof alteration or roof recover, contractors must ensure minimum levels of above deck insulation are able to be installed in the roofing system.
- **Permit Application Phase:** For new construction and additions, plans examiners review the NRCC-ENV-E form and construction plans, and issue the building permit if the roofing products meet the proposed reflectance levels or if the insulation tradeoff levels prescribed in Table 140.3 for new construction or Table 141.0-B for alterations are met. For alterations, permit technicians generally issue the building permit.
- **Construction Phase:** Roofing contractors install products according to construction documents and NRCC-ENV-E form. Roofing contractors would also install insulation to meet the insulation tradeoff if that pathway is selected.
- **Inspection Phase:** Building inspectors ensure that the roof meets the updated radiative requirements or that the insulation level is compliant for the roof’s given aged solar reflectance level. Inspectors verify that the NRCC-ENV-E form is properly documented.

Market actors would work with the same compliance documents and complete the same tasks as they do currently.

This proposed code change should not involve significant changes to the design strategy or standard practices for any of the market actors involved since, as noted in Section 2.1.4.1, current cool roof standards involve the installation of products with high reflectance levels.

2.2 Market Analysis

2.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during two public stakeholder meetings held by the Statewide CASE Team on October 24, 2019 and April 23, 2020. The Statewide CASE Team also reached out to major roofing manufacturer trade organizations, roofing distributors, and retailers. Findings from these interactions are in Appendix F:. This outreach includes cool roof surveys that were distributed to external stakeholders who interact with the roofing industry. More information on these surveys are in Appendix G:.

2.2.1.1 Market Actors

Roofing products for commercial low-sloped roofs typically fall into three main types: coatings, asphalt products (including modified bitumen and built-up roofing), and single-ply. According to a 2015-2016 National Roofing Contractors Association (NRCA) survey of the Pacific market (California, Washington, and Oregon), roughly 40 percent of new construction projects for 2016 were projected to be constructed with thermoplastic polyolefin (TPO) membranes, 20 percent with polyvinyl chloride (PVC), 10 percent with built-up roofs, 10 percent with modified bitumen sheets, and 20 percent with foam or coatings (NRCA 2015). Most of the cool roof survey respondents noted that they worked with single-ply roofing while about one-third have experience working with built-up roofing and coatings. There are no built-up roofs that alone meet the current aged low-sloped reflectance requirement of 0.63, so these types of roofs must have either a modified bitumen membrane or a reflective coating on the roof surface. Major manufacturers for low-sloped roofing products include CertainTeed, Carlisle-SynTec, Firestone, GAF, Johns Manville, Malarkey, Henry Company, Gardner, National Coatings Company, Sika-Sarnafil, and Versico.

Staff from *Western Roofing Magazine* (the current name for *Western Roofing Insulation and Siding*) noted that the vast majority of steep-sloped commercial roofs are metal products (Dodson 2019). Data from the Department of Energy (DOE) Commercial Building Energy Consumption Survey (CBECS) shows a more evenly split market reality between metal, asphalt, and tile roofs (U.S. DOE 2015). For the purposes of this report's analysis, the steep-sloped roofing market was assumed to be split into equal thirds between asphalt shingles, tile, and metal roofs. Steep-sloped roofing manufacturers include CertainTeed, GAF, Malarkey, Owens Corning, Boral, Eagle, ASC Profiles, and Metal Sales Manufacturing Corporation.

Roofing products for both low- and steep-sloped roofs go through a similar process to reach end users. Manufacturers of roofing products play an important role in the market as their decisions determine the availability of products that meet the required cool roof levels. Roofing distributors interact with manufacturers to have adequate products available to meet the needs of local projects. Architects determine the specific products to be used on low- and steep-sloped roofs, and roofing contractors are the individuals that install the cool roof. In the survey that is being conducted in summer 2020, the Statewide CASE Team is seeking to learn more information on the frequency with which contractors get roofing products from suppliers, direct from manufacturers, and retailers.

Major suppliers of roofing products in California include ABC Supply Company, Elite Roofing Supply, and Pacific Supply. There are numerous locations of these companies around the state.

2.2.1.2 Cool Roof Products

Since the first cool roof regulations in Title 24, Part 6 took effect in 2006, products have had to be rated for compliance by the CRRC. The CRRC maintains a directory of rated products, which serves as an overview of the cool roof market for this Final CASE Report. This directory contains the initial and aged solar reflectance, thermal emittance, and SRI of nearly 3,000 roofing products.

These roofing products can be sorted into categories based on various characteristics, such as type, color, and reflectance level. When sorted by slope, products fall into three classes: those with low-sloped applications, those with steep-sloped applications, and those that can be used on both low- or steep-sloped roofs. The different products used in low-sloped roofs compared to steep-sloped roofs are further discussed below.

The nonresidential roofing market primarily comprises buildings with low-sloped roofs. Various estimates have been done to pinpoint the breakdown of steep-sloped roofs compared to low-sloped roofs in California's nonresidential buildings. The 2008 CASE Report, using survey data from NRCA and *Western Roofing Insulation and Siding*

Magazine, found that roughly 20 percent of the nonresidential roofing market in the state is composed of steep-sloped roofs (Akbari, Wray, et al. 2006). In 2019, *Western Roofing Magazine* noted that recent survey data of the western U.S. roofing market (western U.S. states, plus Texas) showed that steep-sloped roofs make up 12.7 percent of the nonresidential roofing market (Dodson 2019). Of the responses to the first cool roof survey conducted in January 2020, most market actors noted that a majority of their projects involved low-sloped nonresidential buildings, but at least 25 percent of respondents had worked on over a dozen steep-sloped nonresidential projects.

As discussed in Section 2.3.1, building prototypes were used in building energy modeling simulations to estimate the energy impacts of proposed code changes. Two of these building prototypes have steep-sloped roofs, and these two building prototypes encompass approximately eight percent of total existing nonresidential floor area in California.

2.2.2 Technical Feasibility, Market Availability, and Current Practices

2.2.2.1 Maintaining Design Flexibility

The Statewide CASE Team values design ingenuity. There are many ways to design a high-performance building envelope, including approaches that allow flexibility in roofing material selections. As the Statewide CASE Team pursues a package of measures to improve building envelope performance there is consideration for how the various measures interact and how best to maintain design flexibility. The proposed changes to prescriptive cool roof requirements are closely related to the recommended revisions to the prescriptive roof/ceiling insulation requirements for both new construction and additions and alterations. The Statewide CASE Team is also pursuing revisions to wall insulation and fenestration performance for nonresidential buildings as detailed in Sections 4 and 5.

For low-sloped roofs, designers can elect to pursue a prescriptive or a performance approach to meeting California's energy code requirements. Within the prescriptive pathway, there is the option of either using a cool roof that meets the prescriptive requirements (Section 140.3(a)1A for new construction and Section 141.0(b)2Bia for alterations and additions) or using the roof/ceiling insulation tradeoff by installing higher performance roof/ceiling insulation (Exception 3 to Section 140.3(a)1A for new construction and Exception to Section 141.0(b)2Bia for alterations and additions). The values in the insulation tradeoff for low-sloped roofs would be updated so that this prescriptive pathway takes into account the proposed changes to roof insulation proposed in Sections 3 and 5 below. Cool roof requirements are being updated to offer the option of achieving a high-performance envelope with highly reflective roofs rather than improved insulation. Designers using the roof/ceiling insulation tradeoff have the option of using cool roof products with an aged solar reflectance as low as 0.25, providing a vast selection of product types and color choice.

If designers prefer more flexibility than is offered in the prescriptive pathways, they have the option of using the performance path to find other energy efficiency improvements in the building envelope. Using the performance approach which is available for both low- and steep-sloped roofs, designers can use any roofing product available on the market including all color options and product types.

2.2.2.2 Achieving Similar Energy Performance with Ceiling Insulation Tradeoff Option

An energy savings analysis was conducted to update the insulation tradeoff table to ensure the tradeoff option leads to the same amount of energy savings as the existing cool roof code. The tradeoff was calculated by comparing the annual savings results of the cool roof simulations with different runs of incremental insulation added the prototype roof. Separate simulations were done for new construction and alterations for both wood-framed and metal roofs. The roof alteration tradeoff table accounted for the proposed roof alteration insulation changes discussed in Section 3 and the new construction table accounted for the opaque envelope changes proposed in Section 5. Added insulation values were simulated at different tiers of reflectance levels to determine what added insulation level would achieve similar savings as the existing cool roof requirements. These simulations accounted for the other building envelope changes in this Final CASE Report to ensure the proposed insulation tradeoff levels would best reflect the overall savings associated the proposal. The specific steps used to determine the insulation tradeoffs are described in Section 2.3.2.3.

2.2.2.3 Product Availability

The Statewide CASE Team considered the impacts of the proposed code change on product availability. Results of a product availability analysis are presented in full in Appendix G:.

In total, 481 of 1,309 products listed in the CRRC Rated Products Directory would meet the potential low-sloped CALGreen proposal. About 72 percent of products that currently meet the low-sloped standards would meet the potential CALGreen standards. For steep-sloped roofs, 1,426 of the 1,711 listed products would meet the proposed Title 24, Part 6 requirements, and 86 percent of those that meet current steep-sloped requirements would meet the proposed requirements. For some of these products, the CRRC used its Rapid Rating test to quickly get an aged solar reflectance level (Cool Roof Rating Council n.d.). Since products that are aged in a test farm tend to have higher aged values than result from Rapid Rating, some of the Rapid Rated products that do not comply now might comply after being aged in the test farm.

Although there is an impact on the number of products that could be used to comply using the primary prescriptive pathway, all roofing products could still be used for California projects. This proposed code change does not prohibit the use of any roofing product. For low-sloped roofs, the option to install cool roof products with an aged solar reflectance of 0.25 or above with additional roof/ceiling insulation is available. For both low-and steep-sloped roofs, the option to install any roofing product with any combination of efficiency measures that allows the building to meet the energy budget through the performance approach is also available.

Some stakeholders noted that the CRRC Rated Products Directory is not a reliable indicator of products available in the California marketplace, citing that some manufacturers may submit products for ratings but never actually bring those products to market, or because some listed products may not be available for sale in California. CRRC staff indicated that they have processes in place to maintain the Rated Products Directory so it remains relevant as an indication of products that are available for sale (Schneider and Egolf 2020). More information on CRRC's processes to maintain the Rated Products Directory is presented in Appendix G:. The Statewide CASE Team conducted outreach to contractors and roofing suppliers to confirm that products that meet the proposed requirements are available throughout California. The summary of this outreach is in Appendix F:.

Additionally, the Statewide CASE Team conducted a survey while the Draft CASE Report was undergoing public review in order to get a more nuanced understanding of products used. Eight contractors specified single-ply products they have recently used. Collectively, the contractors noted they used 18 single-ply products. 10 of these products, in their white color, meet the proposed aged solar reflectance standards of 0.70 while eight do not. Some contractors noted that the single ply products they used were all white while others noted that they used white products more than half of the time. Furthermore, the single-ply products that meet the aged solar reflectance of 0.70 were also used by more contractors than the products that did not.

In this survey, seven contractors were able to provide costs for shipping estimates of single-ply products at the that meet the current requirement versus products that meet the proposed. Six of these seven contractors expected no change in shipping cost. One expected an increase.

Seven contractors were also able to specify what modified bitumen products they have recently used. Of these seven, one noted use of a product that meets the proposed aged solar reflectance level. In total, the seven contractors noted use of nine separate products. Of the seven contractors, five denoted that shipping costs would not increase for products with aged reflectances at the proposed value.

Comprehensive results of the survey are presented in Appendix G:.

2.2.2.4 Maintaining Color Choices

The CRRC Rated Products Directory indicates that roofing products are available in 14 colors. Low-sloped products that meet the current cool roof requirements are available in 13 of the 14 colors. Products that meet the potential CALGreen cool roof requirement are available in 11 colors, though many of these color options are only available in coating products. Table 10 presents the color choices for low-sloped single ply products. Products available that meet the proposed low-sloped reflectance level of 0.70 are available in white, grey, tan, and yellow. Black and brown products for low-sloped roofs are the most limited in terms of availability.

Appendix G: shows the impacts of color by product type.

Table 10: Color Options for Low-Sloped Single Ply Products

Colors Options	Number of Products that Do Not Meet Current or Proposed Requirements	Number of Products That Meet Current Requirements	Number of Products That Meet Potential CALGreen Requirements
Black	5	0	0
Blue	1	0	0
Bright White	3	91	65
Brown	1	0	0
Green	2	0	0
Grey	35	5	0
Metallic	0	0	0
Multicolor	5	0	0
Off-White	1	5	3
Orange	0	0	0
Purple	0	0	0
Red	1	0	0
Tan	25	11	0
Yellow	0	0	0
Total	**79**	**112**	**68**

For steep-sloped roofs, this proposal does not change the number of colors available as 14 color options meet both the current and proposed requirements. The proposed requirements for steep-sloped roofs can be met by numerous products available in many colors, including white, red, orange, tan, yellow, and blue.

Only white single-ply membranes meet the potential CALGreen aged solar reflectance value of 0.70.

One roofing manufacturer shared data with the Statewide CASE Team demonstrating the breakdown of single-ply membrane color by region. In 2019 and 2020, the LA region had a market saturation for non-white membranes (gray or tan) of 3.8 and 3.5 percent respectively. The San Diego market has a non-white membrane saturation of 25 and 28 percent in 2019 and 2020 respectively. And the Northern California market has a non-white membrane market saturation of 20 and 24 percent in 2019 and 2020 respectively.

2.2.2.5 Interaction with Solar Photovoltaics

Current cool roof requirements exempt roof area covered by building integrated photovoltaic systems from installing cool roofs. The Statewide CASE Team recommends keeping this existing exception in place. Literature suggests that reflective roofs may improve the efficiency of solar photovoltaics (Altan 2019, Magallanes 2011). In addition, roof-mounted solar photovoltaic systems often cover only a small portion of the roof area. The Statewide CASE Team is working with the Energy Commission to review any proposed solar photovoltaic requirements that the Energy Commission might proposed for the 2022 cycle relative to the cool roof requirements and may refine the cool roof proposal as a result of this dialogue.

2.2.2.6 Cool Roofs and Moisture Buildup

Highly reflective roofs result in energy savings since they decrease the amount of heat absorbed by the roof cover. Thus, these roofs experience lower temperatures than roofs using less reflective products. One potential disadvantage is that the membrane might be more likely to stay below the dew point temperature, which could allow condensation to accumulate if interior air reaches the roof deck (Kehrer and Ennis 2011). Moisture buildup in roofing systems can cause a variety of problems, including mold growth and roof decay. This moisture is generated inside the building itself and can rise upward to reach the roof deck. In standard roofs, the membrane typically gets hot enough during summer months to dry out any condensation, but this may not be the case with cool roofs.

Numerous simulations have modeled the roof deck moistures of roofs with highly reflective membranes. Some studies and field experience show that under certain conditions, such as high interior humidity levels or little to no above deck insulation, cool roofs can lead to moisture accumulation damage in California climate zones while other studies show that roofs in typical commercial environment may not see such issues. Appendix I: presents a more in-depth literature review of these sources. Additionally, Appendix I: details field studies and surveys of contractors. These sources show that the roofing community does not experience moisture accumulation problems for highly reflective roofs on a regular basis, but that it could be a potential concern depending on certain conditions.

While some sources of tangible evidence show that cool roofs rarely succumb to moisture accumulation problems, the Statewide CASE Team has analyzed methods to mitigate this issue through proper design features. Online articles and simulations show that appropriate amounts of above deck insulation can be added to ensure the roof deck stays above the dew point temperature. In doing so, potential moisture problems would be abated. Appendix I: contains more information as to this pathway to avoid moisture issues and why it is preferable over other solutions.

After discussion moisture buildup with manufacturers, industry associations, roofing contractors, and roofing design consultants, the Statewide CASE Team is recommending that the potential low-sloped CALGreen changes apply to both new construction and alterations. Stakeholders have indicated that moisture buildup is not a concern in new construction as designers can design the roof assembly to account for the more reflective roof surface. For alterations, multiple stakeholders indicated that although the specific conditions of each building need to be taken into account, there is general agreement that adding R-10 above deck would keep the roof deck warm enough to mitigate moisture accumulation in a vast majority of existing buildings. As discussed in the roof alteration section of this report, stakeholders feel comfortable requiring a minimum of R-10 above deck insulation for roof recovers and roof replacements. R-10 is an acceptable value regardless of the equipment and flashing heights on the existing roof. Given an R-10 insulation value would neutralize moisture concerns in most cases, the Statewide CASE Team recommends to require cooler roofs in the hottest climate zones in conjunction with requiring a minimum or R-10 insulation for roof recovers and roof replacements. See Appendix J: for an analysis of the energy and cost-effectiveness of the cool roof and roof alterations requirements combined.

2.2.2.7 Persistence of Savings

This proposal uses the aged solar reflectance of roofing products as the metric to determine if the standard is met. The aged solar reflectance for each product is determined in accordance with the ANSI/CRRC S100 testing methods, which require products to be exposed to natural weathering for three years and uncleaned to attain aged solar reflectance levels (Cool Roof Rating Council 2016). A three-year weathering period was chosen since studies show the loss of reflectance levels off for most roofing types after three years (Desjarlais, Miller and Roodvoets 2004). Thus, the roofing products that meet this proposed standard would generate a consistent level of savings throughout their lifetime and do not need significant maintenance. Stakeholders have commented that these aged values may not be accurate representations of cool roofing product reflectance levels after weathering, but the Statewide CASE Team has not found research demonstrating this to be the case. Nor has the Statewide CASE Team has not found evidence that a roofing product with a high reflectance level has a shorter lifetime. ENERGY STAR’s® qualified products list of roofing products gives the following warranties for various roofing products: asphalt shingles typically cover 15-40 years, metal roofs generally cover 30-50 years, concrete and clay tiles last well over 50 years, single-ply roofs last from 15 to 30 years, and coatings generally last from 10 to 30 years (ENERGY STAR n.d.). These online estimates are consistent with estimates used in the

2008 Draft CASE Report on the inclusion of solar reflectance requirements for steep-sloped nonresidential roofs (Akbari 2006).

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 measures proposed by the Statewide CASE Team for the 2022 code cycle. However, it is standard practice for these businesses to continually adjust to changes in design practices and building codes, which may include engaging in continuing education and training to remain compliant.

California's construction industry is made up of about 80,000 business establishments and 860,000 employees (see Table 11).[7] 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 11: California Commercial 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 roof reflectance 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 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 12 shows the commercial construction subsectors expected to be impacted by the changes proposed in this report and includes employment data from 2018. General contractors have to

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

make decisions regarding the roof reflectivity level, which would therefore also impact roofing contractors' workflow. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 2.2.4.

Table 12: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential Roofing Contractors	347	8,939	$0.6

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 code 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 to remain compliant with these 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 [NAICS] 541310). Table 13 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The code change proposals that the Statewide CASE Team are proposing for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for cool roofs to affect firms that focus on nonresidential construction.

There is no North American Industry Classification System (NAICS) code specifically for energy consultants.[8] 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

[8] 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 developed 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.

residential and nonresidential buildings.[9] 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 13 provides an upper bound indication of the size of this sector in California.

Table 13: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
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 and 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 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. All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

2.2.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants, lodging, retail, mixed-use establishments, and warehouses (including refrigerated) (California Energy Commission 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 is consumed primarily for heating water and for space heating. According to the 2019 California Energy Efficiency Action Plan, more than 7.5 billion square feet of commercial floor space in California accounts for 19 percent of California's total annual energy use (California Energy

[9] 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 contaminants, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

Commission 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.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 2.4.1, when building occupants save on energy bills, it 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 this proposed code change to impact building owners or occupants adversely.

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

Since this proposal involves relatively minor increases to the aged solar reflectance levels to steep- and low-sloped products, the Statewide CASE Team anticipates there would be no material impact on California component retailers. Roofing manufacturers may choose to reformulate existing products in an attempt to meet the proposed reflectance levels.

2.2.3.6 Impact on Building Inspectors

Table 14 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors routinely participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates that the proposed change would have no impact on the employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 14: 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 code change in roof reflectivity would not have modest impacts on employment in California. In Section 2.2.4, the Statewide CASE Team estimates how the proposed change in roof reflectivity would affect statewide employment and economic output, both directly and indirectly, through its impact on builders, designers, and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimates how energy savings associated with the proposed change in roof reflectivity would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

2.2.4 Economic Impacts

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, architects, energy consultants, and building inspectors. 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. There is no expected change to the work processes of building designers or inspectors.

Table 15: Estimated Impact that Adoption of the Proposed Submeasure Would Have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions)
Direct Effects (Additional spending by commercial builders)	10	$0.67	$0.89	$1.46
Indirect Effect (Additional spending by firms supporting commercial builders)	2	$0.16	$0.25	$0.49
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	4	$0.25	$0.44	$0.72
Total Economic Impacts	**17**	**$1.08**	**$1.58**	**$2.68**

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 this code change proposal 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 this section 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 the solar reflectance levels of nonresidential roofs, which would not excessively burden or competitively disadvantage California businesses, nor necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created nor any existing businesses eliminated due to the proposed code change.

2.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The code change proposed by the Statewide CASE Team would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[10] Therefore, the Statewide CASE Team does not anticipate that this submeasure would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate that 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).[11] As Table 16 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

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[10] 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.

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

Table 16: 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	$609.3	$1,740.4	35%
2016	$456.0	$1,739.9	26%
2017	$509.3	$1,813.6	28%
2018	$618.3	$1,843.7	34%
2019	$580.9	$1,827.0	32%
		5-Year Average	**31%**

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

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed submeasure 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 15 through Table 16 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 change to have a measurable impact on 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 budgets for code development, education, and compliance enforcement. While state government allocates 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 cost savings and policy benefits associated with the code change proposals. Like other nonresidential buildings, new construction and alterations of roofs on state buildings would incur a slight cost increase. The cost savings from this proposal, however, would be greater than any incremental cost and the proposed changes are cost effective.

Cost to Local Governments

All revisions 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 retraining 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. Numerous resources are available to local governments to support compliance training that can help mitigate the cost of retraining, including tools 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 Statewide CASE Team proposal is to promote energy efficiency, there is the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team has not found any information to suggest that specific classes of individuals would be negatively impacted by this proposal.

2.3 Energy Savings

2.3.1 Key Assumptions for Energy Savings Analysis

The final 2022 Time Dependent Valuation (TDV) factors were used for the analyses presented in this report (Energy + Environmental Economics 2020). The Energy Commission developed a source energy metric (energy design rating or EDR 1) for the 2022 code cycle.

The Statewide CASE Team used EnergyPlus V9.0.1 to conduct the energy savings calculations for all code change proposals. Energy models are sourced from the California Building Energy Code Compliance (CBECC) software for commercial buildings (CBECC-Com) prototypical building models. These models are modified to include the proposed changes to the energy standards. The grocery building model is sourced from the California Public Utilities Commission (CPUC) Database of Energy Efficient Resources (DEER) because there are currently no prototype models developed in CBECC-Com for these building types. The 2019 Standard Design also serves as the baseline for additions and alterations as a conservative assumption.

To determine the percentage of existing buildings that would be impacted by this submeasure, the Statewide CASE Team analyzed information from the Building Owners and Managers Association and the NRCA, as described later in Section 3.2.1. It was determined that the average lifespan of a roof covering is approximately 15 years. Thus, for the purposes of estimating statewide savings for the cool roof submeasure, an estimated 6.5 percent (i.e., roughly one fifteenth) of the existing building area for the respective building types was impacted. Refer to Appendix A for further details and assumptions regarding the statewide savings methodology.

The Statewide CASE Team simulated the energy savings and cost effectiveness for all prototype buildings and climate zones. Results from simulations informed which building types and climate zones would be subject to the revised cool roof requirements. The statewide energy savings analysis only includes the impacts of climate zones and building types where the cool roof requirements would change.

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 prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 17. The Statewide CASE Team simulated the energy savings and cost effectiveness for all prototype buildings and climate zones and used results to inform recommended revisions to the code requirements. Changes were only recommended when doing so would result in cost-effective energy savings. Energy savings and cost effectiveness are presented Sections 2.3.2.3 and 2.4 for all prototypes and climate zones.

The Retail Mixed Use building prototype does not include a roof, so it was not used in the analysis.

All prototypes except office small and restaurant have low-sloped roofs. Although the prototypical buildings have either a low- or steep-sloped roof, it is expected that some small offices and restaurants have low-sloped roofs. For 20 percent of the statewide square footage, the Statewide CASE Team modified the prototypes for office small and restaurant so the building had a low-sloped roof. Energy savings estimates were calculated using both the low-sloped and steep-sloped versions of the prototypes.

Similarly, it was assumed that a portion of retail buildings would have steep-sloped roofs. The Statewide CASE Team modified the stand alone retail and retail strip mall prototypes, which have low-sloped roofs, so the impacts of steep-sloped roofs could be estimated. Energy savings estimates were calculated using both the low-sloped and steep-sloped versions of the prototypes.

Though the low-sloped recommendation of an aged solar reflectance level of 0.70 is recommended for Title 24, Part 11, the Statewide CASE Team is presenting the simulated results below along with the proposed steep-sloped changes that are recommended for Title 24, Part 6.

Table 17: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Grocery	1	50,002	6-Zone grocery store DEER prototype model provided by SCE
Hospital	3	241,374	5-Story Hospital DOE prototype model
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%
OfficeLarge	12	498,589	12-story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-40%
OfficeMedium	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeMediumLab	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeSmall	1	5,502	1-story, 5 zone office building with pitched roof and unconditioned attic. WWR-24%
RestaurantFastFood	1	2,501	Fast food restaurant with a small kitchen and dining areas. WWR-14%. Pitched roof with an unconditioned attic
RetailLarge	1	240,000	Big-box type retail building with WWR-12% and SRR-0.82%
RetailMixedUse	1	9,375	Retail building with WWR -10%. Roof is adiabatic
RetailStandAlone	1	24,563	Similar to a Target or Walgreens.WWR-7% on the front façade, none on other sides. SRR-2.1%
RetailStripMall	1	9,375	Strip mall building. WWR-10%
SchoolPrimary	1	24,413	Elementary school. WWR-36%
SchoolSecondary	2	210,866	High school. WWR-35% and SRR-1.4%
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR-0.7%,SRR-5%

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of CBECC-Com.

CBECC-Com generates two models based on user inputs: the Proposed Design and the Standard Design. The Proposed Design represents the proposed building design described by the user inputs. The Standard Design represents a building with the same geometry as the Proposed Design, but with construction and equipment parameters that are minimally compliant with the 2019 Title 24, Part 6 code requirements. The Standard Design is described in the 2019 Nonresidential ACM Reference Manual. To develop savings estimates for the proposed code changes, the Statewide CASE Team generated a Standard Design using the CBECC-Com prototype models and created a Proposed Design by modifying the relevant inputs in the Standard Design model to reflect the submeasure. There is an existing Title 24, Part 6 requirement that covers roofing materials and applies to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements. According to Title 24, Part 6, Section 140.3(a), minimal compliance for low-sloped roofs assumes an aged solar reflectance of 0.63 and thermal emittance of 0.75, and compliance for a steep-sloped roof assumes an aged solar reflectance of 0.20 and thermal emittance of 0.75. Insulation values in the Standard Design for both new construction and alterations were minimally compliant with the applicable 2019 Title 24, Part 6 requirements.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 18 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design.

As mentioned, hotels and motels currently have to comply with requirements in Table 140.3-B for nonresidential spaces and requirements in Table 140.3-C for guestroom spaces. For this Final CASE Report, the Statewide CASE Team assumed that in the Standard Design, the entire roof area complies with the nonresidential requirements in Table 140.3-B, and in the Proposed Design the entire roof area complies with the proposed requirements listed in Table 18.

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

Table 18: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change, Cool Roof

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Low-sloped roofs	All	Solar Reflectance	0.63	0.70
Low-sloped roofs	All	Thermal Emittance	0.75	0.75
Steep-sloped roofs	All	Solar Reflectance	0.20	0.25
Steep-sloped roofs	All	Thermal Emittance	0.75	0.80

Using EnergyPlus with CBECC-Com rulesets the Statewide CASE Team determined whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). The 2022 TDV factors were then applied 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) (Energy + Environmental Economics 2020). TDV energy cost savings were calculated using the TDV energy cost impacts over the 30-year period of analysis presented in 2023 present value dollars (2023 PV$).

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

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

Hotels, warehouses, retail buildings, and grocery buildings are not included in the scope of the measure. Additionally, building prototypes of mixed-use retail buildings do not have roofs, so these buildings were also excluded when calculating savings.

2.3.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 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 (Building Type ID) used in the construction forecast 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 19 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.

It was assumed that 80 percent of small offices and restaurants would have a steep-sloped roofs and would be impacted by the steep-sloped proposal, and the remaining 20 percent would have low-sloped roofs and would be impacted by the low-sloped proposal. It was assumed that 20 percent of the retail standalone and strip mall floorspace would be steep-sloped and impacted by the steeps-loped proposal.

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

Table 19: Nonresidential Building Types and Associated Prototype Weighting, Cool Roof

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%
	SchoolSecondary	30%
	ApartmentHighRise	25%
Hospitals	Hospital	100%

2.3.2.3 Methodology for Updating Roof/Ceiling Insulation Tradeoff to Low-Sloped Cool Roof Requirements

The current Title 24, Part 6 code allows designers using the prescriptive approach to elect to either use a cool roof that meets the prescriptive requirements (Section 140.3(a)1A for new construction and Section 141.0(b)2Bia for alterations and additions) or using the roof/ceiling insulation tradeoff by installing higher performance roof/ceiling insulation (Exception 3 to Section 140.3(a)1A for new construction and Exception to Section 141.0(b)2Bia for alterations and additions). The values in the insulation tradeoff would be updated so that this prescriptive pathway takes into account the proposed changes to roof insulation proposed in Sections 3 and 5 of this report. This appendix describes how the Statewide CASE Team developed recommended updates to the roof/ceiling insulation tradeoff tables for both new construction and alterations.

It is recommended that that the Energy Commission evaluate the tradeoff tables closely by running simulations to determine confirm that each combination of aged solar reflectance and roof/ceiling insulation will result in similar energy savings as the primary prescriptive pathway. As a starting point and placeholder to begin discussions, the Statewide CASE Team developed preliminary values for a revised tradeoff table by applying the percentage increase in U-factors for each aged solar reflectance bin from the 2019 tradeoff tables to the updated roof insulation requirements that are proposed for the 2022 code cycle. See

Table 20 and Table 21 for results for new construction and alterations, respectively.

Table 20: Updated Roof/Ceiling Insulation Tradeoff for Low-Sloped Aged Solar Reflectance – Wood Framed and Other – New Construction

	Climate Zones 6, 7, 8			Climate Zones 1-5, 9-16		
Aged Solar Reflectance Bin	**2019 U-factor Requirement**	**U-factor Percent Increase Over No Tradeoff**	**2022 U-Factor Requirement**	**2019 U-factor Requirement**	**U-factor Percent Increase Over No Tradeoff**	**2022 U-Factor Requirement**
No Tradeoff	0.049	---	0.042	0.034	---	0.03
0.62-0.56	0.045	8.2%	0.039	0.032	4.1%	0.029
0.55-046	0.042	14.3%	0.036	0.030	8.2%	0.028
0.45-0.36	0.039	20.4%	0.033	0.029	10.2%	0.027
0.35-0.25	0.037	24.5%	0.032	0.028	12.2%	0.026

Table 21: Updated Roof/Ceiling Insulation Tradeoff for Low-Sloped Aged Solar Reflectance – Alterations

	Climate Zones 6, 7, 8			Climate Zones 1-5, 9-16		
Aged Solar Reflectance Bin	**2019 U-factor Requirement**	**U-factor Percent Increase Over No Tradeoff**	**2022 U-Factor Requirement**	**2019 U-factor Requirement**	**U-factor Percent Increase Over No Tradeoff**	**2022 U-Factor Requirement**
No Tradeoff	0.082	---	0.047	0.055	---	0.037
0.62-0.60	0.075	8.5%	0.043	0.052	5.5%	0.035
0.59-0.55	0.066	19.5%	0.038	0.048	12.7%	0.032
0.54-0.50	0.06	26.8%	0.034	0.044	20.0%	0.030
0.49-0.45	0.055	32.9%	0.032	0.041	25.5%	0.028
0.44-0.40	0.051	37.8%	0.029	0.039	29.1%	0.026
0.39-0.35	0.047	42.7%	0.027	0.037	32.7%	0.025
0.34-0.30	0.044	46.3%	0.025	0.035	36.4%	0.024
0.29-0.25	0.042	48.8%	0.024	0.034	38.2%	0.023

2.3.3 Per-Unit Energy Impacts Results

Electricity, natural gas, and TDVkBTU energy savings per square foot of total building square footage are presented in the tables below. Results for low-sloped roofs on newly-constructed buildings are shown in Table 22 through

Table 24. Results for low-sloped roofs on altered buildings are show in Table 23 through Table 27. Results for steep-sloped roofs on newly-constructed buildings are shown in Table 28 through Table 33. Results for steep-sloped roofs on altered buildings are show in Table 29 through Table 33.

Electricity savings are shown in Wh/ft^2. Natural gas savings are shown in milli therms/ft^2. Total TDV energy savings are shown in TDVKBtu/ft^2. When the proposed code change would increase energy use, the energy savings are negative and depicted in red font and in parentheses ( ). The Statewide CASE Team evaluated energy savings of all prototypical buildings in all climate zones and reviewed results to inform recommended code changes. The Statewide CASE Team is not recommending changes to the cool roof requirements when increasing the stringency would result in increased TDV energy use.

As expected, increasing the stringency of the cool roof requirement results in electricity savings when the cooling load is high. Highly reflective roofs reduce the amount of sunlight a building absorbs which decreases the need for air-conditioning. Climate zones that do not have high cooling loads do not have enough electricity savings for the proposed code change to be cost effective. No changes are recommended for these climate zones. In general, cooler climate zones see less savings and less cost effectiveness than warmer climate zones.

Increasing the stringency of the cool roof requirements increases natural gas use in almost all simulated scenarios. As cool roofs reduce the amount of solar energy a building absorbs, this leads to a slight increase in need for heating.

All simulated results used the weather files the Energy Commission provided, which are based on historic weather. It is expected that energy savings from cool roofs would save more energy than presented in this report because as average temperatures rise in the state, so would energy savings from cool roofs. Temperatures in California have already risen 1° to 2° F since the beginning of the twentieth century (California Energy Commission 2018).

Alterations result in higher savings than new construction since the assumed roof insulation values of an existing building are less than the new construction values stipulated in Table 140.3-B. Improved insulation somewhat cannibalizes the benefits of cool roofs. To reiterate, the new construction simulations model building prototypes with the new construction level of insulation, and the only change is in aged solar reflectance. Alteration simulations model prototypes with the insulation level required in roof alterations in 2019 Title 24, Part 6, and the only change is in aged solar reflectance.

Table 22: Cool Roof Low-Sloped- New Construction; Electricity Savings Per Square Foot (Wh/ft^2) by Climate Zone and Prototype Building[a]

Prototype **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Hospital	10.2	5.4	13.1	10.7	7.4	6.2	19.6	1.1	4.6	4.9	4.0
OfficeLarge	1.8	2.5	2.1	2.0	2.1	3.0	1.8	1.9	2.1	2.1	2.0
OfficeMedium	8.3	13.0	13.4	18.3	11.8	13.4	11.3	10.7	15.0	13.3	18.0
OfficeMediumLab	5.3	7.4	6.5	12.3	8.0	8.6	8.4	6.5	10.4	9.9	16.0
OfficeSmall	52.7	73.7	69.5	84.1	61.8	63.6	55.0	53.6	61.0	57.7	69.0
RestaurantFastFood	47.6	67.7	62.0	86.0	59.6	106.2	50.8	110.4	190.8	189.8	69.7
SchoolPrimary	37.0	58.8	51.0	70.1	43.2	48.1	38.8	41.3	45.7	38.4	54.3
SchoolSecondary	10.8	14.1	12.5	26.1	17.5	18.2	30.3	13.8	35.0	15.7	23.8

a. Low-sloped proposal would potentially impact Title 24, Part 11 (CALGreen)

Table 23: Cool Roof Low-Sloped- New Construction; Natural Gas Savings Per Square Foot (milli therms/ft^2) by Climate Zone and Prototype Building[a]

Prototype **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Hospital	0.40	(0.18)	0.62	(0.16)	(0.01)	(0.04)	0.43	(0.34)	(0.19)	(0.09)	(0.16)
OfficeLarge	(0.03)	(0.04)	(0.05)	(0.16)	(0.05)	0.00	(0.03)	(0.05)	(0.05)	(0.04)	(0.04)
OfficeMedium	(0.26)	(0.21)	(0.21)	(0.26)	(0.20)	(0.23)	(0.20)	(0.29)	(0.22)	(0.23)	(0.11)
OfficeMediumLab	(0.88)	(0.94)	(1.08)	(1.24)	(0.95)	(0.97)	(0.81)	(0.92)	(0.96)	(0.82)	(0.93)
OfficeSmall	(0.75)	(0.41)	(0.36)	(0.50)	(0.42)	(0.56)	(0.90)	(0.96)	(0.85)	(1.04)	(0.22)
Restaurant FastFood	(2.71)	(2.58)	(2.43)	(2.37)	(2.10)	(2.14)	(2.09)	(2.55)	(2.17)	(2.46)	(1.02)
SchoolPrimary	(1.00)	(0.72)	(0.67)	(0.83)	(0.61)	(0.75)	(1.02)	(1.18)	(1.05)	(1.18)	(0.35)
SchoolSecondary	(0.94)	(1.19)	(1.23)	(1.20)	(0.75)	(0.89)	(0.74)	(0.95)	(0.80)	(0.93)	(0.64)

Table 24: Cool Roof Low-Sloped- New Construction; TDV Energy Savings Per Square Foot (TDVKBtu/ft^2) by Climate Zone and Prototype Building[a]

Prototype Climate Zone	4	6	7	8	9	10	11	12	13	14	15
Hospital	0.4	0.1	0.5	0.2	0.2	0.1	0.9	(0.1)	(0.2)	0.1	0.0
HotelSmall	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.4
OfficeLarge	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
OfficeMedium	0.2	0.3	0.2	0.4	0.3	0.3	0.3	0.2	0.3	0.3	0.4
OfficeMediumLab	0.1	(0.1)	(0.2)	0.1	0.1	(0.0)	(0.0)	(0.1)	0.0	0.0	0.6
OfficeSmall	1.2	1.8	1.7	2.2	1.6	1.5	1.3	1.2	1.4	1.3	1.8
Restaurant FastFood	0.5	1.1	0.9	1.7	1.0	2.7	0.8	10.0	17.0	15.4	1.5
SchoolPrimary	0.7	1.3	1.1	1.6	1.0	1.1	0.8	0.8	1.0	0.8	1.3
SchoolSecondary	0.0	(0.0)	(0.1)	0.3	0.3	0.2	0.5	0.0	0.6	0.1	0.4

a. Low-sloped proposal would potentially impact Title 24, Part 11 (CALGreen)

Table 25: Cool Roof Low-Sloped- Alterations; Electricity Savings Per Square Foot (Wh/ft^2) by Climate Zone and Prototype Building [a]

Prototype Climate Zone	4	6	7	8	9	10	11	12	13	14	15
OfficeLarge	4.3	5.4	4.4	6.8	5.7	2.4	2.7	3.0	3.7	4.1	4.8
OfficeMedium	26.9	26.8	22.2	40.7	36.9	25.1	20.1	18.1	25.5	21.2	36.1
OfficeMediumLab	17.5	15.8	14.8	27.8	27.3	16.9	19.8	14.2	23.0	20.2	26.5
OfficeSmall	159.4	142.5	140.1	210.8	202.8	116.5	117.5	101.5	136.7	105.8	152.0
RestaurantFast Food	105.1	107.3	120.5	168.8	160.7	114.1	101.0	97.3	111.7	98.4	130.5
SchoolPrimary	157.9	158.5	115.6	211.3	184.1	127.6	109.9	92.9	119.0	91.8	118.3
SchoolSecondary	48.4	42.6	34.6	74.1	68.5	42.9	32.3	32.5	43.9	34.6	52.1

a. Low-sloped proposal is for Title 24, Part 11 (CALGreen)

Table 26: Cool Roof Low-Sloped- Alterations; Natural Gas Savings Per Square Foot (milli therms/ft^2) by Climate Zone and Prototype Building [a]

Prototype / Climate Zone	4	6	7	8	9	10	11	12	13	14	15
OfficeLarge	(0.1)	(0.0)	(0.1)	(0.0)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
OfficeMedium	(0.5)	(0.1)	(0.5)	(0.2)	(0.3)	(0.4)	(0.4)	(0.5)	(0.5)	(0.5)	(0.2)
OfficeMediumLab	(1.9)	(2.0)	(2.1)	(2.6)	(2.5)	(2.0)	(1.5)	(1.7)	(1.8)	(1.5)	(1.8)
OfficeSmall	(2.9)	(1.3)	(1.1)	(1.7)	(2.1)	(1.3)	(1.9)	(2.1)	(1.8)	(2.3)	(0.6)
RestaurantFast Food	(7.4)	(5.1)	(4.9)	(4.8)	(5.6)	(3.9)	(3.9)	(4.9)	(3.9)	(4.5)	(1.8)
SchoolPrimary	(3.3)	(2.7)	(2.7)	(2.7)	(2.9)	(1.7)	(1.5)	(2.0)	(1.7)	(2.1)	(1.2)
SchoolSecondary	(5.9)	(4.1)	(4.1)	(4.3)	(5.2)	(2.5)	(3.0)	(3.5)	(3.0)	(4.0)	(1.7)

a. Low-sloped proposal would potentially impact Title 24, Part 11 (CALGreen)

Table 27: Cool Roof Low-Sloped- Alterations; TDV Energy Savings Per Square Foot (TDVKBtu/ft^2) by Climate Zone and Prototype Building [a]

Prototype / Climate Zone	1 [b]	2 [b]	3 [b]	4	5 [b]	6	7	8	9	10	11	12	13	14	15	16 [b]
OfficeLarge	(0.1)	0.1	(0.1)	0.1	(0.1)	0.2	0.1	0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.0
OfficeMedium	(0.3)	0.3	0.1	0.6	0.2	0.6	0.4	1.1	0.9	0.5	0.4	0.4	0.5	0.5	0.9	0.0
OfficeMediumLab	(0.5)	(0.2)	(0.4)	(0.1)	(0.4)	(0.2)	(0.3)	0.1	0.2	(0.1)	0.7	(0.1)	0.2	0.2	0.1	(0.3)
OfficeSmall	(0.6)	1.9	2.1	3.6	2.1	3.3	3.2	5.3	4.9	2.7	2.7	2.2	3.3	2.2	3.9	1.1
Restaurant FastFood	(2.9)	0.4	(0.3)	(4.3)	(0.5)	1.0	1.6	3.2	2.6	1.9	1.6	1.3	1.8	1.3	2.9	0.0
SchoolPrimary	(2.8)	1.5	0.5	2.8	1.1	3.5	2.3	4.8	4.0	2.8	2.3	1.8	2.4	1.8	2.9	(0.2)
SchoolSecondary	(1.4)	(0.1)	(0.8)	0.3	(0.7)	0.2	(0.1)	1.1	0.9	0.5	0.3	0.2	0.5	0.3	0.9	(0.5)

a. Low-sloped proposal would potentially impact Title 24, Part 11 (CALGreen)

Table 28: Cool Roof Steep-Sloped- New Construction; Electricity Savings Per Square Foot (W/ft^2) by Climate Zone and Prototype Building

Prototype / Climate Zone	2	4	5	6	7	8	9	10	11	12	13	14	15	16
OfficeSmall	54.5	54.4	48.7	74.6	73.1	88.1	61.3	64.5	57.3	55.8	59.7	57.9	81.8	59.5
RestaurantFastFood	45.7	45.8	35.5	65.2	31.8	82.8	54.8	60.0	53.4	51.5	58.2	53.3	70.0	47.6
RetailStandAlone	20.3	(21.1)	33.5	28.1	2.6	34.9	49.2	11.3	12.8	90.3	(23.3)	2.5	173.9	44.5
RetailStripMall	26.7	39.3	24.8	67.2	62.3	93.4	30.3	75.9	26.0	2.1	56.9	46.5	71.2	17.8

a. The proposed code change would not impact this climate zone.

Table 29: Cool Roof Steep-Sloped- New Construction; Natural Gas Savings Per Square Foot (milli therms/ft^2) by Climate Zone and Prototype Building

Prototype / Climate Zone	2	4	5	6	7	8	9	10	11	12	13	14	15	16
OfficeSmall	(1.3)	(0.8)	(0.9)	(0.4)	(0.3)	(0.5)	(0.5)	(0.5)	(1.0)	(1.0)	(0.8)	(1.1)	(0.2)	(2.3)
RestaurantFastFood	(3.9)	(2.7)	(3.8)	(2.5)	(2.3)	(2.4)	(2.0)	(2.2)	(2.3)	(2.8)	(2.1)	(2.6)	(1.1)	(4.2)
RetailStandAlone	(1.9)	(1.2)	(1.6)	(0.9)	(0.9)	(1.1)	(0.9)	(0.9)	(1.3)	(1.5)	(1.2)	(1.5)	(0.5)	(2.8)
RetailStripMall	(1.3)	(0.8)	(0.9)	(0.5)	(0.5)	(0.5)	(0.5)	(0.6)	(0.9)	(1.0)	(0.9)	(1.0)	(0.3)	(2.3)

a. The proposed code change would not impact this climate zone.

Table 30: Cool Roof Steep-Sloped- New Construction; TDV Energy Savings Per Square Foot (TDVKBtu/ft^2) by Climate Zone and Prototype Building

Prototype / Climate Zone	2	4	5	6	7	8	9	10	11	12	13	14	15	16
OfficeSmall	1.1	1.3	0.9	1.8	1.8	2.3	1.5	1.6	1.3	1.3	1.4	1.2	2.1	0.7
RestaurantFastFood	0.3	0.5	(0.2)	1.0	(0.3)	1.6	0.9	1.0	0.8	0.7	0.9	0.7	1.5	(0.0)
RetailStandAlone	(2.2)	(1.5)	0.8	0.5	0.5	1.9	2.4	(1.6)	5.1	0.3	(0.2)	(2.0)	3.5	0.3
RetailStripMall	4.0	2.9	0.3	0.8	1.1	2.1	0.7	1.8	0.4	(0.2)	1.2	0.9	2.0	(0.4)

a. The proposed code change would not impact this climate zone.

Table 31: Cool Roof Steep-Sloped- Alterations; Electricity Savings Per Square Foot (W/ft²) by Climate Zone and Prototype Building

Prototype **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
OfficeSmall	141.6	217.9	208.0	215.9	214.2	258.0	251.0	174.0	149.7	155.9	158.2	147.6	178.7	164.0
Restaurant FastFood	82.1	125.0	101.7	115.4	204.9	161.9	163.7	111.1	97.3	96.0	107.6	99.4	323.2	96.2
RetailStand Alone	16.6	83.9	71.5	142.8	45.6	166.3	62.6	51.2	66.9	15.5	41.3	27.9	114.7	15.9
RetailStripMall	11.4	196.1	172.3	208.2	206.2	229.2	205.6	117.8	118.5	91.8	195.0	117.5	154.0	142.2

a. The proposed code change would not impact this climate zone.

Table 32: Cool Roof Steep-Sloped- Alterations; Natural Gas Savings Per Square Foot (milli therms/ft²) by Climate Zone and Prototype Building

Prototype **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
OfficeSmall	(2.9)	(2.9)	(3.7)	(1.2)	(1.1)	(1.5)	(1.8)	(1.3)	(2.3)	(2.4)	(2.0)	(2.5)	(0.6)	(5.2)
RestaurantFastFood	(6.8)	(7.0)	(9.6)	(4.8)	(4.5)	(4.6)	(5.4)	(3.8)	(4.0)	(5.1)	(3.9)	(4.6)	(1.9)	(7.9)
RetailStandAlone	(3.9)	(4.5)	(5.5)	(2.5)	(2.3)	(2.7)	(3.3)	(2.0)	(2.7)	(3.1)	(2.6)	(3.2)	(1.1)	(5.6)
RetailStripMall	(2.2)	(3.6)	(4.3)	(1.7)	(1.6)	(2.0)	(2.4)	(1.6)	(2.4)	(2.4)	(2.2)	(2.6)	(0.6)	(5.8)

a. The proposed code change would not impact this climate zone.

Table 33: Cool Roof Steep-Sloped- Alterations; TDV Energy Savings Per Square Foot (TDVKBtu/ft²) by Climate Zone and Prototype Building

Prototype **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
OfficeSmall	3.0	5.0	4.2	5.2	5.2	6.5	6.2	4.2	3.4	3.5	3.7	3.4	4.6	2.4
RestaurantFastFood	0.4	1.4	(0.1)	1.5	4.1	3.1	2.8	1.8	1.4	1.2	1.7	1.3	12.9	0.2
RetailStandAlone	(5.0)	0.1	(0.0)	2.1	0.6	4.3	(0.6)	(0.2)	1.8	(2.5)	2.6	0.3	3.1	(1.5)
RetailStripMall	(2.5)	5.2	3.6	4.2	4.8	6.0	3.0	1.4	2.4	1.5	5.1	2.7	4.2	1.7

a. The proposed code change would not impact this climate zone.

2.3.4 Summary of Literature Demonstrating Energy Savings of Cool Roofs

Numerous field studies and simulations have shown the energy savings benefits of cool roofs. In 1991 and 1992, Akbari et al. analyzed the peak power and cooling savings from adding a reflective coating to one house and two school buildings in California. The baseline reflectance was 0.08, and the applied coating had a reflectivity of 0.68. In the school buildings, energy used to cool the building decreased by 35 percent. The school buildings also saw a reduction in peak demand of 0.63 kWh (Akbari, Bretz, et al. 1997). In 1998, Akbari et al. monitored the energy savings in three California buildings that added a roof coating; the reflectance of the roofs changed from 0.20 to 0.60 on average. Two medical offices and one retail building were analyzed in Gilroy, Davis, and San Jose, respectively. The office building in Gilroy with primarily R-8 insulation saw a summertime air-conditioning decrease of 18 percent. The office building in Davis with primarily R-19 insulation saw a decrease of 13 percent. The retail building, which was internal load driven, saw savings of two percent (H. Akbari, S. Konopacki, et al. 1998). In the summer of 2000, Akbari analyzed the savings of two small nonresidential buildings that went from solar reflectivities of 0.26 to 0.72. The annual estimated energy savings were 8.4 kWh/m^2 (Akbari 2003b). Lastly, for a retail building, Akbari and Konopacki (2001) analyzed the cost and energy savings from putting a highly reflective coating with a reflectance level of 0.83 on a dark roof with a reflectance level of 0.05. The average air-conditioning decrease compared to the base case was 11 percent, and there was a 14 percent decrease in peak air-conditioning demand. In total, over the estimated 13-year life span of the roof coating, an estimated $62,000 to $71,000 would be saved (Akbari and Konopacki 2001).

More recently, in 2006, the MGM Grand in Las Vegas, the largest hotel in the U.S., added a bright-white coating, containing Kynar coating’s latex base, to its roof. Kynar analyzed the cost savings associated with the addition of this coating on top of the existing ethylene propylene diene terpolymer (EPDM) roof. After adding the highly reflective coating, the building saw annual energy cost savings of roughly $15,000 to $30,000 per 100,000 ft^2 of building area and occupant comfort greatly improved (Kynar 2016).

In addition to the above field studies, simulations have been conducted to show the benefits of a cool roofs. In a comprehensive analysis, Akbari and Levinson analyzed the energy and cost impacts for cool roofing in over 200 U.S. cities. Roofs with reflectance levels of 0.55 and 0.20 were analyzed. Nationwide, annual cooling energy savings were simulated to be 5.02 kWh/m^2 of roof area. Average energy cost savings per year were simulated to be $0.356/$m^2$ of roof area (Akbari and Levinson 2010). Dozens of other simulations and models have demonstrated the impacts of reflective roofs in various countries and climate zones.

During one utility-sponsored stakeholder meeting, attendees mentioned that it would be beneficial to see the energy savings impacts of prior cool roof legislation changes. However, during a single code cycle, numerous updates are made to Title 24, Part 6 and identifying the direct benefits of one particular change is rather unworkable. The Statewide CASE Team believes that the field studies noted above and the numerous simulations conducted on cool roofs in the past three decades definitively show that reflective roofs lead to energy savings in climate zones relevant to this proposal. Table 34 below shows some of the many studies on the impacts of cool roofs in the United States.

Table 34: Research on Impacts of Cool Roofs

#	Author(s)	Year	Title
1	Konopacki et al	1997	Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 US metropolitan areas
2	Akbari et al	1997	Peak power and cooling energy savings of high-albedo roofs
3	Parker and Barkaszi	1997	Roof solar reflectance and cooling energy use: field research results from Florida
4	Akbari and Konopacki	1998	The Impact of Reflectivity and Emissivity of Roofs on Building Cooling and Heating Energy Use
5	Akbari et al	1999	Cooling energy savings potential of reflective roofs for residential and commercial buildings in the United States
6	Akbari and Konopacki	2000	Energy Saving Calculations for Heat Island Reduction Strategies in Baton Rouge, Sacramento, and Salt Lake City
7	Akbari and Konopacki	2001	Measured energy savings and demand reduction from a reflective roof membrane on a large retail store in Austin
8	Moujaes et al	2003	Thermal Performance Analysis of Highly Reflective Coating on Residences in Hot and Arid Climates
9	Akbari	2003	Measured energy savings from the application of reflective roofs in two small non-residential buildings
10	Levinson and Akbari	2010	Potential benefits of cool roofs on commercial buildings: Conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants
11	Kynar Coatings	2016	Field Application Case Study

2.3.5 Energy Benefits of Above-Sheath Ventilation

The Statewide CASE Team received feedback from the Tile Roofing Industry Alliance that some roof products, primarily tile and metal roofs, contain air space above the roof deck that can achieve energy savings. Above-sheathing air space leads to reduced heat transfer into the building, and the roof deck can remain cooler. Research has demonstrated the energy savings benefits of above-sheath ventilation (Desjarlais, Miller and Kriner 2013). A metal roof with a reflectance level of 0.10 with above-sheath ventilation saw energy savings similar to that of a metal roof with a reflectance level of 0.25. While these results validate the energy savings of above-sheath ventilation, the

Statewide CASE Team has not taken the added benefit of above-sheath ventilation into account for the energy savings analysis for this report and there are no proposed code changes that aim to ensure above-sheath ventilation is accounted for appropriately in the prescriptive pathway or the compliance software. Above-sheath ventilation is only possible for a limited set of roofing products, so a single standard could not apply to all products. The products that can provide above-sheath ventilation, tile and metal standing-seam, are demonstrably able to meet the proposed steep-sloped changes with no incremental costs; therefore, the added energy savings benefits of above-sheath ventilation are not expected to decrease since these products would still appear on the market.

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 2.3.2.2. 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. In this case, the period of analysis used is 30 years, as with all nonresidential envelope measures. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years. 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 2.3.2.2. 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. In this case, the period of analysis used is 30 years, as with all nonresidential envelope measures. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years.

These proposed changes to solar radiative properties of roofing products apply to both new construction and roof alterations. Since the incremental costs between baseline and proposed reflectance levels only depend on changes to roofing materials, there is no difference between costs in new construction and roof alterations. Thus, per-unit incremental costs are the same for additions and alterations as for new construction. The added cost for the above deck insulation is included in the roof alterations section below in Section 3. The results below show the cost and energy savings associated with just the changes in reflectivity.

Though the low-sloped recommendation of an aged solar reflectance level of 0.70 is recommended for Title 24, Part 11, the Statewide CASE Team is presenting the results below along with the proposed steep-sloped changes that are recommended for Title 24, Part 6.

2.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 35 for the Small Office prototype. Savings for other prototypes are presented in Table 36 and Table 37.

Table 35: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction– OfficeSmall, Steep-Slope

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	N/A	N/A	N/A
2	$0.24	($0.06)	$0.18
3	N/A	N/A	N/A
4	$0.23	($0.04)	$0.20
5	$0.19	($0.04)	$0.14
6	$0.30	($0.02)	$0.28
7	$0.29	($0.02)	$0.27
8	$0.37	($0.02)	$0.35
9	$0.26	($0.02)	$0.24
10	$0.27	($0.03)	$0.24
11	$0.25	($0.05)	$0.20
12	$0.24	($0.05)	$0.19
13	$0.26	($0.04)	$0.21
14	$0.25	($0.06)	$0.19
15	$0.34	($0.01)	$0.33
16	$0.22	($0.11)	$0.11

Table 36: Low-Sloped Cool Roof Total TDV Energy Cost Savings Per Square Foot (2023 PV$/ft²) Over 30-Year Period of Analysis by Climate Zone and Prototype Building- New Construction [a]

Prototype / **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Hospital	$0.06	$0.01	$0.08	$0.03	$0.03	$0.02	$0.14	($0.01)	($0.04)	$0.02	$0.00
OfficeLarge	$0.01	$0.01	$0.00	$0.00	$0.01	$0.01	$0.00	$0.00	$0.01	$0.01	$0.01
OfficeMedium	$0.02	$0.04	$0.03	$0.07	$0.05	$0.04	$0.04	$0.03	$0.05	$0.05	$0.07
OfficeMediumLab	$0.01	($0.01)	($0.02)	$0.01	$0.01	($0.00)	($0.00)	($0.01)	$0.01	$0.01	$0.09
OfficeSmall	$0.19	$0.28	$0.26	$0.33	$0.24	$0.23	$0.19	$0.19	$0.22	$0.20	$0.27
RestaurantFastFood	$0.08	$0.16	$0.14	$0.26	$0.15	$0.41	$0.12	$1.54	$2.61	$2.38	$0.24
SchoolPrimary	$0.11	$0.21	$0.17	$0.24	$0.16	$0.16	$0.12	$0.12	$0.15	$0.12	$0.20
SchoolSecondary	$0.00	($0.00)	($0.01)	$0.05	$0.04	$0.03	$0.08	$0.01	$0.09	$0.02	$0.06

a. Low-sloped proposal would potentially impact Title 24, Part 11 (CALGreen)

Table 37: Low-Sloped Cool Roof Total TDV Energy Cost Savings Per Square Foot (2023 PV$/ft2) Over 30-Year Period of Analysis by Climate Zone and Prototype Building- Alterations[a]

Prototype / **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
OfficeLarge	$0.01	$0.03	$0.01	$0.03	$0.02	$0.00	$0.01	$0.00	$0.01	$0.01	$0.01
OfficeMedium	$0.09	$0.09	$0.06	$0.16	$0.14	$0.08	$0.06	$0.05	$0.08	$0.07	$0.14
OfficeMediumLab	($0.01)	($0.03)	($0.04)	$0.02	$0.03	($0.02)	$0.10	($0.01)	$0.02	$0.03	$0.01
OfficeSmall	$0.55	$0.50	$0.49	$0.82	$0.76	$0.41	$0.41	$0.33	$0.51	$0.33	$0.59
Restaurant FastFood	(0.659	$0.16	$0.25	$0.49	$0.39	$0.30	$0.24	$0.20	$0.27	$0.20	$0.44
SchoolPrimary	$0.44	$0.54	$0.35	$0.73	$0.62	$0.43	$0.35	$0.27	$0.37	$0.27	$0.44
SchoolSecondary	$0.05	$0.03	($0.01)	$0.17	$0.14	$0.08	$0.04	$0.03	$0.08	$0.04	$0.14

a. Low-sloped proposal would potentially impact Title 24, Part 11 (CALGreen)

Table 38: Steep-Sloped Cool Roof Total TDV Energy Cost Savings Per Square Foot (2023 PV$/ft²) Over 30-Year Period of Analysis by Climate Zone and Prototype Building- New Construction

Prototype / **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Office Small	$0.18	$0.20	$0.14	$0.28	$0.27	$0.35	$0.24	$0.24	$0.20	$0.19	$0.21	$0.19	$0.33	$0.11
Restaurant	$0.04	$0.08	($0.02)	$0.15	($0.05)	$0.24	$0.14	$0.15	$0.12	$0.10	$0.14	$0.10	$0.24	($0.00)
Retail Stand Alone	($0.34)	($0.23)	$0.13	$0.08	$0.08	$0.29	$0.37	($0.25)	$0.79	$0.05	($0.03)	($0.31)	$0.54	$0.05
Retail Strip Mall	$0.62	$0.44	$0.05	$0.12	$0.16	$0.33	$0.11	$0.28	$0.06	($0.03)	$0.18	$0.13	$0.30	($0.06)

a. The proposed code change would not impact this climate zone.

Table 39: Steep-Sloped Cool Roof Total TDV Energy Cost Savings Per Square Foot (2023 PV$/ft2) Over 30-Year Period of Analysis by Climate Zone and Prototype Building- Alterations

Prototype / **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Office Small	$0.47	$0.77	$0.64	$0.81	$0.80	$1.00	$0.95	$0.65	$0.52	$0.55	$0.57	$0.52	$0.71	$0.37
Restaurant	$0.06	$0.22	($0.02)	$0.24	$0.64	$0.47	$0.44	$0.28	$0.22	$0.18	$0.25	$0.20	$1.98	$0.02
Retail Stand Alone	($0.77)	$0.02	($0.00)	$0.32	$0.09	$0.66	($0.09)	($0.03)	$0.27	($0.39)	$0.40	$0.05	$0.48	($0.24)
Retail Strip Mall	($0.38)	$0.80	$0.55	$0.65	$0.74	$0.93	$0.47	$0.21	$0.38	$0.23	$0.78	$0.42	$0.64	$0.26

a. The proposed code change would not impact this climate zone.

2.4.3 Incremental First Cost

The incremental first costs for both new construction and roof alterations for this cool roof proposal consist of the difference in material costs of roofing products that meet the current requirements to those that meet the proposed requirements. See the sections below for additional information about incremental material costs for different types of roofing products.

There is no incremental first cost for product installation. The majority of the respondents to the first cool roof survey conducted in January 2020 noted that installation costs of the same type of roofing were the same, regardless of how reflective the roofing products were. This was confirmed with interviews with contractors and trade groups that reiterated there is no added installation cost when installing cool roof products compared to standard products for both new construction and alterations (Spring 2019); (Shoemaker and Haws 2019). Previous CASE studies for cool roofs have made this same assumption (Akbari 2003); (AEC 2013). This assumption was presumed to be accurate for all types of roofing products.

2.4.3.1 Process to Determine Incremental Costs

Incremental costs for roofing products that meet or exceed these proposed standards were determined through online searches, previous research reports, and phone conversations with roofing suppliers and retailers.

Products with an aged solar reflectance or an SRI at or near the 2019 Title 24, Part 6 Standards were assumed to be the baseline. These products did not necessarily have the thermal emittance level that is prescribed in the code, as few products in the CRRC directory have both the exact aged solar reflectance and thermal emittance levels required by Title 24, Part 6, Section 140.3.

After collecting costs for products at the baseline and proposed levels, the Statewide CASE Team averaged the costs of the products in both groups. Next, contractor markups were gathered from construction cost estimating software, RS Means. The associated markups per product category are noted in Table 41 and Table 42. After adding these markups to products at both the baseline and proposed levels, the incremental cost per square foot was calculated through subtraction.

Table 40 shows the specific products for which costs were gathered. Table 41 shows incremental cost estimates for low-sloped roofing products. Table 42 shows incremental cost estimates for steep-sloped roofing. The costs in Table 41 and Table 42 include contractor markups and represent cost to the building owner.

Table 40: Roofing Products Used in Cool Roof Cost Analysis

Slope	Product	Type	Manufacturer
Low	287 Solar-flex	Coating	Henry Company
Low	587 Dura-Brite	Coating	Henry Company
Low	687 Environwhite	Coating	Henry Company
Low	Sta-kool 770	Coating	Gardner
Low	Roof-gard 700	Coating	Black Jack
Low	Ultra Roof 1000	Coating	Black Jack
Low	Asphalt 911 Eternalastic	Coating	Tropical Roofing
Low	Asphalt 921 Reflex	Coating	Tropical Roofing
Low	GACO S2000	Coating	GACO
Low	TopGard 5000 Tan	Coating	Johns Manville
Low	TopGard 5000 White	Coating	Johns Manville
Low	Everguard White	TPO	GAF
Low	Everguard Extreme	TPO	GAF
Low	PVC White	PVC	GAF
Low	Versiweld TPO	TPO	Versico
Low	PVC White	PVC	Johns Manville
Low	TPO Tan	TPO	Johns Manville
Low	TPO White	TPO	Johns Manville
Low	Genflex EZ Fleece backed	TPO	Genflex
Low	PVC white	PVC	Mulehide
Low	TPO white	TPO	Mulehide
Low	Sure-flex PVC white	PVC	Carlisle
Low	Carlisle KEE	PVC	Carlisle
Low	Roof Cap Polyfresko	Modified Bitumen	Polyglass
Low	Dynaflex G	Modified Bitumen	Johns Manville
Low	Dynaflex CR	Modified Bitumen	Johns Manville
Low	Ruberoid EnergyCap Torch Granule	Modified Bitumen	GAF
Low	CoolStar Flintastic	Modified Bitumen	CertainTeed
Steep	Timberline Natural Shadow	Asphalt	GAF
Steep	Timberline HD	Asphalt	GAF
Steep	Royal Sovereign	Asphalt	GAF
Steep	Oakridge	Asphalt	Owens
Steep	Supreme	Asphalt	Owens
Steep	TruDefinition Cool Duration	Asphalt	Owens
Steep	Duration Premium	Asphalt	Owens
Steep	Duration Cool	Asphalt	Owens
Steep	Landmark Solaris	Asphalt	CertainTeed
Steep	Landmark Solaris Pro	Asphalt	CertainTeed
Steep	Villa 900	Tile	Boral
Steep	Belair	Tile	Eagle

Table 41: Low-Sloped Incremental Cost Estimates

Product Type	Coatings	TPO[a]	PVC[b]	Cap Sheet
Contractor Markup	10%	20%	20%	33%
Low-Sloped Market Share	30%	40%	20%	10%
$ per Square Foot at Baseline	0.47	0.76	0.95	1.68
$ per Square Foot at Proposed	0.48	0.78	0.95	1.94
Incremental Cost per Square Foot [c]	0.01	0.02	0.00	0.26
Source(s)	Calls to distributors / online searches	Calls to distributors / 2016 TRC reports	Calls to distributors	2016 TRC report / Calls to distributors

a. Thermoplastic polyolefin

b. Polyvinyl chloride

c. Incremental cost is only the change in material costs. Changes in installation, labor, and maintenance are assumed to be zero.

Table 42: Steep-sloped Incremental Cost Estimates

Product Type	Tile	Asphalt Shingles	Metal
Contractor Markup	30%	40%	30%
Steep-sloped Market Share	33%	33%	33%
Average Cost at Baseline level ($ per square foot)	1.18	1.57	4.55
Average Cost at Proposed Level ($ per square foot)	1.18	1.64	4.55
Incremental Cost ($ per square foot) [a]	0.00	0.07	0.00
Source(s)	2016 TRC report / calls to distributors	Online searches/ calls to retailers	2008 CASE Report / Calls with trade groups

a. Incremental cost is only the change in material costs. Changes in installation, labor, and maintenance are assumed to be zero.

Using the above incremental cost information as well as the percentage of the market that these roofing products occupy, as noted in Section 2.2, a blended incremental cost per square foot of roofing area was estimated for both low- and steep-sloped roofs. Year one incremental costs were assumed to be $0.04 per square foot for low-sloped roofs and $0.02 per square foot for steep-sloped roofs. These incremental costs include contractor markups to determine the costs to the building owner.

The estimate for low-sloped roof incremental costs is conservative in that prior reports, such as the 2016 reach code analysis, calculated either no change or a cost decrease for most climate zones when going from an aged solar reflectance of 0.63 to 0.70 (Farahmand, Cost-Effectiveness Study for Cool Roofs 2016a).

2.4.3.2 Incremental Product Cost – Asphalt Shingles

Costs were available for many steep-sloped roofing products. These products included roughly 17 asphalt shingle products. The Statewide CASE Team collected cost from publicly available data sources and calls to distributors. Cost estimates were presented at a public stakeholder meeting held on April 23, 2020 where feedback was also requested. Specifically, online searches and calls were made to stores in Southern California, Central California, and Bay Area to gather a representative sample of the state. Roughly the same percentage (25 percent) of asphalt shingles used to estimate costs at baseline and proposed levels come from more premium products. This ensures that costs are not skewed one way or the other. Per-square foot costs for roofing products at or near baseline reflectance levels and products at or near the proposed reflectance levels were gathered.

2.4.3.3 Incremental Product Cost – Tile

Costs for tile roofing products were assumed to not vary based upon solar reflectivity, as noted in a 2016 study on cool roof costs (Farahmand, Cost-Effectiveness Study for Cool Roofs 2016a). Costs for tile roofing products were gathered through cold calls with suppliers around the state. Roofing suppliers also confirmed during these calls that the color of the same product does not change costs. As color of tile changes, so does its solar reflectivity.

2.4.3.4 Incremental Product Cost – Metal

Representatives from the Metal Construction Association provided an estimate for per square foot costs of standing seam metal roofs and noted that costs generally do not change based upon the color of the product. This same assumption was used in the 2008 CASE Report.

2.4.3.5 Incremental Product Cost – Single-Ply and Asphaltic Membrane

For low-sloped building products, calls to roofing suppliers around the state provided cost data for the majority of asphaltic membrane and single-ply products. A few data points from reach code cost-effectiveness studies were also used (Farahmand 2016a); (Farahmand 2016b).

2.4.3.6 Incremental Product Cost – Coatings

Online searches yielded costs for six products in multiple locations across the state. Calls to suppliers were also conducted for additional costs, and a few data points from reach code cost-effectiveness studies were also used (Farahmand 2016a).

2.4.3.7 Incremental Cost – Shipping of products

The Statewide CASE Team conducted a survey while the Draft CASE Report was out for public review in order to better understand the cool roof market place. The survey focused on low-slope products as these comprise the vast proportion of the commercial market. As noted in Section 2.2.2.3, majority of contractors who provided shipping estimates did not note an increase in shipping costs. Thus, there was no assumed increase for the report.

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 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 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:

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

Interviews with stakeholders and past research on cool roofs have shown there are no incremental maintenance cost increases for new construction and alterations. One consideration would be the added cost of cleaning the roof to maintain high reflectance levels. As described in Section 2.2.2.7, an aged solar reflectance requirement is used in this proposal, and roofs do not undergo cleaning due the weathering process to determine aged reflectance. The Statewide CASE Team has determined that if a building owner has decided to clean their roof with products having aged solar reflectance of 0.70, it is likely they would be cleaning their roof with products having aged solar reflectance of 0.63. Therefore, there is no added incremental cost. Since cool roofs undergo less thermal stress than standard roofing materials, they may have a longer lifetime, but this assumption was not considered for cost-effectiveness calculations (Akbari 2003). Therefore, cost-effectiveness results presented in this report may be underestimated compared to what occurs in the field.

Appendix J: presents cost-effectiveness analysis for the cool roof changes and along with the insulation improvements discussed in Section 3.

It was assumed that the roof membrane would be replaced in year 15. As with new construction, there is no incremental installation cost of installing a cooler roof, but there is an incremental cost associated with the cooler roofing product. The assumed incremental product cost was the same cost as used for the incremental first cost, but a three percent discount rate was applied to discount the cost that would occur in the future.

2.4.5 Cost Effectiveness

This submeasure proposes a prescriptive requirement. As such, a cost analysis is required to demonstrate that the submeasure is cost effective over the 30-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 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas 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 30 years by the total incremental costs, which includes roof membrane costs at year 20. 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 43 for new construction and alterations for the Small Office prototype. Results for other prototypes are presented in Table 44 and Table 46.

As shown in Table 44 through Table 47, this submeasure is cost-effective for most building prototypes where changes are recommended. The construction-weighted benefit-to-cost ratio by climate zone is provided in Table 2. All climate zones that the submeasure makes proposed changes for are cost-effective. The Statewide CASE Team prioritized consistency between the new construction and alteration proposals in terms of impacted climate zones. Additionally, the Statewide CASE Team received feedback that code simplicity was key to ensuring compliance with any updates. While individual requirements for each specific building type could ensure all impacted buildings in every climate zone only saw changes if they were cost effective, establishing different requirements by building type and climate zone adds complexity to the code language. Thus, the Statewide CASE Team recommended applying the requirements across entire building types and climate zones.

Though the low-sloped recommendation of an aged solar reflectance level of 0.70 is recommended for Title 24, Part 11, the Statewide CASE Team is presenting the results below along with the proposed steep-sloped changes that are recommended for Title 24, Part 6.

Table 43: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction– OfficeSmall, Steep-sloped Cool Roof

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	N/A	N/A	N/A
2	0.18	0.036	4.82
3	N/A	N/A	N/A
4	0.20	0.036	5.39
5	0.14	0.036	3.95
6	0.28	0.036	7.67
7	0.27	0.036	7.53
8	0.35	0.036	9.53
9	0.24	0.036	6.52
10	0.24	0.036	6.57
11	0.20	0.036	5.46
12	0.19	0.036	5.33
13	0.21	0.036	5.91
14	0.19	0.036	5.27
15	0.33	0.036	9.06
16	0.11	0.036	3.06

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. Includes PV maintenance cost savings 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 and 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 B/C ratio is infinite.

Table 44: Cool Roof Low-Sloped- New Construction; Benefit-to-Cost Ratio by Climate Zone and Prototype Building [a]

Prototype / **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Hospital	5.8	1.2	7.7	3.2	3.1	2.1	14.0	(0.9)	(3.7)	1.6	0.5
OfficeLarge	1.6	1.9	0.8	0.1	1.6	2.5	0.8	0.9	1.4	1.4	1.3
OfficeMedium	1.2	1.9	1.6	3.3	2.3	2.1	1.9	1.6	2.6	2.5	3.2
OfficeMediumLab	0.7	(0.5)	(1.2)	0.5	0.5	(0.1)	(0.1)	(0.4)	0.3	0.3	4.2
OfficeSmall	2.7	3.8	3.6	4.6	3.4	3.3	2.7	2.6	3.1	2.8	3.8
Restaurant FastFood	1.2	2.4	2.1	3.8	2.2	6.0	1.7	22.6	38.2	34.8	3.4
SchoolPrimary	1.8	3.4	2.8	4.0	2.6	2.7	2.0	2.0	2.5	1.9	3.3
SchoolSecondary	0.1	(0.1)	(0.4)	1.5	1.2	0.8	2.2	0.2	2.5	0.6	1.5

a. Low-sloped changes are not proposed for Title 24, Part 6.

Table 45: Cool Roof Low-Sloped- Alterations; Benefit-to-Cost Ratio by Climate Zone and Prototype Building [a]

Prototype / **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
OfficeLarge	2.2	4.7	1.8	5.1	3.1	0.7	1.6	0.7	1.5	2.2	2.3
OfficeMedium	4.0	4.3	2.6	7.6	6.4	3.7	2.9	2.5	3.6	3.2	6.3
OfficeMediumLab	(0.5)	(1.3)	(1.8)	0.9	1.6	(0.8)	4.8	(0.3)	1.0	1.2	0.6
OfficeSmall	7.2	6.6	6.5	10.7	10.0	5.4	5.4	4.4	6.7	4.4	7.8
Restaurant FastFood	(9.1)	2.2	3.4	6.8	5.5	4.1	3.3	2.7	3.8	2.8	6.1
SchoolPrimary	6.8	8.4	5.4	11.3	9.6	6.7	5.4	4.2	5.7	4.2	6.9
SchoolSecondary	1.2	0.7	(0.4)	4.4	3.7	2.1	1.0	0.9	2.0	1.1	3.6

a. Low-sloped changes are not proposed for Title 24, Part 6.

Table 46: Cool Roof Steep-Sloped- New Construction; Benefit to Cost Ratio by Climate Zone and Prototype Building

Prototype / **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Statewide Construction-Weighted Average**
OfficeSmall	4.82	5.39	3.95	7.67	7.53	9.53	6.52	6.57	5.46	5.33	5.91	5.27	9.06	3.06	6.56
Restaurant FastFood	1.13	2.37	(0.71)	4.41	(1.32)	6.96	4.14	4.40	3.49	2.87	4.12	3.00	6.82	(0.07)	3.87
RetailStandAlone	(11.24)	(7.52)	4.12	2.68	2.65	9.47	11.97	(8.14)	25.81	1.69	(1.04)	(10.24)	17.55	1.69	3.15
RetailStripMall	19.87	14.30	1.66	3.86	5.28	10.48	3.41	8.97	1.81	(1.07)	5.76	4.23	9.81	(1.83)	5.91

Table 47: Cool Roof Steep-Sloped- Alterations; Benefit to Cost Ratio by Climate Zone and Prototype Building

Prototype / **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Statewide Construction-Weighted Average**
OfficeSmall	12.8	21.1	17.6	22.2	21.9	27.6	26.2	17.9	14.2	15.0	15.6	14.3	19.6	10.1	19.95
Restaurant FastFood	1.7	6.4	(0.6)	6.9	18.4	13.6	12.6	8.2	6.3	5.2	7.3	5.7	57.3	0.7	10.52
RetailStandAlone	(25.1)	0.5	(0.1)	10.6	2.9	21.5	(2.8)	(0.9)	8.9	(12.8)	13.1	1.5	15.7	(7.7)	2.21
RetailStripMall	(12.3)	25.6	17.7	20.9	23.7	29.9	15.0	6.9	12.1	7.5	25.0	13.5	20.7	8.5	16.33

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 2.3.2.3, 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 first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023 that would be impacted by the proposed code change. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

As discussed above, the Statewide CASE Team simulated the energy savings and cost effectiveness for all prototype buildings and climate zones and used results to inform recommended revisions to the code requirements. Changes were only recommended when doing so would result in cost-effective energy savings. The statewide energy savings analysis only includes the impacts of climate zones and building types that would be impacted by the proposed code changes. The proposed requirements for steep-sloped roofs would apply to all building types and all climate zones except Climate Zones 1 and 3.

Table 48 and Table 49 present the first-year statewide energy and energy cost savings from newly constructed buildings and alterations by climate zone. Building types included in these totals are noted in Table 17.Table 48 and Table 49 present the first-year statewide energy and energy cost savings from newly constructed buildings and alterations by climate zone. Building types included in these totals are noted in Table 17.

It was assumed that 80 percent of building square footage classified as small office and restaurant have steep-sloped roofs, and the remaining 20 percent was presumed to be low-sloped. Twenty percent of the square footage of retail standalone and retail strip mall was presumed to be steep-sloped.

Table 52 presents first-year statewide steep-sloped savings from new construction, additions, and alterations.

Table 48: Statewide Energy and Energy Cost Impacts – New Construction, Cool Roof, Low-Sloped[a]

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (square feet)	First-Year[b] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A
4	4,321,764	0.05	0.00	(0.00)	$0.15
5	N/A	N/A	N/A	N/A	N/A
6	5,290,117	0.08	0.01	(0.00)	$0.24
7	3,920,824	0.07	0.00	(0.00)	$0.23
8	7,755,730	0.15	0.00	(0.00)	$0.50
9	13,686,697	0.17	0.01	(0.00)	$0.61
10	5,186,581	0.12	0.00	(0.00)	$0.38
11	1,289,888	0.03	0.00	(0.00)	$0.11
12	7,903,232	0.11	0.00	(0.00)	$0.42
13	2,526,453	0.07	0.00	(0.00)	$0.28
14	1,339,112	0.03	0.00	(0.00)	$0.15
15	631,974	0.02	0.00	(0.00)	$0.06
16	N/A	N/A	N/A	N/A	N/A
TOTAL	**53,852,372**	**0.90**	**0.03**	**(0.02)**	**$3.14**

a. Low-sloped changes are proposed for Title 24, Part 11.

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

Table 49: Statewide Energy and Energy Cost Impacts – New Construction, Cool Roof, Steep-Sloped

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	335,540	0.02	0.00	(0.00)	$0.04
3	N/A	N/A	N/A	N/A	N/A
4	640,820	0.03	0.00	(0.00)	$0.09
5	136,642	0.01	0.00	(0.00)	$0.01
6	1,007,985	0.07	0.00	(0.00)	$0.22
7	1,063,588	0.07	0.00	(0.00)	$0.21
8	1,384,064	0.12	0.01	(0.00)	$0.42
9	2,253,447	0.13	0.01	(0.00)	$0.46
10	1,782,866	0.11	0.01	(0.00)	$0.34
11	383,372	0.02	0.00	(0.00)	$0.08
12	1,936,967	0.11	0.01	(0.00)	$0.32
13	828,773	0.05	0.00	(0.00)	$0.16
14	367,490	0.02	0.00	(0.00)	$0.05
15	275,047	0.02	0.00	(0.00)	$0.09
16	129,926	0.01	0.00	(0.00)	$0.01
TOTAL	**12,526,528**	**0.76**	**0.05**	**(0.02)**	**$2.48**

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

Table 50: Statewide Energy and Energy Cost Impacts – Alterations, Cool Roof, Low-Sloped[a]

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (square feet)	First-Year[b] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	$0.00
2	N/A	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	$0.00
4	11,719,895	0.51	0.03	(0.02)	$1.24
5	N/A	N/A	N/A	N/A	$0.00
6	15,405,359	0.68	0.03	(0.01)	$2.07
7	10,954,339	0.44	0.02	(0.01)	$1.10
8	22,329,788	1.40	0.06	(0.02)	$4.77
9	37,940,781	2.00	0.06	(0.04)	$6.41
10	15,392,259	0.84	0.04	(0.02)	$2.54
11	3,316,582	0.16	0.01	(0.00)	$0.48
12	20,635,819	0.69	0.04	(0.02)	$1.78
13	6,429,761	0.41	0.02	(0.01)	$1.20
14	3,966,064	0.15	0.01	(0.01)	$0.41
15	1,782,438	0.12	0.00	(0.00)	$0.43
16	N/A	N/A	N/A	N/A	N/A
TOTAL	**149,873,086**	**7.42**	**0.30**	**(0.17)**	**$22.43**

a. Low-sloped changes are proposed for Title 24, Part 11.

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

Table 51: Statewide Energy and Energy Cost Impacts – Alterations, Cool Roof, Steep-Slope

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	735,612	0.09	0.01	(0.00)	$0.21
3	N/A	N/A	N/A	N/A	N/A
4	1,410,319	0.26	0.02	(0.01)	$0.82
5	304,860	0.05	0.00	(0.00)	$0.13
6	2,355,487	0.42	0.03	(0.01)	$1.36
7	2,412,039	0.50	0.04	(0.00)	$1.78
8	3,226,690	0.70	0.05	(0.01)	$2.54
9	5,171,502	1.07	0.08	(0.02)	$3.57
10	4,422,036	0.64	0.05	(0.01)	$2.11
11	838,685	0.11	0.01	(0.00)	$0.37
12	4,073,731	0.55	0.04	(0.01)	$1.73
13	1,851,222	0.27	0.02	(0.00)	$0.92
14	905,845	0.11	0.01	(0.00)	$0.34
15	674,923	0.14	0.01	(0.00)	$0.69
16	307,398	0.04	0.00	(0.00)	$0.07
TOTAL	**28,690,350**	**4.95**	**0.37**	**(0.08)**	**$16.63**

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

Table 52: Cool Roof Statewide Energy and Energy Cost Impacts – Steep-sloped

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	0.8	0.05	(0.02)	25
Additions and Alterations	4.9	0.37	(0.08)	16.6
TOTAL	**5.7**	**0.42**	**(0.10)**	**41.6**

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

2.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the U.S. 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 factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 53 present the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 848 metric tons CO2e would be avoided.

Table 53: First-Year Statewide GHG Emissions Impacts, Steep-Slope

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a, b] (Metric Tons CO2e)
New Construction	1	184	(0.02)	(84)	99
Alterations	4.9	1,190	(0.08)	(440)	749

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

b. Assumes the following emission factors: 240 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

2.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

2.5.4 Statewide Material Impacts

As shown above, the current nonresidential cool roof code in California requires the use of reflective roofing products. This proposal simply raises the prescriptive radiative requirements and is unlikely to significantly change any of the material impacts in California.

2.5.5 Other Non-Energy Impacts

By reducing the amount of heat transferred from the roof to the nearby air, cool roofs reduce the urban heat island effect. The urban heat island effect is the temperature increase in built-up, metropolitan areas compared to more rural areas. On average, the air temperature in a city with a million or more people is 1.8°F to 5.4°F warmer than its surroundings (EPA n.d.). This reality is particularly acute in California which has three of the ten largest cities in the country, each with over a million residents (US Census 2016). On a clear day, about 80 percent of the reflected sunlight from a horizontal roof goes back into space without warming the surrounding air (EPA n.d.); (Levinson 2009).

Therefore, increasing roof reflectance lessens the urban heat island effect. Using the existing exceptions to the prescriptive cool roof requirements would not provide as many benefits to urban heat islands.

Reduction of smog levels in urban settings would be another important non-energy impact. Smog is created through photochemical reactions that occur more frequently in higher temperatures; reducing urban ambient air temperatures decreases the rate of smog formation. This reduction in smog would also lead to decreases in frequencies of heat stroke and asthma (CRRC n.d.).

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 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

A building complies with this section by being designed with and having constructed to meet all prescriptive requirements in Subsection (a) and the requirements of Subsection (c) and (d) where they apply.

(a) **Envelope Component Requirements.**

1. **Exterior roofs and ceilings.** Exterior roofs and ceilings shall comply with each of the applicable requirements in this subsection:

   A. **Roofing Products.** Shall meet the requirements of Section 110.8 and the applicable requirements of Subsections i through ii:

      i. Nonresidential buildings:

         a. Low-sloped roofs in Climate Zones 1 through 16 shall have:

            1. A minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75; or

            2. A minimum Solar Reflectance Index (SRI) of 75.

            EXCEPTION 1 to Section 140.3(a)1Aia: Wood-framed roofs in Climate Zones 3 and 5 are exempt from the requirements of Section 140.3(a)1Aia if the roof assembly has a U-factor of 0.034 or lower.

            EXCEPTION 2 to Section 140.3(a)1Aia: Roof constructions with a weight of at least 25 lb/ft² over the roof membrane are exempt from the requirements of Section 140.3(a)1Aia.

EXCEPTION 3 to SECTION 140.3(a)1Aia: An aged solar reflectance less than 0.63 is allowed provided the maximum roof/ceiling U-factor in TABLE 140.3 is not exceeded.

b. Steep-sloped roofs:

a. I~~i~~n Climate Zones 1 and 3 shall have either a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

b. In Climate Zones 2 and 4 through shall have either: a minimum aged solar reflectance of 0.25 and a minimum thermal emittance of 0.80, or a minimum SRI 23

~~ii. High-rise residential buildings and hotels and motels:~~

~~a. Low-sloped roofs in Climate Zones 9, 10, 11, 13, 14 and 15 shall have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75 or a minimum SRI of 64.~~

~~**EXCEPTION to Section 140.3(a)1Aiia:** Roof constructions with a weight of at least 25 lb/ft² over the roof membrane.~~

~~b. Steep-sloped roofs in Climate Zones 2 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.~~

TABLE 140.3 Roof/Ceiling Insulation Tradeoff For Aged Solar Reflectance – Nonresidential Buildings

~~**Nonresidential**~~			
Aged Solar Reflectance	**Metal Building All Climate Zones U-factor**	**Wood framed and Other Climate Zone 6 ~~&~~ 7, & 8 U-factor**	**Wood Framed and Other All other Climate Zones U-factor**
0.62-0.56	0.038	0.039 ~~0.045~~	0.029 ~~0.032~~
0.55-0.46	0.035	0.036 ~~0.042~~	0.028 ~~0.030~~
0.45-0.36	0.033	0.033 ~~0.039~~	0.027 ~~0.029~~
0.35-0.25	0.031	0.032 ~~0.037~~	0.026 ~~0.028~~

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS ~~AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS~~)

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	**Maximum U-factor**	**Roofs/ Ceilings**	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
			Wood Framed and Other	0.034	0.034	0.034	0.034	0.034	0.049	0.049	0.049	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
		Walls	Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
			Metal-framed	0.069	0.062	0.082	0.062	0.062	0.069	0.069	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
			Mass Light[1]	0.196	0.170	0.278	0.227	0.440	0.440	0.440	0.440	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
		Floors/ Soffits	Raised Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
			Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
	Roofing Products	**Low-sloped**	Aged Solar Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		Steep-Sloped	Aged Solar Reflectance	0.20	0.25 ~~0.20~~	0.20	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~
			Thermal Emittance	0.75	0.80 ~~0.75~~	0.75	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~
	Air Barrier			NR	NR	NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Exterior Doors, Maximum U-factor		Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
			Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

TABLE 140.3-D Prescriptive Envelope Criteria For Relocatable Public School Buildings For Use In All Climate Zones

Roofs/ Ceilings	**Metal Buildings**	Maximum U-factor			0.041
	Non-Metal Buildings				0.034
Walls	**Wood frame buildings**				0.042
	Metal frame buildings				0.057
	Metal buildings				0.057
	Density ≤ 95				0.170
	All Other Walls				0.059
Floors and Soffits	**Floors and Soffits**				0.048
Roofing Products	**Low-Sloped**	Aged Solar Reflectance			0.63
		Thermal Emittance			0.75
	Steep-Sloped	Aged Solar Reflectance			0.25 ~~0.20~~
		Thermal Emittance			0.80 ~~0.75~~
Fenestration	**Windows**	Maximum U-factor			0.47
		Maximum SHGC			0.26
	Glazed Doors (Site-Built and Factory Assembled)	Maximum U-factor			0.45
		Maximum SHGC			0.23
	Skylights	Glass with Curb		Maximum U-factor	0.99
		Glass without Curb			0.57
		Plastic with Curb			0.87
		Glass Type	0-2% SRR	Maximum SHGC	0.46
			2.1-5% SRR		0.36
		Plastic Type	0-2% SRR		0.69
			2.1-5% SRR		0.57
Exterior Doors	**Non-Swinging doors**	Maximum U-factor			0.50
	Swinging doors				0.70

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

Additions, alterations, and repairs to existing nonresidential, high-rise residential, and hotel/motel buildings, existing outdoor lighting for these occupancies, and internally and externally illuminated signs, shall meet the requirements specified in Sections 100.0 through 110.10, and 120.0 through 130.5 that are applicable to the building project, and either the performance compliance approach (energy budgets) in Section 141.0(a)2 (for additions) or 141.0(b)3 (for alterations), or the prescriptive compliance approach in Section 141.0(a)1 (for additions) or 141.0(b)2 (for alterations), for the Climate Zone in which the building is located. Climate zones are shown in FIGURE 100.1-A.

Covered process requirements for additions, alterations and repairs to existing nonresidential, high-rise residential, and hotel/motel buildings are specified in Section 141.1.

EXCEPTION to Section 141.0: Alterations to healthcare facilities are not required to comply with this Section.

NOTE: For alterations that change the occupancy classification of the building, the requirements specified in Section 141.0(b) apply to the occupancy after the alterations.

(Sections omitted)

(b) **Alterations.** Alterations to components of existing nonresidential, high-rise residential, hotel/motel, or relocatable public school buildings, including alterations made in conjunction with a change in building occupancy to a nonresidential, high-rise residential, or hotel/motel occupancy shall meet item 1, and either Item 2 or 3 below:

(Section omitted)

2. **Prescriptive approach.** The altered components of the envelope, or space conditioning, lighting, electrical power distribution and water heating systems, and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110.0 through 110.9, Sections 120.0 through 120.6, and Sections 120.9 through 130.5.

(Section omitted)

B. Existing roofs being replaced, recovered or recoated, of a nonresidential, high-rise residential and hotels/motels shall meet the requirements of Section 110.8(i). Roofs with more than 50 percent of the roof area or more than 2,000 square feet of roof, whichever is less, is being altered the requirements of i <u>and ii </u>~~through iii ~~below apply:

i. Roofing Products <u>shall comply with requirements in Section 140.3(a)1A</u>. ~~Nonresidential buildings:~~

a. ~~Low-sloped roofs in Climate Zones 1 through 16 shall have a minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75, or a minimum SRI of 75.~~

b. ~~Steep-sloped roofs in Climate Zones 1 through 16 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.~~

EXCEPTION 1 to Section 141.0(b)2Bi~~a~~: An aged solar reflectance less than 0.63 is allowed for low-sloped roofs provided the maximum roof/ceiling U-factor in TABLE 141.0-B is not exceeded.

ii. ~~Roofing Products. High-rise residential buildings and hotels and motels:~~

a. ~~Low-sloped roofs in Climate Zones 10, 11, 13, 14 and 15 shall have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.~~

b. ~~Steep-sloped roofs Climate Zones 2 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.~~

EXCEPTION 2 ~~1~~ to Section 141.0(b)2Bi ~~and ii~~: Roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

EXCEPTION 3 ~~2~~ to Section 141.0(b)2Bi ~~and ii~~: Roof constructions with a weight of at least 25 lb/ft² are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

Table 141.0-B Roof/Ceiling Insulation Tradeoff for Low-Sloped Aged Solar Reflectance

Aged Solar Reflectance	Climate Zone 1, 3-9 U-factor	Climate Zone 2, 10-16 U-factor
0.62-0.60	0.043 ~~0.075~~	0.035 ~~0.052~~
0.59-0.55	0.038 ~~0.066~~	0.032 ~~0.048~~
0.54-0.50	0.034 ~~0.06~~	0.03 ~~0.044~~
0.49-0.45	0.032 ~~0.055~~	0.028 ~~0.041~~
0.44-0.40	0.029 ~~0.051~~	0.026 ~~0.039~~
0.39-0.35	0.027 ~~0.047~~	0.025 ~~0.037~~
0.34-0.30	0.025 ~~0.044~~	0.024 ~~0.035~~
0.29-0.25	0.024 ~~0.042~~	0.023 ~~0.034~~

2.6.3 Reference Appendices

There will be no changes to the reference appendices.

2.6.4 ACM Reference Manual

The Standard Design for cool roofs would have to be updated with the values in Tables 140.3-B or D. However, the text of the Nonresidential ACM Reference Manual Section 5.5.3 – Roof Construction would not have to be changed.

2.6.5 Compliance Manuals

Chapter 3 of the Nonresidential Compliance Manual would need to be revised.

Table 3-2: Prescriptive Criteria for Roofing Products for Nonresidential Buildings would need to be updated to show the proposed aged solar reflectance levels for steep-sloped roofs. The emittance level for steep-sloped roofs would also need to be updated to the proposed level.

Table 3-4: Prescriptive Criteria for Roofing Products for Relocatable Public School Buildings would need to be updated to show the proposed aged solar reflectance levels for steep-sloped roofs. The emittance level for steep-sloped roofs would also need to be updated to the proposed level.

Table 3-5: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance would need to be revised to show the proposed insulation tradeoff levels.

Section 3.6.2.2(C) would need to be edited with the proposed minimum aged solar reflectance and thermal emittance levels for nonresidential steep-sloped roofs.

Table 3-23: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance would need to be updated with new insulation levels for alterations.

2.6.6 Compliance Documents

NRCI-ENV-01-E forms would need to be updated to include the updated reflectance values.

3. Roof Alterations

3.1 Submeasure Description

3.1.1 Measure Overview

This proposed submeasure would update the existing prescriptive requirements for roof replacements[12] and add new requirements for roof recovers.[13] The proposed changes would increase the stringency of insulation requirements that must be met when roofs are replaced. Depending on climate zone, roofs would be required to have either R-17 or R-23. The proposal would remove the exception that states that if the existing roof has R-7 insulation, insulation does not need to be added or replaced.

For roof recovers, the proposed changes would establish a requirement that a minimum of R-10 insulation be added during roof recovers or meet the insulation requirements for roof replacements, whichever is less.

In addition to increasing the stringency of insulation requirements, the proposed code change would update existing exceptions and recommend revisions to improve the compliance verification process. With the proposed revisions, all buildings even those that qualify for the revised exceptions would be required to have R-10 above-deck insulation upon completion of a roof replacement or roof recovers alteration. Existing above deck insulation counts towards the required R-10 insulation levels. Specific changes to the exceptions would:

- Completely remove the exception that states that insulation is not required to be added if doing so would reduce the base flashing height to less than eight inches at penthouse and parapet walls. Stakeholders provided feedback that having to raise base flashing heights at penthouse or parapet walls does not add significant complexity or costs to projects. This change would reduce complexity of the code and remove an exception that stakeholders have said is unnecessary.
- Modify the exception for limited base flashing height of mechanical equipment so that at least R-10 must be installed above deck regardless of base flashing height. The language for the exception is also changed to reference manufacturers' instructions rather than a height of eight inches.

[12] The California Building Code (Title 24, Part 2) and California Existing Building Code, Title 24 Part 10 define roof replacement as follows, "Roof Replacement. The process of removing the existing roof covering, repairing any damaged substrate and installing a new roof covering."

[13] The California Building Code (Title 24, Part 2) and the California Existing Building Code (Title 24 Part 10) define roof recover as follows, "Roof Recover. The process of installing an additional roof covering over a prepared existing roof covering without removing the existing roof covering."

- Add a performance option for third-party inspection of existing conditions that can be used to count existing insulation towards meeting the proposed requirements.
- Add a field inspection requirement to verify insulation is installed.
- Add a requirement that insulation installers complete a progress report, contingent on a forthcoming nonresidential registry. This allows building officials to more easily follow the progress of projects and schedule inspections.

The proposed code changes would not require any significant software changes. The proposed changes would apply to all nonresidential buildings, including guestrooms of hotel/motels, but not including hospitals. The Statewide CASE Team is proposing that the entire roof of hotels/motels comply with the requirements above. Healthcare facilities are excluded from all requirements in Section 141.0 of Title 24, Part 6.

Currently, hotel/motel buildings are subject to two different sets of envelope requirements. Requirements in Table 141.0-C have separate requirements for nonresidential spaces and guestroom spaces. This proposal would simplify requirements for hotel/motel by removing requirements that only apply to guestroom space. See Appendix M: for recommendations for hotel/motel.

See Table 54 for a summary of the proposed scope.

Table 54: Scope of Code Change Proposal – Roof Alterations

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)
Roof Alterations	Prescriptive	141.0(b)2Biii 141.0(b)3C	N/A	Yes	NRCC-ENV-E

3.1.2 Measure History

Adding roof insulation is a cost-effective way to save energy. A report by Bayer Material Science in 2009 found that increasing roof insulation from R-12 to R-25 reduced energy consumption in existing buildings from 1.4 percent in medium offices up to 11.3 percent in primary school buildings (Phelan, Pavlovich and Ma 2009). It also found a market-weighted payback period of 10.1 years for ASHRAE Climate Zone 3, which is the majority of California. The Statewide CASE Team estimated roof cover lifetimes to be 15 years and was told by the Polyisocyanurate Manufacturers Association that approximately half the time, it is possible to recover the roof rather than replace it. See Section 3.2.2 for more information.

Improving the energy performance of existing buildings is critical to reducing energy consumption across California. According to the Energy Commission, the state has approximately 7.8 billion ft^2 of existing building space, 50 times more than the new construction forecast for 2023. About 75 percent of the nonresidential roofing market is for alterations, replacements, or repairs according to independent surveys by the NRCA (NRCA 2015) and by Western Roofing Magazine (Dodson 2019).

However, the current standards for roof alterations in Title 24, Part 6 do not take full advantage of this important opportunity to improve building energy performance. Roofing insulation requirements for alterations were introduced in 2008 and have remained unchanged since, while the new construction standards have been modified each cycle. Furthermore, the standards for alterations have always been less stringent than those for new roofs. This is inconsistent with both ASHRAE 90.1 and IECC, which require alterations to have the same insulation as new construction.

Prescriptive requirements for cool roofs were introduced in the 2005 code cycle and became effective in 2006, the year that the insulation requirements for roof alterations were being developed. This was a time of transition and uncertainty for the roofing industry, when stakeholders were becoming accustomed to the new technology of single-ply membranes, and so concerns around new insulation requirements in addition to the newly effective cool roof requirements were understandable. Roofing contractors have since gained the necessary expertise to install cool roofs appropriately, and single-ply membranes are now standard practice. There is no longer the same uncertainty in the market, so this is an ideal time to increase the insulation requirements without causing major disruptions.

California has a history of being a leader in energy efficiency but has historically lagged behind the IECC and ASHRAE 90.1 when it comes to insulation requirements for roof alterations. Model building energy codes have been applied to renovations, alterations, and additions of existing buildings in other parts of the country since 2000, but insulation requirements for roof alterations were only added to Title 24, Part 6 in 2008 and are still less stringent than the model building energy codes. Table 55 summarizes current and proposed requirements. The U-factors are used when insulation is not continuous above deck and therefore requires more insulation and are determined using the lookup tables in JA4. The R-values are only for continuous insulation above deck.

Not only are the requirements for roof replacements less stringent than those for new construction, there are exceptions that reduce the stringency further: roofs insulated to at least R-7, when lifting equipment would be needed, or when adjusting the flashing at penthouse or parapet walls would be necessary.

Roof recovers are exempt from any insulation requirements in both the model codes and Title 24, Part 6.

Table 55: Insulation Requirements for Roof Replacements

Code Requirement	R-value	U-factor
IECC-2018/ASHRAE 90.1-2019 Climate Zone 3	R-25 above deck or R-38 below deck	U-0.039 above deck or U-0.027 below deck
Title 24, Part 6 - 2019 New Construction (current)	Climate Zone 6-8: R-20 Others: R-29	Climate Zone 6-8: U-0.049 Others: U-0.034
Title 24, Part 6 – 2019 Roof Replacements (current)	Climate Zone 1, 3-9: R-8 Climate Zone 2, 10-16: R-14	Climate Zone 1, 3-9: U-0.082 Climate Zone 2, 10-16: U-0.055
Title 24, Part 6 – 2022 Requirements for Roof Replacements (proposed)	Climate Zone 6-8: R-17 Others: R-23	Climate Zone 6-8: U-0.047 Others: U-0.037

3.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 3.5.6 of this report for detailed proposed revisions to code language.

3.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 3.6.1 of this report for marked-up code language.

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

- **Section 141.0(b)2Biii:** The purpose of this change is to add insulation requirements roof recovers and provide terminology consistency for all of Section 141.0(b)2B. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)2Biii:** The purpose of this change is to add requirements for third-party verification of insulation installation for roof replacements and roof recovers. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)2Biii:** The purpose of this change is to require at least R-10 insulation above deck for roof replacements and roof recovers. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)2Biii:** The purpose of this change is to allow R-10 insulation to be installed above deck during a roof recover as an alternate requirement to

meeting the insulation levels in TABLE 141.0-C. This change is necessary to clearly implement the proposed code change.

- **Section 141.0(b)2Biii – Exception a:** The purpose of the change is to remove the current exception for existing roofs that are insulated with at least R-7 or a U-factor of 0.089 to not have to meet the requirements of TABLE 141.0-C. Current Exception b. will be renumbered as Exception a. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)2Biii – Exception b:** The purpose of this change is to modify current Exception b. to refer to manufacturers' instructions rather than eight inch base flashing height and to require either the maximum insulation thickness be added that will comply with manufacturer's instructions or R-10, whichever is greater. This exception is also moved from Exception b. to Exception a. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)2Biii – Exception c:** The purpose of this change is to remove this exception to limit installed insulation if it will reduce the base flashing height at penthouse or parapet walls. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)2Biii – TABLE 141.0-C:** The purpose of this change is to increase the insulation requirements for roof alterations and to have a single requirement for nonresidential buildings and all parts of hotel/motel buildings. This change is necessary to clearly implement the proposed code change.
- **Section 141.0(b)3C – TABLE 141.0-E:** The purpose of this change to allow project teams to use third-party inspections of existing insulation to help meet the requirements of 141.0(b)2Biii. This change is necessary to clearly implement the proposed code change.

3.1.3.2 Summary of Changes to the Reference Appendices

The Statewide CASE Team is proposing updating Table 4.2.2 in JA4 with the corresponding U-factors for R-17, R-20, and R-23.

3.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The Standard Design for roof alterations in Section 5.5.3 – Roof Construction of the Nonresidential ACM Reference Manual would be updated with the proposed insulation values for Section 141.0.

3.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Section 3.6.2.2 C of the Nonresidential Compliance Manual. See Section 3.6.5 of this report for the detailed proposed revisions to the text of the compliance manuals.

3.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 3.6.6.

- NRCC-ENV-E – The insulation requirements would always be prompted when a roof alteration permit is filled out and would ask for documentation for any exception.
- If a nonresidential registry is approved by the Energy Commission, the Statewide CASE Team is proposing including roof alterations in the registry and incorporating a project status report so that building officials can easily verify the completion of all compliance documentation for a given project.

3.1.4 Regulatory Context

3.1.4.1 Existing Requirements in Title 24, Part 6

The existing requirements for new construction and alterations are in Table 55. Currently, Title 24, Part 6 requires roof alterations on existing roofs to be insulated with at least R-8 continuous insulation in Climate Zones 1 and 3 through 9, and at least R-14 continuous insulation in all other climate zones. Altered roofs that have at least R-7 existing insulation are exempt from the current code requirements. There are four distinct exceptions for adding insulation during roof replacements:

- If the roof has at least R-7, no more insulation needs to be added.
- If the mechanical equipment will not be lifted as part of the roof alteration, only as much insulation needs to be added that allow for eight inches of base flashing height.
- If the penthouse or parapet walls are finished with a different exterior cladding material than the roof cover membrane, that material must be removed to add insulation and maintain a base flashing height of eight inches and have less than the specified ratio of replaced roof area to the linear dimension of the affected wall.
- Tapered insulation is allowed to aid drainage.

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

There are overlaps with Chapter 15 – Roof Assemblies and Rooftop Structures of the California building Code (Title 24, Part 2). Section 1511.3 states that roof replacement shall include the removal of all existing layers of roof coverings down to the roof deck, which means that partial tear-offs of roof coverings are not code compliant. Section 1511.6 states that flashings shall be reconstructed in accordance with the approved manufacturer's installation instructions, which needs to be considered when insulation is added.

3.1.4.3 Relationship to Local, State, or Federal Laws

The California Efficiency Strategic Plan has a goal for 50 percent of existing nonresidential buildings to be retrofit to meet zero net energy standards by 2030. Adding insulation during roof alterations is one of the clearly cost-effective ways to contribute to that goal (California Public Utilities Commission 2020).

The Tax Cuts and Jobs Act of 2017 includes improvements to existing nonresidential roofs as "qualified real property." Businesses can now deduct—in the year completed—the full cost of replacing a roof on an existing nonresidential building instead of following the previous requirement to depreciate that cost over a 39-year period. This reduces overall costs and improves cost effectiveness for adding insulation during roof recovers or replacements (NRCA 2018). However, this reduction in cost was not factored into the Statewide CASE Team's cost-effectiveness calculations, and so the resulting costs are higher than building owners would be expected to pay.

3.1.4.4 Relationship to Industry Standards

Unlike Title 24, Part 6, IECC and ASHRAE 90.1 require that insulation be added during a roof replacement to meet the new construction requirements. This has been the case since the 2000 version of the IECC and 1999 version of ASHRAE 90.1. IECC-2018 and ASHRAE 90.1-2019 have separate requirements for continuous insulation and below deck insulation, while Title 24, Part 6 does not differentiate between the two. IECC-2018 and ASHRAE 90.1-2019 have more stringent below deck insulation requirements than the new construction roof insulation requirements in Title 24, Part 6. ASHRAE 189.1 has the same provision that insulation be added during roof replacements to meet the new construction requirements and requires insulation with a 10 percent lower U-factor than ASHRAE 90.1.

3.1.5 Compliance and Enforcement

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

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

- **Design Phase:** Stakeholders said that the roof contractor is typically the only entity involved in consulting with the building owner and designing the project. In the case of a more complex project, a roofing consultant, architect, or other specifier may be involved. The roof contractor is responsible for choosing materials that meet the requirements, as well as the budget and other performance needs of the building owner. Contractors would take a look at existing insulation and decide whether to have a third-party verification to take advantage of the existing conditions, including existing insulation and base flashing height of mechanical equipment. This would inform the amount of insulation that is installed. The contractor would then enter the roofing product information as well as the roofing alteration (insulation) information on the NRCC-ENV-E form, which would trigger the requirements if roof assembly and/or roofing material is checked. If an exception is checked off, documentation would be submitted to support the use of the exception by a third-party or the contractor.

- **Permit Application Phase:** The documentation author would submit the NRCC-ENV-E form, or an equivalent form based on local requirements. The form would be reviewed by a counter technician or a plans examiner, who evaluates the validity and accuracy of the form. The relevant documents would be uploaded to the Nonresidential Data Registry.
- **Construction Phase:** In the case of a roof replacement, the roofing contractor would remove the roof cover, ensure the integrity of the roof deck, and install the necessary insulation to meet code requirements before adding a new cover. In the case of a roof recover, insulation would be added on top of the existing roof cover and a new cover added on top. In both cases, the installed insulation would be inspected by either a third-party or through a video call with a building official before the new cover is added. Throughout the construction phase, the Project Status Report would be updated in the Nonresidential Data Registry.
- **Inspection Phase:** If a video call and/or geotagged photos are used to verify insulation installation, the building inspector would participate in the call and/or review the photos. On the other hand, if third-party inspection is used to verify insulation installation, the building inspector would review the documentation provided.

The recommended enhancements to the compliance process seek to make code enforcement easier. The Statewide CASE Team recommends: 1) modifying the existing NRCC-ENV-E form to ensure that the insulation requirements are triggered for roof replacement and recover projects; 2) adding a nonresidential registry and project status report; and 3) adding field inspection requirements to verify preexisting and installed insulation.

Currently, if in Table B the NRCC-ENV-E “Roofing Material” is checked off but “Roof Assembly” is not then the insulation requirements are not triggered. The Statewide CASE Team is concerned that this might lead to confusion and user error. The Statewide CASE Team is working with the Compliance Improvement Team to ensure insulation requirements are triggered for every roof replacement and roof recover project.

For roof alterations, often an over-the-counter permit is provided, in which the counter technician or plans examiner does not evaluate the validity of the form or that the project meets the insulation requirements. The Statewide CASE Team recommends that the permit application be reviewed thoroughly every time and that supporting documentation be provided for using exceptions.

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 use certain quality assurance features, such as the Project Status Report (PSR). Reporting construction status on the PSR would require an update to the language in the Data Registry Requirements Manual.

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 PSR 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 is proposing to add two third-party inspections: one performance option before the permit application phase to verify existing conditions of the roof (if the project claims to have any below or above deck insulation or qualify for an exception) and a second inspection that would take place before the roof cover is installed to verify the necessary improvements were made. The Statewide CASE Team has been told by stakeholders that building departments do not have the time to perform such inspections and so recommends they be carried out by a qualified third-party. The verification of existing installation and installed insulation would be very similar to the current quality insulation installation procedures found in RA3.5 and so those qualified to perform the procedures in RA3.5 would not need significant training. If a project team saw that there was existing below deck insulation, they would ask the building owner to hire a qualified third-party to verify the amount and quality of existing below deck insulation, which would then allow the team to install less additional installation. This inspection would be a performance option. Whether or not existing conditions were verified, all projects would be required to have the installed insulation verified, in order to confirm proper installation and the amount.

The other aspect of verifying existing conditions would be to verify whether a project qualifies for the following exception: if mechanical equipment is located on the roof and will not be disconnected and lifted as part of the roof replacement, insulation added may be limited to the maximum insulation thickness that will allow a height in accordance with manufacturers' instructions from the roof membrane surface to the top of the base flashing or R-10, whichever is greater. This would include verifying which mechanical equipment is within the area of the roof replacement, whether that equipment is going to be disconnected and lifted as part of the roof replacement, and if not, what amount of insulation shall be added.

The Energy Commission has indicated it is unlikely that they will accepting the recommendation to require insulation installation verification, citing the challenges associated with creating and maintaining qualification criteria for qualified third-party entities to conduct the verifications. Verifying existing conditions and insulation installation will result in improved compliance and enforcement while providing flexibility. The Statewide CASE Team continues to support the verification requirements and options presented in this report and is interested in working with the Energy Commission and other stakeholders to develop the infrastructure needed to implement the recommended requirements. The third-party verification procedures have therefore not been added to Section 3.6.3

The Statewide CASE Team is also amenable to exploring the possibility of adding an acceptance test and/or having the contractor video call the inspector and submit geographically tagged photos if third-party verification is not feasible. The Compliance Improvement Team suggested the latter to the Statewide CASE Team to minimize the number of in person inspections and alleviate the burden on inspectors if third-party inspections are not feasible. The Compliance Improvement Team stated that this is being considered in general to support current social distancing protocols due to COVID-19.

3.2 Market Analysis

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard would impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during two public stakeholder meetings that the Statewide CASE Team held on October 24, 2019 and April 23, 2020.

3.2.1 Market Structure

3.2.1.1 Market Actors

The primary market actors affected by this proposal are roofing contractors, building owners, and building inspectors. Existing insulation levels and additional insulation needs would need to be determined for each roof replacement and recover. Roofing contractors are accustomed to assessing above deck insulation but may need to consult other trades or market actors for determining the existing levels of below deck insulation. Building officials or a third-party would need to inspect the conditions before the roof is recovered to confirm the insulation installation. Building officials and third parties are used to performing these inspections during new construction.

3.2.2 Technical Feasibility, Market Availability, and Current Practices

3.2.2.1 Current Practices

Simple roof replacements or recovers are often handled by the roofing contractors, whereas more complex or complete roof replacements that include lifting mechanical equipment to raise curb heights and rebuilding penthouse or parapet walls may involve general contractors, mechanical contractors, and electricians.

The most popular insulation used for reroofing in the Pacific region is polyisocyanurate, with a 77 percent market share. Wood fiberboard has a 12 percent market share, and polystyrene has an 8.5 percent (7.1 percent extruded, 1.4 percent expanded) market share (NRCA 2015). Polyisocyanurate and polystyrene are both foam plastic insulation materials.

Western Roofing Magazine's 2019 low-sloped commercial roofing market survey found that new roofing only made up 27 percent of the market, with reroofing being the majority of work at 53 percent and repairs taking the remaining 20 percent (Dodson 2019). When the Statewide CASE Team spoke with employees of *Western Roofing Magazine*, it was clarified that reroofing meant that more than 50 percent of the roof was being altered, which is consistent with the Title 24, Part 6 definition of roof replacement. This is consistent with the 2015-2016 NRCA roofing market survey, which found that new construction accounted for only 24 percent of roof cover board installations (NRCA 2015). The Statewide CASE Team was told by *Western Roofing Magazine* that low-sloped roofs make up 87.3 percent of the roofing market. The Statewide CASE Team assumed that 80 percent of existing OfficeSmall and

RestaurantFastFood buildings are steep sloped and 20 percent of RetailStandAlone and RetailStripMall buildings are steep sloped.

The average lifespan of roof coverings cited by the Roofing Industry Alliance for Progress is 17 years (Ducker Worldwide 2003). This is consistent with the 2010 Building Owners and Managers Association (BOMA) Preventative Maintenance Guidebook, which estimates a lifetime of 15-20 years for single-ply membranes (TPO, PVC, and EPDM), 15 years for modified bitumen, and 18-35 years for built-up roofing (Shoen 2010). A 2005 study by Carl Cash found a mean lifetime of 14-16 years for different types of single-ply membranes and 14-18 years for modified bitumen (Cash 2005). Built-up roofing only made up six percent of the 2019 western commercial market, whereas single-ply products was about 44.5 percent, and modified bitumen was 24 percent (Dodson 2019). The Statewide CASE Team estimated roof cover lifetimes to be 15 years and was told by the Polyisocyanurate Manufacturers Association that approximately half the time it is possible to recover the roof at the end of its service life rather than replace it.

3.2.2.2 Accelerated Depreciation

Until recently, there has been a financial incentive to stretch a roof's lifespan to as close to 39 years as possible because of how long it depreciates under IRS Regs. Sec. 1.263(a)-3(d) (Coddington 2018). The Roofing Industry Alliance for Progress survey found that most building owners were familiar with the rule and more than a third identified it as a significant barrier for reroofing/roof replacement. An even greater proportion of architects, specifiers, consultants, and contractors saw the rule as a serious barrier (Ducker Worldwide 2003). The adjustment to Section 179 under the Tax Cuts and Jobs Act now qualifies roof replacements as a specific building improvement that can be fully expensed by businesses up to $1 million (indexed for inflation after 2018) in one year. With this change, effective in 2018, small businesses are now able to deduct—in the year completed—the full cost of replacing a roof on an existing nonresidential building instead of depreciating that cost over a 39-year period (IIBEC 2018). This is likely to increase the frequency of roof replacements, as more than 50 percent of building owners in the survey said they would be willing to reroof more if the 39-year period were to be updated to under 20 years (Ducker Worldwide 2003). The roofing market is primarily alterations to existing buildings, so this is a significant change and opportunity.

3.2.2.3 Technical Feasibility

Insulation for Roof Replacements

In the Draft CASE Report, the Statewide CASE Team proposed that roof replacements meet the same insulation requirements as new construction. This was done to have a single requirement in the same way as ASHRAE 90.1 and IECC, which have had a single insulation requirement for new construction and roof replacements since 2000. The Statewide CASE Team spoke with a senior architect at the City and County of Denver planning and development department who confirmed that roof replacements meet the insulation requirements of the 2015 IECC for new construction.

However, after the Draft CASE Report was available for public review several stakeholders expressed concerns at the requirement, stating that even with the option to take advantage of existing insulation this would be a significant change to current practices and would add considerable cost and complexity to projects that would be difficult to capture in a cost effectiveness analysis, such as having to raise or rebuild mechanical equipment, skylights, door thresholds, window sills, etc. There were also concerns that with the proposed insulation levels the roof/ceiling insulation trade-offs for cool roofs would require very high levels of insulation. This could add project complexity for those that would want to take advantage of the trade-off table. Reducing the proposed insulation requirements makes the trade-off more attainable.

After considering this feedback, the Statewide CASE Team worked with stakeholders to revise the proposed insulation levels to address concerns of first costs and project complexity, even though the proposed levels in the Draft CASE Report were found to be cost effective. The revised proposal in this Final CASE Report result in significant cost-effective energy savings while also adjusting to stakeholder concerns. The R-values proposed in the Draft CASE Report and the revised R-values for the Final CASE Report can be found in Table 56 and assume an R-value of 5.7 per inch for above deck insulation, which is the value cited by PIMA.

Table 56: Draft and Final CASE Report Proposed Insulation Requirements for Roof Replacements

Proposed Requirement	R-value	Inches
Draft CASE Report	CZ 1-5, 9-16: R-29 CZ 6-8: R-20	CZ 1-5, 9-16: 5.1 CZ 6-8: R-20: 3.5
Final CASE Report	CZ 1-5, 9-16: R-23 CZ 6-8: R-17	CZ 1-5, 9-16: 4 CZ 6-8: 3

Insulation for Roof Recovers and Minimum Threshold

In the Draft CASE Report the Statewide CASE Team proposed that a minimum of R-8 above deck insulation be added during a roof recover after contractors indicated that it is typically feasible to add some insulation (one to two inches) above deck without increasing the complexity of the job given the existing conditions of the roof. Therefore, the Statewide CASE Team also asked stakeholders if it would be reasonable to require a minimum amount of insulation be added regardless of existing conditions.

After the Draft CASE Report was released for public review, the Statewide CASE Team met with the Roofing Contractors Association of California (RCAC), Associated Roofing Contractors of the Bay Area Counties (ARCBAC), and PIMA. All three stakeholders stated that adding R-10 above deck insulation (1.75 inches) would be feasible for the vast majority of roof recovers and roof replacements without incurring those additional costs mentioned above.

Exceptions for Insulation Requirements

There is currently an exception for adding roof insulation if mechanical equipment is not temporarily raised during the roof replacement and adding insulation would reduce the base flashing height at the mechanical equipment to less than eight inches. The exception is written this way because it was found to be cost effective to permanently raise the mechanical equipment if it was already being temporarily raised (Pacific Gas and Electric Company 2008). Contractors indicated there is an economic feasibility concern associated when adding insulation reduces the base flashing height at the mechanical equipment so much that manufacturers do not provide a warrantee for the roofing membrane. In this case, the mechanical equipment needs to be permanently lifted to provide the necessary clearance so that the membrane can be warranted against water infiltration. This would add costs to the project. The Statewide CASE Team investigated the incremental cost of lifting mechanical equipment and received feedback from several roofing and mechanical contractors. In the Draft CASE Report, the Statewide CASE Team estimated the incremental cost to be $1500/5 ton unit, but after speaking with stakeholders and collecting additional estimates, it became more difficult to estimate a definitive cost because of variance in information collected. This is discussed further in Section 3.4.3. However, as mentioned above, contractors stated that in the vast majority of cases it is economically feasible to add R-10 insulation and felt comfortable adding that as a minimum requirement regardless of existing conditions.

Based on feedback from roofing contractors, the Statewide CASE Team is also looking into advocating for a change in the California Mechanical Code so that when mechanical equipment is replaced, the base flashing meets a minimum height.

There is currently a similar exception for maintaining the necessary base flashing height at penthouse and parapet walls for the roofing membrane to be warranted against water infiltration. Stakeholders provided feedback that having to raise base flashing heights are penthouse or parapet walls does not add significant complexity or costs to projects. Removing this exception would reduce complexity of the code and remove an exception that stakeholders have said is unnecessary.

The main difference between roof alterations and new construction when installing insulation is that alterations must often account for existing conditions, which may add cost or complexity. There are also fewer tradeoffs possible. The Statewide CASE Team balanced these challenges with the fact that significant energy savings can be realized from adding adequate insulation during roof alterations by modifying and eliminating exceptions a-c while leaving exception d intact.

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 measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training 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 57)[14]. In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector.

Table 57 California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establish ments	Employ ment	Annual Payroll ($ billion)
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 changes to roof alterations would likely affect commercial builders. The effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 58 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Chiefly, contractors that focus on the building envelope would be impacted by this proposal. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.2.4.

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

Table 58: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll ($ billion)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential Roofing Contractors	347	8,939	$0.6

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 the 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 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 59 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for this measure to affect firms that focus on nonresidential construction.

There is not a North American Industry Classification System (NAICS)[15] code specific for 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.[16] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on

[15] 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.

[16] 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.

energy efficiency consulting. The information shown in Table 59 provides an upper bound indication of the size of this sector in California.

Table 59: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billion $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

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

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;

b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

3.2.3.3 Impact on Occupational Safety and Health

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

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.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 3.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect this proposed code change to impact building owners or occupants adversely.

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

The Statewide CASE Team is proposing significant increases to the amount of insulation required during a roof replacement or roof recover and so anticipates that there may be a positive material impact on California insulation manufacturers and distributors.

3.2.3.6 Impact on Building Inspectors

Table 60 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 60: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (million $)
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.
Impact on Statewide Employment

As described in Sections 3.2.3.1 through 3.2.3.6, 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 3.2.4 the Statewide CASE Team estimates that the proposed change would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, it is estimated how energy savings associated with the proposed changes in air distribution would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.2.3.7 Impact on Statewide Employment

As described in Sections 3.2.3.1 through 3.2.3.6, 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 3.2.4, the Statewide CASE Team estimated the proposed change in roof alterations would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in roof alterations would lead to modest ongoing financial savings for California residents, which would then be available for other economic activity.

3.2.4 Economic Impacts

3.2.4.1 Creation or Elimination of Jobs

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 develop estimates of the economic impacts associated with each of the proposed code changes.[17] 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

[17] 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.

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, architects, energy consultants, and building inspectors. 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 61: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income ($ million)	Total Value Added ($ million)	Output ($ million)
Total Economic Impacts	1,994	$128.47	$189.07	$319.97
Direct Effects (Additional spending by Commercial Builders)	1,207	$79.81	$105.75	$174.92
Indirect Effect (Additional spending by firms supporting Commercial Builders)	262	$19.10	$30.42	$58.69
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	525	$29.56	$52.90	$86.36

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

3.2.4.2 Creation or Elimination of Businesses in California

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.

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.[18]

[18] 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.

Therefore, the Statewide CASE Team does not anticipate that the proposed measures 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).[19] As Table 62 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 62: 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.)

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 62 above by 31 percent.

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

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

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

3.2.4.6 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. This proposal may increase costs to construct state buildings such as large offices, but all submeasures are cost effective.

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.

3.2.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, there is the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team does not believe there would be negative impacts towards one any specific persons as a result of this code change proposal.

3.3 Energy Savings

3.3.1 Key Assumptions for Energy Savings Analysis

The final 2022 Time Dependent Valuation (TDV) factors were used for the analyses presented in this report (Energy + Environmental Economics 2020).

The Statewide CASE Team used EnergyPlus V9.0.1 to conduct the energy savings calculations for all code change proposals. Energy models are sourced from the CBECC software for commercial buildings (CBECC-Com) prototypical building models. These models are modified to include the proposed changes to the energy standards. Grocery building models is sourced from the CPUC DEER because there are currently no prototype models developed in CBECC-Com for these building types. Hospital building model is sourced from the DOE's Commercial Prototype Buildings ASHRAE 90.1-2016

The baseline model is generated for these building types by modifying the DEER models with the 2019 Title 24, Part 6 mandatory and prescriptive envelope requirements.

The Statewide CASE Team evaluated new construction roof insulation requirements from previous code cycles and the current requirements for roof alterations when determining the insulation in the Standard Design. The Statewide CASE Team factored in that:

- There were no insulation requirements for buildings built before 1979.
- 2005 Title 24, Part 6 had a prescriptive requirement of R-19 for Climate Zones 1-5 and 10-16 and R-11 for Climate Zones 6-9.
- Insulation was often traded off against other building systems before 2008 Title 24, Part 6 went into effect.
- Currently, Title 24, Part 6 requires roof alterations on existing roofs to be insulated to at least R-8 continuous insulation in Climate Zones 1 and 3 through 9, and at least R-14 continuous insulation in all other climate zones.
- Altered roofs that have at least R-7 existing insulation are exempt from the current code requirements.
- Roof recovers are exempt from the insulation requirements.
- The Statewide CASE Team heard from California insulation contractors that existing insulation levels can be as little as no insulation, R-11, or R-19 and that R-11 and R-19 are most often found.
- The 2019 new construction insulation requirements for Climate Zones 6–8 are less stringent than Climate Zones 1–5 and 9–16 (see Table 55).

- In Chapter 12 of Title 24, Part 2 – Interior Environment, Table 1202.3 specifies a minimum R-value for condensation control of R-5 in Climate Zones 3–15, R-10 in Climate Zones 1 and 2, and R-15 in Climate Zone 16.

The Statewide CASE Team applied this information to come up with four distinct baseline insulation levels, as shown in Table 63. The Statewide CASE Team circulated a survey while the Draft CASE Report was available for public review and asked participants what insulation levels they typically see on existing buildings before the roof is replaced. Eleven participants responded to the question, with six participants giving answers between R-0 and R-4, three respondents giving answers between R-8 and R-15, and two respondents saying R-30. This supports the baselines used in Table 63, and indicates that the baselines for roof recovers are likely conservative.

Table 63: Baseline for Each Climate Zone and Roof Alteration

Roof Alteration Type	Climate Zones	Baseline
Recover	1, 3 – 9	R-5
Recover	2, 10 – 16	R-11
Replacement	1, 3 – 9	R-8
Replacement	2, 10 – 16	R-14

The effective energy savings were calculated by subtracting the energy consumption for the Proposed Design cases from the Standard Design energy consumptions. Statewide energy savings were calculated by multiplying the effective energy savings by the existing building stock areas forecast by the Energy Commission.

3.3.2 Energy Savings Methodology

3.3.2.1 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 prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 89. However, the following prototypes were excluded from the statewide savings results and the cost-effectiveness analysis: Hospital, because healthcare facilities are currently exempt from all alterations and addition requirements and RetailMixedUse because it has and adiabatic roof. The results of energy modeling for the HotelSmall prototype can be found in Appendix M:

Table 64: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis, Roof Alterations

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Grocery	1	50,002	6-Zone grocery store DEER prototype model provided by SCE
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%
OfficeLarge	12	498,589	12-story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-40%
OfficeMedium	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeMediumLab	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
RetailLarge	1	240,000	Big-box type retail building with WWR-12% and SRR-0.82%
RetailMixedUse	1	9,375	Retail building with WWR -10%. Roof is adiabatic
RetailStandAlone	1	24,563	Similar to a Target or Walgreens.WWR-7% on the front façade, none on other sides. SRR-2.1%
RetailStripMall	1	9,375	Strip mall building. WWR-10%
SchoolPrimary	1	24,413	Elementary school. WWR-36%
SchoolSecondary	2	210,866	High school. WWR-35% and SRR-1.4%
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR-0.7%,SRR-5%

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of CBECC-Com.

CBECC-Com generates two models based on user inputs: the Standard Design and the Proposed Design. The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs – i.e. the changes in roof insulation. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building. The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 90 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design for each simulation. Comparing the energy difference between the baseline models and the Proposed Design reveals the impacts of the proposed code change.

Energy savings were estimated by simulating both Standard Design models and the Proposed Design models in each climate zone. Proposed Design values for roof replacements and roof recovers can be found in Table 90. The Proposed Design value for the roof recovers is equivalent to adding R-10 insulation to the Standard Design, which is what is being proposed as a minimum amount to add for roof recovers in exception a. to Section 141.0(b)2Biii. Energy savings were estimated by simulating both Standard Design models and the Proposed Design models in each climate zone.

As mentioned, hotels and motels currently have to comply with separate requirements in Table 141.0-C for nonresidential and guestroom spaces. For this Final CASE Report, the Statewide CASE Team assumed that in the Standard Design, the nonresidential and residential portions of the roof meet their respective requirements in Table 141.0-C, and in the Proposed Design the entire roof area complies with the proposed requirements listed in Table 90. As discussed in Appendix M:, the Statewide CASE Team is recommending that envelope requirements for hotel/motel be simplified and that there be a single set of requirements in Table 141.0-C apply for the entire roof area regardless of space type.

Table 65: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Roof Alteration Type	Prototype ID	Climate Zones	Parameter Name	Standard Design Parameter Value (R-value/U-factor)	Proposed Design Parameter Value (R-value/U-factor)
Recover	All Nonresidential Prototypes	1, 3-9	Roof Insulation	R-5/U-0.200	R-15/U-0.067
Recover	All Nonresidential Prototypes	2, 10-16	Roof Insulation	R-11/U-0.091	R-21/U-0.048
Replacement	All Nonresidential Prototypes	1, 3-5, 9	Roof Insulation	R-8/U-0.125	R-23/U-0.043
Replacement	All Nonresidential Prototypes	6-8	Roof Insulation	R-8/U-0.125	R-17/U-0.059
Replacement	All Nonresidential Prototypes	2, 10-16	Roof Insulation	R-14/U-0.071	R-23/U-0.043

Using EnergyPlus with CBECC-Com rulesets the Statewide CASE Team determined whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). The 2022 TDV factors were then applied 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)

(Energy + Environmental Economics 2020). TDV energy cost savings were calculated using the TDV energy cost impacts over the 30-year period of analysis presented in 2023 present value dollars (2023 PV$).

The energy impact of the proposed code change varies by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors to calculate energy and energy cost impacts.

Energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

3.3.2.2 Statewide Energy Savings Methodology

The per-square foot energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 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 (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 91 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. The Statewide CASE Team did not consider the ApartmentHighRise prototype that is part of the college building ID because it would fall under the multifamily requirements.

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

Table 66: Nonresidential Building Types and Associated Prototype Weighting, Roof Alterations

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%

3.3.3 Per-Unit Energy Impacts Results

Electricity, natural gas, and TDV energy savings per square foot of total building floorspace are presented in the tables below. Results for roof replacements are presented in Table 67 through

Table 69. and roof recovers are presented in Table 70 through Table 72.

The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per square foot electric savings for roof replacements in the first year are expected to range from -153 to 787 Wh/ft^2 and -194 to 1,024 Wh/ft^2 for roof recovers. Per square foot gas savings for the first year are expected to range from 1 to 106 millitherms/ft^2 and 1 to 154 millitherms/ft^2 depending upon climate zone and building type for roof replacements and roof recovers, respectively. There are minor negative electric savings in some climate zones for some prototype buildings. Based on the model output reports, the causes for these negative savings come from increased fan or HVAC cooling or both of these end use energy consumptions. For example, there is a heated-only storage space above the conditioned office in the Warehouse prototype. Therefore, the increased insulation reduces the heat loss through the roof and increases the ceiling heat gain to the office which resulted in increased HVAC cooling consumption in the office unit.

Table 67: Roof Replacements Electricity Savings Per Square Foot (Wh/ft^2) by Climate Zone and Prototype Building

Prototype / **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	672	322	667	787	739	508	470	584	787	358	365	338	385	392	409	372
OfficeLarge	1	(0)	2	6	3	3	17	0	4	(5)	2	4	5	9	17	5
OfficeMedium	(6)	8	4	30	8	16	2	43	46	20	20	15	32	20	59	5
OfficeSmall	12	29	(1)	95	(34)	39	8	157	182	62	124	55	142	83	292	6
Restaurant FastFood	24	120	155	226	134	88	93	219	321	146	163	137	181	155	387	69
RetailLarge	(3)	(4)	6	18	(24)	(29)	(13)	88	106	28	68	44	35	(44)	35	25
RetailStandAlone	72	(23)	(16)	23	3	17	(8)	69	59	(5)	142	71	71	110	127	45
RetailStripMall	(153)	(43)	(27)	(38)	(108)	(112)	(82)	112	88	117	44	98	212	88	240	26
SchoolPrimary	69	128	98	282	179	130	58	363	371	139	167	128	189	145	213	111
SchoolSecondary	72	42	51	124	74	59	40	136	196	63	71	55	89	83	133	78
Warehouse	(1)	(3)	(2)	(3)	(7)	(4)	(2)	(3)	(4)	(3)	(2)	(2)	(5)	(7)	(5)	(4)

Table 68: Roof Replacements Natural Gas Savings Per Square Foot (milli therms/ft^2) by Climate Zone and Prototype Building

Prototype / **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	68	14	37	32	36	14	13	17	24	8	13	13	10	13	5	29
OfficeLarge	6	2	4	4	4	2	2	2	3	1	2	2	1	1	1	3
OfficeMedium	22	7	14	14	15	7	6	9	11	4	6	7	4	6	3	10
OfficeSmall	61	15	27	24	30	8	7	9	14	7	13	13	10	13	2	28
RestaurantFastFood	85	24	52	44	54	23	20	22	32	14	19	20	15	18	8	31
RetailLarge	106	24	56	47	54	20	18	21	32	12	23	22	18	21	6	44
RetailStandAlone	96	24	55	47	53	20	18	21	32	12	22	22	18	21	6	40
RetailStripMall	96	21	45	39	44	15	13	17	25	10	20	19	15	17	4	38
SchoolPrimary	83	18	41	34	40	14	12	15	22	9	16	16	13	15	4	31
SchoolSecondary	65	19	43	40	44	21	19	24	33	12	16	17	13	16	7	30
Warehouse	69	16	36	32	34	13	13	15	22	9	16	15	12	14	5	28

Table 69: Roof Replacements TDV Energy Savings Per Square Foot (TDVKBtu/ft²) by Climate Zone and Prototype Building

Prototype / **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	38.7	14.0	29.8	34.2	30.8	19.2	16.9	22.9	31.5	13.1	15.6	14.7	15.2	16.1	14.3	19.1
OfficeLarge	1.7	0.6	1.1	1.3	1.2	0.6	1.0	0.5	1.0	0.2	0.6	0.7	0.6	0.8	0.7	0.9
OfficeMedium	6.5	2.5	4.5	5.5	4.7	2.7	2.1	4.0	5.0	2.0	2.8	2.7	2.6	2.8	2.6	3.2
OfficeSmall	18.7	5.9	8.6	11.6	8.0	3.7	2.3	8.1	10.9	4.2	8.3	6.2	8.1	7.2	9.9	8.8
Restaurant FastFood	25.7	13.2	20.2	20.2	19.1	8.7	8.4	13.1	18.9	8.5	10.6	10.3	10.0	10.1	17.6	11.2
RetailLarge	32.0	6.6	16.2	17.0	15.6	6.3	5.7	8.3	15.0	9.4	9.3	6.7	7.9	4.3	4.8	14.1
RetailStandAlone	30.3	9.8	11.2	10.1	16.3	7.4	6.2	10.2	12.1	2.7	14.3	11.8	6.9	12.6	(0.6)	13.0
RetailStripMall	24.9	4.9	15.6	9.1	9.9	0.9	1.1	8.0	12.3	6.5	4.4	9.7	11.5	9.1	8.5	12.4
SchoolPrimary	26.6	9.9	15.0	19.7	16.6	8.3	5.1	15.4	19.1	7.5	10.8	9.6	10.4	10.3	8.1	12.4
SchoolSecondary	21.3	7.1	14.4	16.5	14.9	7.9	6.7	11.7	16.6	5.5	7.1	6.8	6.9	8.0	6.2	11.3
Warehouse	20.4	5.0	11.1	9.8	10.3	4.3	4.2	4.8	7.0	2.7	4.8	4.7	3.7	4.3	1.5	8.3

Table 70: Roof Recovers Electricity Savings Per Square Foot (Wh/ft²) by Climate Zone and Prototype Building

Prototype / **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	1,017	456	843	1,005	938	896	840	994	1,024	396	528	469	546	574	622	(133)
OfficeLarge	3	4	5	10	7	6	19	17	14	0	6	4	8	12	14	7
OfficeMedium	(1)	15	13	50	21	40	19	86	75	33	30	25	46	29	84	9
OfficeSmall	85	64	40	266	85	148	40	427	421	130	209	125	228	148	378	36
RestaurantFastFood	31	144	186	314	172	231	167	425	416	147	235	197	260	223	107	104
RetailLarge	2	(7)	22	49	(1)	(46)	1	221	259	49	88	46	84	23	160	18
RetailStandAlone	92	25	74	103	60	71	12	208	185	18	170	43	165	176	288	54
RetailStripMall	(194)	(1)	(32)	64	(117)	21	(72)	664	614	141	138	19	79	158	400	(0)
SchoolPrimary	81	222	339	642	335	491	342	848	805	229	287	255	269	257	397	137
SchoolSecondary	123	74	113	257	131	156	117	328	319	107	121	93	143	145	198	115
Warehouse	(2)	(5)	(3)	(8)	(7)	(4)	(2)	(5)	(6)	(4)	(4)	(2)	(5)	(9)	(9)	(3)

Table 71: Roof Recovers Natural Gas Savings Per Square Foot (milli therms/ft²) by Climate Zone and Prototype Building

Prototype Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	113	23	63	56	64	31	27	38	43	15	22	22	17	22	8	67
OfficeLarge	7	3	5	5	5	3	3	4	4	2	2	3	2	2	1	4
OfficeMedium	27	10	18	17	20	13	11	16	16	7	9	10	8	8	4	15
OfficeSmall	75	21	35	30	37	14	12	15	18	10	18	18	14	19	4	40
RestaurantFast Food	105	33	64	53	65	36	32	35	39	19	27	29	22	26	11	43
RetailLarge	154	37	84	69	80	39	35	41	49	19	34	34	27	32	9	66
RetailStandAlone	151	37	80	68	77	38	34	40	48	19	34	33	27	31	9	60
RetailStripMall	145	32	71	61	69	30	27	32	39	15	29	29	24	27	7	58
SchoolPrimary	121	26	58	47	59	26	23	27	32	13	24	24	19	23	6	48
SchoolSecondary	95	28	68	64	71	43	38	52	55	19	26	26	21	26	11	45
Warehouse	91	24	49	42	46	24	23	26	30	13	23	22	17	21	7	40

Table 72: Roof Recovers TDV Energy Savings Per Square Foot (TDVKBtu/ft²) by Climate Zone and Prototype Building

Prototype Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	61.8	20.7	43.0	48.7	44.6	35.1	31.5	41.5	44.6	16.4	23.4	21.3	22.3	24.6	21.6	16.8
OfficeLarge	2.1	1.0	1.6	1.8	1.7	1.1	1.4	1.7	1.7	0.6	1.0	0.9	0.9	1.1	0.7	1.3
OfficeMedium	8.2	3.7	6.0	7.3	6.4	5.0	4.0	7.4	7.3	3.0	4.0	4.0	4.0	3.8	3.9	4.8
OfficeSmall	24.9	9.2	12.3	18.5	13.4	8.5	4.7	17.9	19.0	7.2	12.6	10.3	12.2	11.3	12.4	13.2
RestaurantFastFood	31.6	14.4	24.0	31.0	23.5	17.3	13.9	23.4	24.7	7.3	15.3	14.8	14.4	14.7	2.5	15.6
RetailLarge	46.1	10.6	24.7	26.8	24.2	13.0	9.7	18.2	25.5	9.3	13.7	9.7	13.6	10.1	10.0	20.8
RetailStandAlone	47.2	14.3	24.4	21.9	23.4	13.0	10.9	17.6	23.3	4.4	18.5	14.3	13.0	17.5	4.4	19.5
RetailStripMall	38.1	9.0	20.9	21.0	16.7	8.0	5.8	30.9	32.7	9.6	10.7	10.5	7.3	10.4	13.7	17.6
SchoolPrimary	38.1	15.6	27.2	34.5	26.5	22.2	15.9	33.0	35.3	11.6	17.0	15.8	15.1	16.0	14.9	18.1
SchoolSecondary	31.8	11.0	23.4	28.0	24.4	17.2	14.5	25.6	27.0	8.9	11.5	10.9	10.8	12.9	9.2	17.0
Warehouse	26.7	7.3	14.9	13.0	13.8	7.6	7.1	8.2	9.4	4.0	7.1	6.9	5.4	6.4	2.1	12.1

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 3.5.6.1. 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. In this case, the period of analysis is 30 years. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years. Appendix K: presents the energy cost savings in nominal dollars.

This proposed code change only applies to alterations.

3.4.2 Energy Cost Savings Results

Per-ft^2 energy cost savings for roof replacements and roof recovers that are realized over the 30-year period of analysis are presented in present value 2023 dollars in Table 73 and Table 74. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 73: Roof Replacements Total TDV Energy Cost Savings Per Square Foot (2023 PV$/ft²) Over 30-Year Period of Analysis by Climate Zone and Prototype Building

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	$5.96	$2.16	$4.59	$5.27	$4.75	$2.95	$2.60	$3.52	$4.85	$2.02	$2.41	$2.26	$2.34	$2.48	$2.20	$2.94
OfficeLarge	$0.27	$0.10	$0.17	$0.19	$0.19	$0.09	$0.15	$0.08	$0.15	$0.03	$0.09	$0.10	$0.10	$0.12	$0.11	$0.14
OfficeMedium	$1.00	$0.38	$0.69	$0.85	$0.72	$0.41	$0.32	$0.62	$0.77	$0.30	$0.43	$0.42	$0.39	$0.43	$0.41	$0.50
OfficeSmall	$2.88	$0.91	$1.33	$1.79	$1.23	$0.56	$0.35	$1.25	$1.68	$0.64	$1.28	$0.96	$1.25	$1.11	$1.52	$1.36
RestaurantFastFood	$3.96	$2.03	$3.12	$3.11	$2.94	$1.34	$1.29	$2.02	$2.92	$1.31	$1.63	$1.59	$1.54	$1.56	$2.72	$1.73
RetailLarge	$4.92	$1.01	$2.49	$2.61	$2.40	$0.96	$0.87	$1.28	$2.31	$1.45	$1.43	$1.03	$1.22	$0.66	$0.74	$2.17
RetailStandAlone	$4.67	$1.51	$1.72	$1.56	$2.50	$1.13	$0.95	$1.56	$1.86	$0.42	$2.21	$1.81	$1.06	$1.95	($0.09)	$1.99
RetailStripMall	$3.84	$0.76	$2.41	$1.41	$1.52	$0.14	$0.17	$1.23	$1.90	$0.99	$0.68	$1.49	$1.77	$1.40	$1.30	$1.91
SchoolPrimary	$4.10	$1.53	$2.31	$3.04	$2.56	$1.28	$0.78	$2.37	$2.95	$1.15	$1.66	$1.47	$1.60	$1.59	$1.24	$1.90
SchoolSecondary	$3.28	$1.09	$2.21	$2.55	$2.29	$1.22	$1.03	$1.81	$2.55	$0.85	$1.09	$1.05	$1.06	$1.23	$0.95	$1.74
Warehouse	$3.14	$0.77	$1.71	$1.52	$1.58	$0.66	$0.64	$0.74	$1.07	$0.42	$0.74	$0.72	$0.56	$0.66	$0.22	$1.28

Table 74: Roof Recovers Total TDV Energy Cost Savings Per Square Foot (2023 PV$/ft2) Over 30-Year Period of Analysis by Climate Zone and Prototype Building

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	$9.51	$3.19	$6.62	$7.50	$6.86	$5.41	$4.85	$6.39	$6.86	$2.52	$3.61	$3.29	$3.44	$3.79	$3.33	$2.58
OfficeLarge	$0.33	$0.15	$0.24	$0.28	$0.26	$0.18	$0.22	$0.27	$0.27	$0.10	$0.15	$0.13	$0.13	$0.17	$0.11	$0.19
OfficeMedium	$1.26	$0.57	$0.92	$1.12	$0.98	$0.77	$0.62	$1.14	$1.12	$0.47	$0.62	$0.61	$0.62	$0.58	$0.60	$0.73
OfficeSmall	$3.83	$1.41	$1.89	$2.85	$2.06	$1.31	$0.73	$2.76	$2.93	$1.11	$1.95	$1.58	$1.87	$1.75	$1.90	$2.04
RestaurantFastFood	$4.86	$2.22	$3.70	$4.77	$3.62	$2.66	$2.15	$3.61	$3.81	$1.13	$2.36	$2.28	$2.22	$2.27	$0.38	$2.40
RetailLarge	$7.10	$1.63	$3.80	$4.13	$3.73	$1.99	$1.49	$2.80	$3.93	$1.44	$2.11	$1.49	$2.09	$1.55	$1.55	$3.20
RetailStandAlone	$7.27	$2.21	$3.76	$3.38	$3.61	$2.00	$1.68	$2.71	$3.59	$0.67	$2.84	$2.19	$2.01	$2.70	$0.67	$3.00
RetailStripMall	$5.87	$1.39	$3.21	$3.24	$2.57	$1.23	$0.90	$4.76	$5.03	$1.48	$1.65	$1.62	$1.12	$1.61	$2.11	$2.71
SchoolPrimary	$5.87	$2.40	$4.19	$5.32	$4.08	$3.42	$2.44	$5.09	$5.44	$1.79	$2.62	$2.44	$2.33	$2.46	$2.30	$2.78
SchoolSecondary	$4.90	$1.69	$3.61	$4.31	$3.76	$2.65	$2.23	$3.94	$4.15	$1.37	$1.77	$1.67	$1.66	$1.99	$1.42	$2.62
Warehouse	$4.12	$1.13	$2.30	$2.00	$2.12	$1.17	$1.10	$1.26	$1.45	$0.61	$1.10	$1.07	$0.83	$0.98	$0.32	$1.86

3.4.3 Incremental First Cost

The Statewide CASE Team heard from three HERS Raters that operate in Northern California and the Central Valley that the cost of third-party verification of existing conditions and insulation installation for roof alterations would cost $600-$1000 each depending on the size and complexity of the roof. Verification of existing conditions is likely to cost a bit more but is a performance option. The third-party would also then have an incentive to contract for the verification of insulation installation. The HERS Raters emphasized that an inspection was unlikely to be more than a day's work. The Statewide CASE Team found an average cost/ft^2 of roof area for the inspection by dividing $1000 – conservatively using the maximum cost – by the construction weighted roof area of the affected buildings for roof replacements – see Table 75. This gives a construction weighted average cost of $0.03/ft^2.

Table 75: Construction Weighted Cost of Insulation Installation Verification

Building Prototype	Affected building floor area (million ft^2)	Roof area (ft^2)	Cost/ft^2
Grocery	16.6	50,002	$0.02
OfficeLarge	35.0	38,357	$0.03
OfficeMedium	37.4	17,878	$0.06
OfficeSmall	4.2	6,446	$0.16
RestaurantFastFood	2.0	2,787	$0.36
RetailLarge	47.0	236,647	$0.00
RetailStandAlone	5.0	24,183	$0.04
RetailStripMall	2.5	9,376	$0.11
SchoolPrimary	18.3	24,415	$0.04
SchoolSecondary	17.0	126,277	$0.01
Warehouse	58.9	47,025	$0.02

The incremental first cost estimate includes the material cost of insulation, the labor to install it, and the cost of lifting mechanical equipment to maintain the necessary base flashing height. Table 76 presents the material cost data used. The Statewide CASE Team used RSMeans to determine the cost of polyisocyanurate for roof decks for each R-value of interest by taking the average cost/inch for thicknesses of 1.5-3.5 inches – 1.0 inch was excluded by the recommendation of the Polyisocyanurate Insulation Manufacturers Association – PIMA – because it is used less often and costs more. The description in RSMeans is "Polyisocyanurate insulation, for roof decks, 2#/CF density, fastening excluded." This was done for each climate zone and the Energy Commission estimate for the existing building stock in each climate zone was used to determine a construction weighted average cost per inch of insulation. An R-value of R-5.7 per inch was assumed for rigid insulation, based on feedback from manufacturers. Four manufacturers from PIMA informed the Statewide CASE Team that the bare material costs in RSMeans were on average 25 percent higher than their costs to contractors, so the Statewide CASE Team reduced the bare material cost from RSMeans for each climate zone by 25 percent.

The Associated Roofing Contractors of the Bay Area Counties (ARCBAC) expressed concern at this 25 percent reduction, citing concerns that PIMA is not an objective stakeholder and would benefit from the measure appearing to be more cost effective than it is. The Statewide CASE Team regularly asks stakeholders who have a vested interest in measures to provide cost estimates and takes these estimates in good faith. Furthermore, the material costs used in this submeasure are equivalent to the roof insulation cost estimates gathered for the Opaque Envelope submeasure for above deck insulation in new construction (see Section 5.4.3) and so the Statewide CASE Team believes the costs used to be reasonable.

Table 76 displays the data used to estimate the labor cost for installation. As with material costs, the Statewide CASE Team used RSMeans and the Energy Commission estimate for the existing building stock in each climate zone to come up with a construction weighted average labor cost for installing the specified R-value of polyisocyanurate. The labor cost is not linear, and therefore the cost was plotted and fitted with a logarithmic line of best fit to determine the cost in each climate zone. See Figure 1 for an example. The total cost used for each Standard Design and Proposed Design simulated for the analysis are presented in Table 76, and the incremental cost for each scenario is presented in Table 77.

The cool roof survey that the Statewide CASE Team circulated while the Draft CASE Report was available for public review asked participants about the labor costs associated with installing different amounts of above deck insulation and the cost of lifting mechanical equipment. The Statewide CASE Team received responses from five participants, both contractors and consultants. The survey had five responses for these questions and so could not be used as a quantitative estimate of either labor costs for installing insulation or the cost of lifting mechanical equipment but are included in Appendix G:, to be used qualitatively.

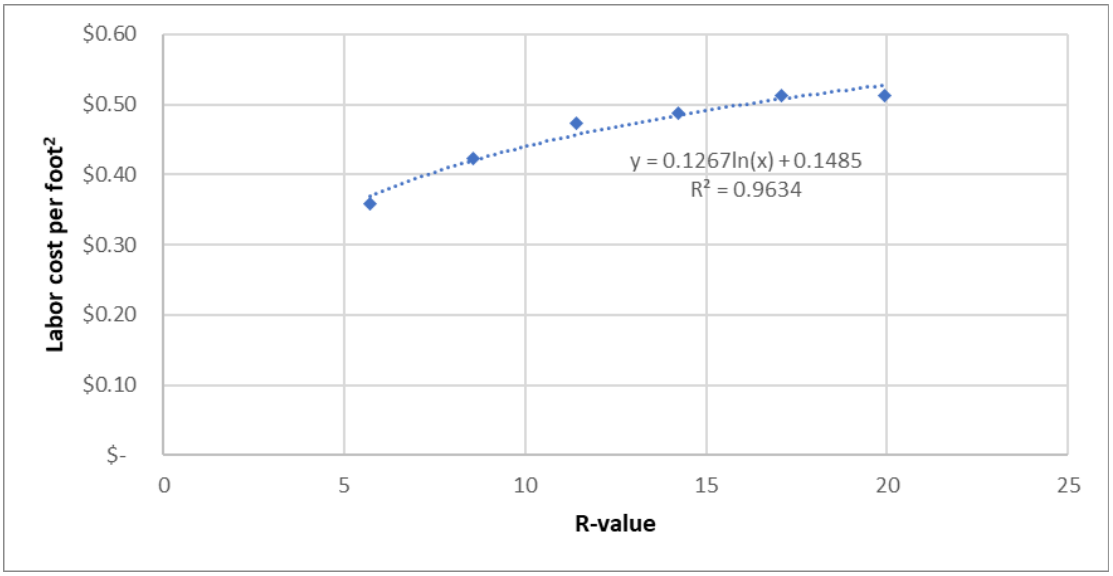

Figure 1: Labor cost for installing polyisocyanurate in Sacramento, representing Climate Zone 12.

Table 76: Roof Alterations Total Installed Cost of Rigid Insulation per ft^2

R-value	Existing Building Stock Weighted Cost of Polyisocyanurate ($/$ft^2$ insulation)	Existing Building Stock Weighted Labor Cost	Total Building Stock Weighted Installed Costs
5	$0.36	$0.33	$0.70
8	$0.58	$0.39	$0.97
11	$0.80	$0.43	$1.23
14	$1.02	$0.45	$1.47
15	$1.09	$0.46	$1.55
17	$1.24	$0.48	$1.71
21	$1.53	$0.50	$2.03
23	$1.67	$0.51	$2.19

Table 77: Total Incremental Cost for Roof Alterations and Roof Recovers

Where Applicable	Standard Design Insulation	Proposed Design Insulation	Incremental Material Cost	Incremental Labor Cost	Verification Cost ($)	Total Incremental First Cost
Recover, CZ 1, 3-9	R-5	R-15	$0.73	$0.13	$0.03	$0.89
Recover, CZ 2, 10-16	R-11	R-21	$0.73	$0.08	$0.03	$0.83
Replacement, CZ 1, 3-5, 9	R-8	R-23	$1.09	$0.12	$0.03	$1.24
Replacement, CZ 2, 10-16	R-14	R-23	$0.66	$0.06	$0.03	$0.74
Replacement, CZ 6-8	R-8	R-17	$0.66	$0.09	$0.03	$0.77

The incremental cost per prototypical building was calculated per ft^2 of conditioned floor area. This was done by calculating the total cost based on the roof area of each building prototype and then dividing by the conditioned floor area. The costs for the R-14 Standard Design are provided in Table 78 below as an example. For a single story building such as Grocery the cost per ft^2 of conditioned floor area is the same as cost per ft^2 of roof area.

Table 78: Example of Calculating Cost per ft^2 of Floor Area – R-14 Baseline and R-23 Proposed

Prototypical building	Roof area (ft^2)	Total incremental cost per prototypical building	Conditioned floor area (ft^2)	Cost per ft^2 of conditioned floor area
Grocery	50,002	$35,501.31	50,002	$0.74
OfficeLarge	38,357	$27,233.27	460,281	$0.06
OfficeMedium	17,878	$12,693.15	53,633	$0.25
OfficeSmall	6,446	$4,769.77	5,503	$0.87
RestaurantFastFood	2,787	$1,978.48	2,501	$0.82
RetailLarge	236,647	$168,019.43	240,023	$0.73
RetailStandAlone	24,183	$17,169.68	24,566	$0.73
RetailStripMall	9,376	$6,656.90	9,376	$0.74
SchoolPrimary	24,415	$17,334.69	24,415	$0.74
SchoolSecondary	126,277	$89,656.60	210,907	$0.44
Warehouse	47,025	$33,387.78	52,050	$0.67

The Statewide CASE Team heard concerns from a stakeholder that requiring above deck insulation for roof recovers would require the addition of a cover board when using a coating as the new roof cover. The Statewide CASE Team consulted Luke Nolan of Central Coating and SGH to determine the prevalence of coatings being used as new roof covers. Luke Nolan said that while it is possible to use a coating as a new roof cover it is not widespread. He also reached out to one of his material supplier representatives who confirmed that these coating systems are no being installed anymore because insulated single-ply or SPF systems would be more cost effective and have longer lifespans. Kenneth Klein of SGH agreed that not many people use a roof coating system over insulation and a cover board. The Statewide CASE Team therefore did not add the cost of a cover board to the overall cost effectiveness calculation of the measure. However, the Statewide CASE Team did perform the cost effectiveness analysis for adding a roof cover board for those scenarios in which a coating is used as a new roof so that interested stakeholders could see the result. The RSMeans 2020 bare material cost of “Roof deck insulation, perlite, ½” thick, R1.32, fastening excluded” for Sacramento is $0.28/ft^2. The Statewide CASE Team assumed a material cost of $0.40/ft^2 to the end customer to account for overhead and profit. An additional $0.26/ft^2 of maintenance cost was included for a new cover board to be installed after 15 years, using the methodology described in Section 3.4.4. The cost effectiveness results for adding a cover board can be found in Table 84.

Table 79 presents the cost data for lifting mechanical equipment. In the 2008 CASE Report, the Statewide CASE Team gathered the costs of temporarily and permanently lifting a 5-ton mechanical unit to see if an exception should be proposed for not adding insulation if mechanical equipment would need to be lifted to make room for it (Pacific

Gas and Electric Company 2008). Temporarily lifting equipment refers to disconnecting it, lifting it with a crane, and then putting it back. Permanently lifting equipment refers to raising the curb height once the equipment has been temporarily lifted.

The costs from the 2008 CASE Report came from four mechanical and one roofing contractor. Costs for permanently lifting equipment include preparing and inserting a curb adapter, securing ductwork, installing an extended gas supply line, installing an extended supply cable, and preparing the curb adapter. The costs associated with temporarily lifting equipment were estimated at least $500 and were not included in the costs for permanently lifting equipment (Pacific Gas and Electric Company 2008). The Statewide CASE Team from 2008 found that it was cost effective to permanently lift equipment to make room for roof insulation when the equipment was planned to be temporarily lifted. The exception therefore only applies when the mechanical equipment is not temporarily lifted. Table 79 shows the individual costs broken out from 2008.

For the 2020 code cycle, the Statewide CASE Team reevaluated the exception by including the costs of temporarily lifting equipment. To adjust the 2008 costs to 2020, the line items were reviewed by two mechanical contractors and one roofing contractor (see Table 80). In the Draft CASE Report, The Statewide CASE Team decided to use $1,500 as the incremental cost for lifting mechanical equipment based on feedback from contractors that costs were likely to be lower in the rest of California than in the Bay Area. The Statewide CASE Team estimated one 5-ton unit for every 2,000 ft^2 of roof area, which gives an incremental cost of $0.75/$ft^2$ roof area to lift mechanical equipment. It is important to note that this is a conservative estimate, as the cost of the crane would not scale linearly with the number of HVAC units, since more than one unit could be lifted while the crane is on-site. The incremental cost of $0.75/$ft^2$ was used to evaluate if the exception should apply in each climate zone.

Table 79: Cost for Lifting Mechanical Equipment Form 2008

Cost	Northern California roofing company	Southern California HVAC Contractor	Northern California HVAC Contractor
Cost of crane	$600	$1,200	$500
Labor for lifting and replacing AC unit and curb	$100	$600	$100
Temporarily lifting Equipment	**$700**	**$1,200**	**$600**
Insert curb ($500) and secure ductwork	$566	$500	$550
Install extended gas supply line	$50	$100	$30
Install extended supply cable	$75	$100	$130
Prepare curb adapter			$50
Permanently Lifting equipment	**$691**	**$700**	**$760**
Total Cost	**$1,391**	**$2,500**	**$1,360**

Table 80: Cost of Lifting Mechanical Equipment

	Range from 2008 CASE Report	Bay Area Roofing Contractor (2020)	Two Different Bay Area Mechanical Contractors (2020)
Cost	$1,200–3,000	$2,000–3,000	$1,500–2,000

While the Draft CASE Report was available for public review, the Statewide CASE Team circulated a survey to collect additional information from stakeholders, including the cost of lifting mechanical equipment – see Appendix G:. Five respondents filled out cost information for lifting mechanical equipment, and answers ranged from a total cost of $1,650 to $17,250. The Statewide CASE Team also heard concerns from some roofing contractors that having to raise mechanical equipment to add insulation can drastically increase the cost of and complexity of a project. They also said that the more insulation that is required, the more likely that base flashing heights would not be high enough to meet manufacturer's instructions. Representatives from ARCBAC and the Roofing Contractors of California (RCAC) said that a requirement that all roofs have at least R-10 above deck regardless of existing conditions was a reasonable adjustment to the exception to ensure a minimum performance threshold. ARCBAC and RCAC also requested that this exception be kept as simple and straightforward as possible.

Based on the wide range in possible costs and concerns raised by stakeholders, the Statewide CASE Team recommends that the exception for mechanical equipment still apply across all climate zones, but proposes two significant changes:

1. There would be a minimum requirement of R-10 regardless of existing conditions.
2. Base flashing height would have to meet manufacturers' instructions, rather

than eight inches across the board.

3.4.4 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 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 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:

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

Insulation has an expected useful life of 30 years or greater and so roof replacements were not assumed to have an incremental replacement cost for the additional insulation. However, as in the cool roof measure, it was assumed that a roof membrane has an effective life of 15 years. The Statewide CASE Team therefore assumed that 15 years after a roof recover both the membrane and the insulation would need to be replaced.

The Statewide CASE Team included an incremental replacement cost for the insulation added during roof recovers. The assumed incremental replacement cost was the same used for the incremental first cost of roof recovers, but a three percent discount rate was applied over 15 years. Again, no incremental replacement or maintenance cost is expected for roof replacements. Recovers had a maintenance cost of $0.55/ft^2 and $0.51 in Climate Zones 1, 3-9 and 2, 10-16 respectively, bringing the total cost to $1.41/ft^2 and $1.31/ft^2.

3.4.5 Cost Effectiveness

This submeasure proposes a prescriptive requirement. As such, a cost analysis is required to demonstrate that the submeasure is cost effective over the 30-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 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas 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 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Prototypical building	**Roof area (ft^2)**	**Total incremental cost per prototypical building**	**Conditioned floor area (ft^2)**	**Cost per ft^2 of conditioned floor area**
Grocery	50,002	$35,501.31	50,002	$0.74
OfficeLarge	38,357	$27,233.27	460,281	$0.06
OfficeMedium	17,878	$12,693.15	53,633	$0.25
OfficeSmall	6,446	$4,769.77	5,503	$0.87
RestaurantFastFood	2,787	$1,978.48	2,501	$0.82
RetailLarge	236,647	$168,019.43	240,023	$0.73
RetailStandAlone	24,183	$17,169.68	24,566	$0.73
RetailStripMall	9,376	$6,656.90	9,376	$0.74
SchoolPrimary	24,415	$17,334.69	24,415	$0.74
SchoolSecondary	126,277	$89,656.60	210,907	$0.44
Warehouse	47,025	$33,387.78	52,050	$0.67

The construction weighted cost-effectiveness analyses are presented in Table 81. Cost effectiveness was calculated and weighted by impacted construction forecast using the following equation where BCR is the B/C ratio, CF is the impacted construction forecast, and *i* is the building prototype:

$$B/C\ Ratio_{Climate\ Zone} = \sum \frac{BCR_{building\ prototype(i),Climate\ Zone} * CF_{building\ prototype(i),Climate\ Zone}}{CF_{Climate\ Zone}}$$

The following prototypes were excluded from the analysis: Hospital, because it is exempt from the requirement and RetailMixedUse because it has an adiabatic roof. The requirement was found to be cost effective in every climate zone except for roof recovers in Climate Zone 10, which has a benefit-to-cost cost of 0.95 instead of 1.0. Results of the per-unit cost-effectiveness analyses for all prototype buildings are presented in Table 82 and Table 83 for roof replacements and recovers. Values in red are less than one, values in red and with parenthesis are negative.

Table 81: Construction Weighted Benefit-to-Cost Ratio for Each Climate Zone

Climate Zone	Benefit-to-Cost Ratio Replacements	Benefit-to-Cost Ratio Recovers
1	3.27	3.86
2	1.67	1.38
3	1.93	2.41
4	2.12	2.69
5	1.98	2.47
6	1.53	1.62
7	1.51	1.48
8	2.02	2.25
9	1.83	2.47
10	1.31	0.95
11	1.85	1.51
12	1.66	1.32
13	1.73	1.44
14	1.59	1.37
15	1.16	1.00
16	2.58	1.95

Table 82: Roof Replacements Benefit-to-Cost Ratio by Climate Zone and Prototype Building

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	4.8	2.9	3.7	4.3	3.8	3.8	3.4	4.6	3.9	2.7	3.3	3.1	3.2	3.4	3.0	4.0
OfficeLarge	2.6	1.6	1.7	1.9	1.8	1.3	2.3	1.3	1.5	0.6	1.5	1.7	1.5	1.9	1.8	2.2
OfficeMedium	2.4	1.6	1.7	2.1	1.7	1.6	1.2	2.4	1.9	1.2	1.8	1.7	1.6	1.8	1.7	2.0
OfficeSmall	2.0	1.0	0.9	1.2	0.8	0.6	0.4	1.4	1.2	0.7	1.5	1.1	1.4	1.3	1.8	1.6
RestaurantFastFood	2.9	2.5	2.3	2.3	2.1	1.6	1.5	2.4	2.1	1.6	2.0	1.9	1.9	1.9	3.3	2.1
RetailLarge	4.0	1.4	2.0	2.1	2.0	1.3	1.1	1.7	1.9	2.0	2.0	1.4	1.7	0.9	1.0	3.0
RetailStandAlone	3.8	2.1	1.4	1.3	2.1	1.5	1.3	2.1	1.5	0.6	3.0	2.5	1.5	2.7	(0.1)	2.7
RetailStripMall	3.1	1.0	1.9	1.1	1.2	0.2	0.2	1.6	1.5	1.3	0.9	2.0	2.4	1.9	1.8	2.6
SchoolPrimary	3.3	2.1	1.9	2.4	2.1	1.7	1.0	3.1	2.4	1.6	2.2	2.0	2.2	2.1	1.7	2.6
SchoolSecondary	4.4	2.5	3.0	3.4	3.1	2.6	2.2	3.9	3.4	1.9	2.5	2.4	2.4	2.8	2.1	3.9
Warehouse	2.8	1.2	1.5	1.4	1.4	0.9	0.9	1.1	1.0	0.6	1.1	1.1	0.8	1.0	0.3	1.9

Table 83:Roof Alterations Benefit-to-Cost Ratio by Climate Zone and Prototype Building – Roof Recovers

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	6.5	2.3	4.5	5.1	4.7	3.7	3.3	4.4	4.7	1.8	2.6	2.4	2.5	2.8	2.4	1.9
OfficeLarge	2.7	1.3	2.0	2.3	2.1	1.4	1.8	2.2	2.2	0.8	1.3	1.2	1.2	1.5	1.0	1.7
OfficeMedium	2.6	1.2	1.9	2.3	2.0	1.6	1.3	2.4	2.3	1.0	1.4	1.3	1.4	1.3	1.3	1.6
OfficeSmall	2.2	0.9	1.1	1.7	1.2	0.8	0.4	1.6	1.7	0.7	1.2	1.0	1.2	1.1	1.2	1.3
RestaurantFastFood	3.0	1.5	2.3	2.9	2.2	1.6	1.3	2.2	2.3	0.7	1.6	1.5	1.5	1.5	0.2	1.6
RetailLarge	4.9	1.2	2.6	2.9	2.6	1.4	1.0	1.9	2.7	1.1	1.6	1.1	1.6	1.2	1.2	2.4
RetailStandAlone	5.1	1.6	2.6	2.3	2.5	1.4	1.2	1.9	2.5	0.5	2.1	1.6	1.5	2.0	0.5	2.2
RetailStripMall	4.0	1.0	2.2	2.2	1.8	0.8	0.6	3.3	3.4	1.1	1.2	1.2	0.8	1.2	1.6	2.0
SchoolPrimary	4.0	1.8	2.9	3.6	2.8	2.3	1.7	3.5	3.7	1.3	1.9	1.8	1.7	1.8	1.7	2.0
SchoolSecondary	5.6	2.1	4.1	4.9	4.3	3.0	2.5	4.5	4.7	1.7	2.2	2.0	2.0	2.4	1.7	3.2
Warehouse	3.1	0.9	1.7	1.5	1.6	0.9	0.8	1.0	1.1	0.5	0.9	0.9	0.7	0.8	0.3	1.5

The Statewide CASE Team also performed a cost-effectiveness analysis of adding a cover board during a roof recover, with an additional first cost of $0.40/ft^2 and additional maintenance cost of $0.26/ft^2 for the cover board. These results are not used in the overall cost effectiveness analysis because the small number of recovers that would use a coating rather than a membrane. The results are presented Table 84. The roof recover would be cost effective overall even when including the cost of a cover board.

Table 84: Cost Effectiveness for Adding a Cover Board and Insulation for Recovers

Climate Zone	Benefit-to-Cost Ratio
1	2.66
2	0.93
3	1.66
4	1.85
5	1.70
6	1.12
7	1.02
8	1.55
9	1.71
10	0.64
11	1.02
12	0.89
13	0.97
14	0.92
15	0.67
16	1.32

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 alterations by multiplying the per-unit savings, which are presented in Section 3.3.3, by assumptions about the percentage of existing buildings that would be impacted by the proposed code. The statewide existing building forecast for 2023 is presented in Appendix A: as are the Statewide CASE Team's assumptions about the percentage of existing buildings that would be impacted by the proposal (by climate zone and building type).

The first-year energy impacts represent the first-year annual savings from all buildings that were altered in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 85 presents the first-year statewide energy and energy cost savings from altered buildings by climate zone. The following prototypes were excluded: Hospital, because it is exempt from the requirements for alterations and additions in Section 141.0, and RetailMixedUse because it has an adiabatic roof.

These statewide savings results are conservative for several reasons. First, the modeling was done using 2019 prototype buildings with modified roof insulation, whereas this submeasure would apply to older, less efficient buildings. Second, the Statewide CASE Team used a standard insulation level of R-11 for roof recovers in Climate Zones 2, 9-16, which, because they have no insulation requirements, is likely an overestimation of the existing insulation in roofs.

Table 85: Statewide Energy and Energy Cost Impacts, Roof Replacements

Climate Zone	Statewide Alterations 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 (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.93	0.05	0.01	0.06	$2.80
2	5.54	0.21	0.01	0.08	$4.78
3	26.56	1.40	0.13	0.82	$43.75
4	13.65	1.20	0.10	0.37	$24.08
5	2.67	0.17	0.02	0.08	$4.54
6	20.15	0.86	0.07	0.25	$16.53
7	13.82	0.62	0.08	0.16	$10.44
8	28.94	2.88	0.13	0.40	$31.90
9	46.84	5.41	0.50	0.90	$72.53
10	28.48	1.52	0.09	0.25	$23.67
11	5.32	0.41	0.02	0.08	$5.97
12	28.07	1.48	0.08	0.39	$24.84
13	10.19	0.90	0.06	0.12	$10.93
14	6.60	0.29	0.03	0.09	$5.80
15	3.89	0.35	0.03	0.02	$2.75
16	2.01	0.11	0.01	0.06	$3.13
Total	**243.67**	**17.84**	**1.38**	**4.14**	**$288.45**

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

Table 86: Statewide Energy and Energy Cost Impacts, Roof Recovers

Climate Zone	Statewide Alterations 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 (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.56	0.05	0.01	0.05	$2.38
2	3.30	0.20	0.02	0.07	$4.34
3	15.81	1.47	0.18	0.72	$39.12
4	8.13	1.23	0.13	0.31	$21.91
5	1.59	0.16	0.02	0.07	$4.02
6	12.00	1.26	0.17	0.28	$19.87
7	8.23	0.90	0.09	0.18	$12.03
8	17.23	3.75	0.21	0.45	$38.24
9	27.88	5.83	0.49	0.81	$68.68
10	16.95	1.25	0.11	0.23	$17.89
11	3.17	0.37	0.03	0.07	$5.34
12	16.71	1.28	0.12	0.34	$21.91
13	6.07	0.82	0.05	0.11	$10.00
14	3.93	0.35	0.03	0.08	$5.63
15	2.32	0.37	0.02	0.02	$2.68
16	1.20	0.02	0.00	0.05	$2.57
Total	**145.04**	**19.31**	**1.68**	**3.85**	**$276.62**

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

Table 87: Statewide Energy and Energy Cost Impacts – Roof Replacements and Roof Recovers

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (PV$ million)
Roof Replacement	18	1.38	4.14	$288.45
Roof Recover	19	1.68	3.85	$276.62
TOTAL	**37**	**3.06**	**7.99**	**$565.08**

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

3.5.2 Statewide Greenhouse Gas GHG Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the U.S. EPA eGRID for the 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 factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 88 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 52, 529 metric tons of CO2e would be avoided.

Table 88: First-Year Statewide GHG Emissions Impacts, Roof Alterations

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Replacements	18	4,289	4.14	22,581	26,870
Recovers	19	4,642	3.85	21,017	25,660
TOTAL	**37**	**8,931**	**7.99**	**43,598**	**52,529**

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

b. Assumes the following emission factors: 240 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

3.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

3.5.4 Statewide Material Impacts

The material impacts of this submeasure would potentially include an increase in the use of continuous insulation products, such as rigid polyisocyanurate. There are no significant anticipated statewide impacts on material use.

3.5.5 Other Non-Energy Impacts

A properly insulated roof would improve comfort within the building and allow the HVAC system to meet its set points. In very hot weather, it is unlikely that a building could meet its setpoints without a properly insulated roof. Above deck roof insulation would also reduce moisture problems and increase the roof life.

3.5.6 Energy Savings Methodology

3.5.6.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 89. However, the following prototypes were excluded from the statewide savings results and the cost-effectiveness analysis: Hospital, because healthcare facilities are currently exempt from all alterations and addition requirements and RetailMixedUse because it has an adiabatic roof.

Table 89: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis, Roof Alterations

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Grocery	1	50,002	6-Zone grocery store DEER prototype model provided by SCE
Hospital	3	241,374	5-Story Hospital DOE prototype model
HotelSmall	4	42,554	4 story Hotel with 77 guest rooms. WWR-11%
OfficeLarge	12	498,589	12-story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-40%
OfficeMedium	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeMediumLab	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
RetailLarge	1	240,000	Big-box type retail building with WWR-12% and SRR-0.82%
RetailMixedUse	1	9,375	Retail building with WWR -10%. Roof is adiabatic
RetailStandAlone	1	24,563	Similar to a Target or Walgreens.WWR-7% on the front façade, none on other sides. SRR-2.1%
RetailStripMall	1	9,375	Strip mall building. WWR-10%
SchoolPrimary	1	24,413	Elementary school. WWR-36%
SchoolSecondary	2	210,866	High school. WWR-35% and SRR-1.4%
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR-0.7%,SRR-5%

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of CBECC-Com.

CBECC-Com generates two models based on user inputs: the Standard Design and the Proposed Design. The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs – i.e. the changes in roof insulation. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building. The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 90 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design for each simulation. Comparing the energy difference between the baseline models and the Proposed Design reveals the impacts of the proposed code change.

Energy savings were estimated by simulating both Standard Design models and the Proposed Design models in each climate zone. Proposed Design values for roof replacements and roof recovers can be found in Table 90. The Proposed Design value for the roof recovers is equivalent to adding R-10 insulation to the Standard Design, which is what is being proposed as a minimum amount to add for roof recovers in exception a. to Section 141.0(b)2Biii. Energy savings were estimated by simulating both Standard Design models and the Proposed Design models in each climate zone.

As mentioned, hotels and motels currently have to comply with separate requirements in Table 141.0-C for nonresidential and guestroom spaces. For this Final CASE Report, the Statewide CASE Team assumed that in the Standard Design, the entire roof area complies with the nonresidential requirements in Table 141.0-C, and in the Proposed Design the entire roof area complies with the proposed requirements listed in Table 90. As discussed in Appendix M:, the Statewide CASE Team is recommending that envelope requirements for hotel/motel be simplified and that there be a single set of requirements in Table 141.0-C apply for the entire roof area regardless of space type.

Table 90: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Roof Alteration Type	Prototype ID	Climate Zones	Parameter Name	Standard Design Parameter Value (R-value/U-factor)	Proposed Design Parameter Value (R-value/U-factor)
Recover	All Nonresidential Prototypes	1, 3-9	Roof Insulation	R-5/U-0.200	R-15/U-0.067
Recover	All Nonresidential Prototypes	2, 10-16	Roof Insulation	R-11/U-0.091	R-21/U-0.048
Replacement	All Nonresidential Prototypes	1, 3-5, 9	Roof Insulation	R-8/U-0.125	R-23/U-0.043
Replacement	All Nonresidential Prototypes	6-8	Roof Insulation	R-8/U-0.125	R-17/U-0.059
Replacement	All Nonresidential Prototypes	2, 10-16	Roof Insulation	R-14/U-0.071	R-23/U-0.043

CBECC-Com calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). 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) (Energy + Environmental Economics 2020). CBECC-Com also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$).

The energy impact of the proposed code change varies by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors to calculate energy and energy cost impacts.

Energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

3.5.6.2 Statewide Energy Savings Methodology

The per-square foot energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 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 (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 91 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. The Statewide CASE Team did not consider the ApartmentHighRise prototype that is part of the college building ID because it would fall under the multifamily requirements.

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

Table 91: Nonresidential Building Types and Associated Prototype Weighting, Roof Alterations

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%

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).

3.6.2 Standards

Section 141.0(b)2B. Existing roofs being replaced, recovered or recoated, of a nonresidential, high-rise residential and hotels/motels shall meet the requirements of Section 110.8(i). Roofs with more than 50 percent of the roof area or more than 2,000 square feet of roof, whichever is less, is being altered the requirements of i through iii below apply:

(sections omitted)

iii: For nonresidential buildings, ~~high-rise residential buildings~~ and hotels/motels when low-sloped roofs ~~are exposed to the roof deck or to the roof recover boards, and~~ meets~~s~~ Section 141.0(b)2Bi~~a~~ or ii~~a~~, the ~~exposed~~ area of the roof replacement or roof recover shall meet the following requirements: ~~be insulated to the levels specified in TABLE 141.0-C.~~

a. Insulation shall be installed by the insulation installer and verified by a qualified third-party.

b. For both roof replacements and recovers, the altered roof shall have at least R-10 insulation above deck.

c. The area of the roof replacement or roof recover shall be insulated to the levels specified in TABLE 141.0-C; or

d. Insulation of at least R-10 shall be installed above deck during the roof recover.

EXCEPTION to Section 141.0(b)2Biii

~~a. Existing roofs that are insulated with at least R-7 insulation or that has a U-factor lower than 0.089 are not required to meet the R-value requirement of TABLE 141.0-C.~~

a. ~~b.~~ If mechanical equipment is located on the roof and will not be disconnected and lifted as part of the roof replacement, insulation added may be limited to the maximum insulation thickness that will allow a height in accordance with manufacturers' instructions ~~of 8 inches (203 mm)~~ from the roof membrane surface to the top of the base flashing or R-10, whichever is greater.

~~c. If adding the required insulation will reduce the base flashing height to less than 8 inches (203 mm) at penthouse or parapet walls, the insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (203 mm) from the roof membrane surface to the top of the base flashing, provided that the conditions in Subsections i through iv apply:~~

~~i. The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material; and~~

~~ii. The penthouse or parapet walls have exterior cladding material that must be removed to install the new roof covering membrane to maintain a base flashing height of 8 inches (203 mm); and~~

~~iii. For nonresidential buildings, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for Climate Zones 2, and 10 through 16, and less than 100 square feet per linear foot for Climate Zones 1, and 3 through 9; and~~

~~iv. For high-rise residential buildings, hotels or motels, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for all Climate Zones.~~

b. ~~d~~ Tapered insulation may be used which has a thermal resistance less than that prescribed in TABLE 141.0-C at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds the value that is specified in TABLE 141.0-C.

TABLE 141.0-C INSULATION REQUIREMENTS FOR ROOF ALTERATIONS

Climate Zone	**Continuous Insulation R-value**	**U-factor**
1-5, 9-16	R-23	0.037
6-8	R-17	0.047

	~~**Nonresidential**~~		~~**High-Rise Residential and Guest Rooms of Hotel/Motel Buildings**~~	
~~**Climate Zone**~~	~~**Continuous Insulation R-value**~~	~~**U-factor**~~	~~**Continuous Insulation R-value**~~	~~**U-factor**~~
~~**1**~~	~~**R-8**~~	~~**0.082**~~	~~**R-14**~~	~~**0.055**~~
~~**2**~~	~~**R-14**~~	~~**0.055**~~	~~**R-14**~~	~~**0.055**~~
~~**3-9**~~	~~**R-8**~~	~~**0.082**~~	~~**R-14**~~	~~**0.055**~~
~~**10-16**~~	~~**R-14**~~	~~**0.055**~~	~~**R-14**~~	~~**0.055**~~

Section 141.0(b)3

3. Performance approach.

A. The altered envelope, space–conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110.0 through 110.9, Sections 120.0 through 120.6, and Sections 120.9 through 130.5.

EXCEPTION 1 to Section 141.0(b)3A Window Films. Applied window films installed as part of an alteration complies with the U-factor, RSHGC and VT requirements of TABLE 141.0-E.

EXCEPTION 2 to Section 141.0(b)2: The requirements of Section 120.2(i) shall not apply to alterations of space-conditioning systems or components.

B. The standard design for an altered component shall be the higher efficiency of existing conditions or the requirements of Section 141.0(b)2. For components not being altered, the standard design shall be based on the unaltered existing conditions such that the standard and proposed designs for these components are identical.

C. When the third-party verification option is specified, all components proposed for alteration, for which the additional credit is taken, must be verified. Existing roof/ceiling insulation shall be verified. The Executive Director shall determine the qualifications required by the third-party inspector.

TABLE 141.0-E – The Standard Design For An Altered Component

Altered Component	Standard Design Without Third-party Verification of Existing Conditions Shall be Based On	Standard Design With Third-party Verification of Existing Conditions Shall be Based On
Roof/Ceiling Insulation, Wall Insulation, and Floor/Soffit Insulation	The requirements of Section 141.0(b)1 and 141.0(b)2Biii.	Existing insulation levels may be used to help meet the requirements of Section 141.0(b)2Biii.
Fenestration The allowed glass area shall be the smaller of the a. or b. below: a. The proposed glass area: or b. The larger of: 1.The existing glass area that remains; or 2.The area allowed in Section 140.3(a)5A.	The U-factor and RSHGC requirements of TABLE 141.0-A.	The existing U-factor and RSHGC levels.
Space-Conditioning System Equipment and Ducts	The requirements of Sections 141.0(b)2C, 141.0(b)2Di or Section 141.0(b)2Dii, and Section 141.0(b)2E.	
Window Film	The U-factor of 0.40 and SHGC value of 0.35.	The existing fenestration in the alteration shall be based on TABLE 110.6-A and Table 110.6-B.
Service Water Heating Systems	The requirements of Section 140.5 without solar water heating requirements.	
Roofing Products	The requirements of Section 141.0(b)2B.	
Lighting System	The requirements of Sections 141.0(b)2F, through 141.0(b)2K.	
All Other Measures	The proposed efficiency levels.	

3.6.3 Reference Appendices

Joint Appendix JA4

Appendix JA4 – U-factor, C-factor, and Thermal Mass Data

(sections omitted)

JA4.2 Roofs and Ceilings

Table 4.2.2 – U-factors of Wood Framed Rafter Roofs

Rafter Spacing	R-value of Cavity Insulation	Nominal Framing Size		Rated R-value of Continuous Insulation[5]										
				None	R-2	R-4	R-6	R-7	R-8	R-10	R-14	R-17	R-20	R-23
				A	B	C	D	E	F	G	H	I	J	K
16 in. OC	None	Any	1	0.297	0.186	0.136	0.107	0.096	0.088	0.075	0.058	0.049	0.043	0.038
	R-11[2]	2x4	2	0.084	0.072	0.063	0.056	0.053	0.050	0.046	0.039	0.035	0.031	0.029
	R-13[2]	2x4	3	0.075	0.065	0.058	0.052	0.049	0.047	0.043	0.037	0.033	0.030	0.028
	R-15[2]	2x4	4	0.068	0.060	0.053	0.048	0.046	0.044	0.040	0.035	0.032	0.029	0.027
	R-19[2]	2x4	5	0.075	0.065	0.058	0.052	0.049	0.047	0.043	0.037	0.033	0.030	0.028
	R-19[2,3]	2x4	6	0.062	0.055	0.050	0.045	0.043	0.041	0.038	0.033	0.030	0.028	0.026
	R-11	2x6	7	0.076	0.066	0.058	0.052	0.050	0.047	0.043	0.037	0.033	0.030	0.028
	R-13	2x6	8	0.069	0.061	0.054	0.049	0.047	0.044	0.041	0.035	0.032	0.029	0.027
	R-15	2x6	9	0.062	0.055	0.050	0.045	0.043	0.041	0.038	0.033	0.030	0.028	0.026
	R-19[2]	2x6	10	0.056	0.050	0.046	0.042	0.040	0.039	0.036	0.031	0.029	0.026	0.024
	R-21[2]	2x6	11	0.052	0.047	0.043	0.040	0.038	0.037	0.034	0.030	0.028	0.025	0.024
	R-19[2]	2x8	12	0.051	0.046	0.042	0.039	0.038	0.036	0.034	0.030	0.027	0.025	0.023
	R-21	2x8	13	0.048	0.044	0.040	0.037	0.036	0.035	0.032	0.029	0.026	0.024	0.023
	R-22	2x10	14	0.044	0.040	0.037	0.035	0.034	0.033	0.031	0.027	0.025	0.023	0.022
	R-25	2x10	15	0.041	0.038	0.035	0.033	0.032	0.031	0.029	0.026	0.024	0.023	0.021
	R-30[4]	2x10	16	0.036	0.034	0.031	0.030	0.029	0.028	0.026	0.024	0.022	0.021	0.020
	R-30	2x12	17	0.035	0.033	0.031	0.029	0.028	0.027	0.026	0.023	0.022	0.021	0.019
	R-38[4]	2x12	18	0.029	0.027	0.026	0.025	0.024	0.024	0.022	0.021	0.019	0.018	0.017
	R-38[4]	2x14	19	0.028	0.027	0.025	0.024	0.023	0.023	0.022	0.020	0.019	0.018	0.017
24 in. OC	None	Any	25	0.237	0.161	0.122	0.098	0.089	0.082	0.070	0.055	0.047	0.041	0.037
	R-11[2]	2x4	26	0.081	0.070	0.061	0.055	0.052	0.049	0.045	0.038	0.034	0.031	0.028
	R-13[2]	2x4	27	0.072	0.063	0.056	0.050	0.048	0.046	0.042	0.036	0.032	0.030	0.027
	R-15[2]	2x4	28	0.065	0.058	0.052	0.047	0.045	0.043	0.039	0.034	0.031	0.028	0.026
	R-19[2]	2x4	29	0.072	0.063	0.056	0.050	0.048	0.046	0.042	0.036	0.032	0.030	0.027
	R-19[2,3]	2x4	30	0.059	0.053	0.048	0.044	0.042	0.040	0.037	0.032	0.029	0.027	0.025
	R-11	2x6	31	0.075	0.065	0.058	0.052	0.049	0.047	0.043	0.037	0.033	0.030	0.028
	R-13	2x6	32	0.067	0.059	0.053	0.048	0.046	0.044	0.040	0.035	0.031	0.029	0.026
	R-15[2]	2x6	33	0.060	0.054	0.048	0.044	0.042	0.041	0.038	0.033	0.030	0.027	0.025
	R-19[2]	2x6	34	0.054	0.049	0.044	0.041	0.039	0.038	0.035	0.031	0.028	0.026	0.024
	R-21[2]	2x6	35	0.049	0.045	0.041	0.038	0.036	0.035	0.033	0.029	0.027	0.025	0.023
	R-19[2]	2x8	36	0.049	0.045	0.041	0.038	0.036	0.035	0.033	0.029	0.027	0.025	0.023
	R-21	2x8	37	0.046	0.042	0.039	0.036	0.035	0.034	0.032	0.028	0.026	0.024	0.022
	R-22	2x10	38	0.043	0.040	0.037	0.034	0.033	0.032	0.030	0.027	0.025	0.023	0.022
	R-25	2x10	39	0.039	0.036	0.034	0.032	0.031	0.030	0.028	0.025	0.023	0.022	0.021
	R-30[4]	2x10	40	0.034	0.032	0.030	0.028	0.027	0.027	0.025	0.023	0.022	0.020	0.019
	R-30	2x12	41	0.033	0.031	0.029	0.028	0.027	0.026	0.025	0.023	0.021	0.020	0.019
	R-38 [4]	2x12	42	0.028	0.027	0.025	0.024	0.023	0.023	0.022	0.020	0.019	0.018	0.017
	R-38[4]	2x14	43	0.027	0.026	0.024	0.023	0.023	0.022	0.021	0.020	0.019	0.018	0.017

3.6.4 ACM Reference Manual

The Standard Design for roof alterations would have to be updated with the values in Tables 140.3-B or D. However, the text of the Nonresidential ACM Reference Manual Section 5.5.3 – Roof Construction would not change because the ACM Reference Manual references Tables 140.3-B and -D.

3.6.5 Compliance Manuals

Chapter 3.6.2.2 C of the Nonresidential Compliance Manual would need to be revised. The insulation requirements would need to be updated to meet the proposed requirements. The list of exceptions would need to be revised based on the changes to the standard. Language would also be added to say that existing below deck insulation would need to be inspected if the performance approach is used and the existing insulation is going to be used to meet the insulation requirements and that all insulation would need to be inspected before the project is completed. An example would be added to show how to meet the requirements with only above deck insulation and a mix of above and below deck insulation.

3.6.6 Compliance Documents

Compliance document NRCC-ENV-E would need to be updated, specifically Tables B and F. Table F contains the insulation requirements for roof alterations and would need to be updated with the changes to the exceptions and insulation requirements, with prompts for documentation when exceptions are selected. Table B prompts the user to fill out Table F if "Roof Assembly" is checked. The Statewide CASE Team is recommending updating this to also be triggered if only "Roofing Material" is checked to avoid user error. The Statewide CASE Team is concerned that, without this change, roof insulation requirements may not always be triggered. The Statewide CASE Team is also working with the IOU Compliance Improvement Team on a standardized, simpler form. The Statewide CASE Team is also proposing that roof alterations be included if a nonresidential registry is available and that a project status report be included so that building inspectors know when to perform field inspections.

4. High Performance Windows

4.1 Submeasure Description

4.1.1 Measure Overview

The structural, thermal, and optical characteristics of windows (also known as vertical fenestration) have great influence on a building's energy performance as well as occupant comfort. High performance windows are characterized by performing as a key component in the building envelope to maintain interior occupancy comfort. This submeasure applies to new nonresidential construction only. Requirements for high-rise residential would move to the forthcoming multifamily code, which would be separate for 2022. The requirements for hotel/motel guestrooms would no longer be separated from the overall hotel/motel requirements, which fall under nonresidential.

This submeasure focuses on the fixed window and curtain wall/storefront window categories described in Title 24, Part 6. Fixed window is fenestration that is not designed to be opened or closed. Curtain wall/storefront is defined as an external nonbearing wall intended to separate the exterior nonconditioned and interior conditioned spaces. The Statewide CASE Team recommends maintaining current Title 24, Part 6 code structure and varying prescriptive requirements by window category.

The Statewide CASE Team considered updates to three requirements for windows to optimize performance across the 16 California climate zones: U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT). U-factor measures the rate of heat transfer, specifically conductive and convective, with lower U-factors indicating better window insulation. SHGC is the fraction of solar radiation transmitted directly through the window, with lower SHGC indicating lower transmittance. VT is the fraction of visible light that is transmitted through the window. Both SHGC and VT reflect percentage values, while U-factor is measured in Btu/(hr/ft^2/°F). Current code specifies a single value for U-factor, SHGC, and VT across all climate zones. For fixed windows this is 0.36, 0.25, 0.42 respectively. For curtain wall/storefront windows this is 0.41, 0.26, and 0.46 respectively.

After a lengthy process of soliciting stakeholder feedback, the proposed update would reflect more stringent U-factor and SHGC values while VT would remain the same and include values that vary across climate zones to account for climate-specific needs. Fixed requirements would be updated to a U-factor and maximum RSHGC of 0.34 and 0.22 respectively in Climate Zones 2, 5-9, and 11-15. Curtain wall/storefront requirements would be updated to a U-factor and maximum RSHGC of 0.38 and 0.25 respectively in Climate Zones 1, 7, and 16. Exceptions for site-built fenestration would be removed.

The submeasure also revises the relative solar heat gain coefficient (RSHGC) formula. This formula currently calculates the RSHGC for a given combination of fenestration SHGC, orientation and overhang, effectively lowering the net solar heat gain of fenestration through an overhang credit. The revision updates the formula to adjust TDV values and add horizontal slats to the credit. See Table 92 for a summary of the proposed scope.

This proposal also includes recommendations to revise definitions for glazed doors, as recommended by the Compliance Improvement Team and stakeholders to better explain the applicability of code requirements to this product category.

Prior to publishing the Draft CASE Report, the Statewide CASE Team was approached with a proposal to regulate maximum window U-factor along the performance path of compliance. Currently there are maximum thermal performance values for wall insulation, but none for fenestration. This would have updated Section 120.7 of the code with maximum thermal transmittance values (U-factor) for fenestration in order to prevent drastically lower performing fenestration, as compared to the prescriptive requirements, from being installed due to the allowed trade-off with higher performing HVAC and lighting in the performance compliance path. The Statewide CASE Team is not pursuing these updates at this time and recommends that the California Energy Commission consider the stakeholder feedback outlined in Appendix N: for both the upcoming Title 24, Part 11 (CALGreen) language as well as the next code change cycle.

Table 92: Scope of Code Change Proposal – High Performance Windows

Update	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)
U-factor, SHGC	Prescriptive	110.6, 130.1, 140.3	N/A	Yes	NRCI-ENV-01-E
RSHGC Calculation	Prescriptive	100.1, 130.1, 140.3	NA7.4.5	N/A	N/A

4.1.2 Measure History

Title 24, Part 6 already sets certification requirements for U-factors, SHGCs, VT, and air leakage for fenestration products and exterior doors in Section 110.6 and Section 140.3 of Title 24, Part 6. Fenestration requirements in Title 24, Part 6 were first established in 2001 (California Energy Commission 2001) and most recently updated in 2013 (California Energy Commission 2012) due to significant changes in window pricing and technology. Since then there have been further developments in both technology and pricing allowing for higher-performing cost-effective windows, as reflected in the ASHRAE 90.1-2019 Standard and 2021 IECC code, to be published in fall 2020.

The Statewide CASE Team considered updates to three window characteristics along the prescriptive path.

- U-factor indicates the rate of heat loss in units of Btu/(hr/ft²/°F). Lower U-factors indicate higher resistance to heat flow and therefore better insulated windows.
- SHGC is the fraction of solar radiation that comes in through a fenestration element. This energy could be directly transmitted or absorbed then released to the building interior. A SHGC rating of zero equals no radiative heat passing through the window, while one indicates maximum radiative heat passing through the window.
- VT indicates the fraction of visible light that comes through the window. VT is not a direct indicator of energy efficiency when daylighting is not present, but drastically affects natural light levels and is an important factor in occupancy health, comfort, and daylighting energy savings.

Improving overall window thermal performance increases occupancy comfort and reduces the energy needed to heat and cool the building. Maximum RSHGC is a prescriptive requirement that is calculated to give credits for various window factors when the window's SHGC might not meet the code requirements.

Currently, RSHGC gives solar heat gain credits beyond a window's SHGC when overhangs are included in the design. This gives designers flexibility to choose fenestration with either SHGC equal to the maximum RSHGC, or with a high SHGC but a sufficient overhang. In 2013, an update to the RSHGC credit was proposed to address issues with the formula and to update the credit with the latest TDV values.[20] However, this proposal was not pursued further in 2013 because of the focus on fenestration VT.

In 2019, a power adjustment factor (PAF) and a compliance option in the performance path were introduced for horizontal slats. When horizontal slats are installed on the exterior, they reduce the solar heat gain through fenestration overhangs. Adding exterior horizontal slats to the RSHGC credit would allow designers added flexibility.

[20] The equation gives equal credit to east and west orientations and although large overhangs should get more credit, as overhang projections extended beyond a certain value, the credit decreased instead of increasing.

4.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 4.6 of this report for detailed proposed revisions to code language.

4.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 4.6.1 of this report for marked-up code language.

Section 100.1 - Definitions and Rules of Construction

- **Azimuth:** The purpose of this change is to define azimuth, as the updated RSHGC calculation relies on this value.
- **Overhang projection and overhang rise:** The purpose of this change is to provide consistency with light shelves and horizontal slats, the definitions for overhang projection and overhang rise would be deleted. The projection ratio for overhangs, which currently uses these terms, would instead become the projection factor and calculated using Equation 140.3-D, making it consistent with light shelves and horizontal slats.
- **Curtain wall/storefont, glazed door, and site-built:** The purpose of this change is to revise definitions for curtain wall/storefront, glazed door, and site-built as recommended by the Compliance Improvement Team to better explain applicability of code language to glazed doors and therefore increase ease of compliance.

Section 110.6 - MANDATORY REQUIREMENTS FOR FENESTRATION PRODUCTS AND EXTERIOR DOORS

- **(a) Certification of Fenestration Products and Exterior Doors other than Field-fabricated:** The purpose of this change is to revise exceptions for U-factor, SHGC, and VT so vertical site-built fenestration and projects under 200 square feet are no longer exempt. Doing so would simplify the code and therefore increase ease of compliance.

— **Section 130.1 - MANDATORY INDOOR LIGHTING CONTROLS**

- **EXCEPTION 2 to Section 130.1.d:** The purpose of this change is to increase consistency within the code. Instead of calculating the ratio of overhang projection to overhang rise, the section would refer to Equation 140.3-D. This does not change the calculation but makes it consistent with the references for calculating projection factor for light shelves and horizontal slats.

Section 140.3 - PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

The Statewide CASE Team recommends updates to the prescriptive criteria tables, as well as splitting values by climate zone groupings. The Statewide CASE Team also recommends splitting criteria for high-rise residential buildings and hotel/motel requirements into a separate code section, as further outlined in Appendix M:.

- **Section 140.3(a)5Cii:** The purpose of this change is to add exterior horizontal slats for calculation in Equation 140.3-A.
- **Equation 140.3-A Relative Solar Heat Gain Coefficient, RSHGC:** The purpose of this change is to revise the formula to increase credit for overhang projections.
- **Equation 140.3-D Projection and Distance Factor Calculation:** The purpose of this change is to add overhangs so that credit can be given.
- **Table 140.3-B:** The purpose of this change is to update table format to accommodate unique fenestration values for each climate zone. Revise U-factor and SHGC for each climate zone for fixed windows.
- **Table 140.3-C:** The purpose of this change is to remove the table and simplify the code. The Statewide CASE Team is proposing to split out the multifamily code language into its own section, as described in the multifamily restructuring CASE Report. The hotel/motel guest room requirements would be the same as the rest of the nonresidential requirements included in Table 140.3-B.

4.1.3.2 Summary of Changes to the Reference Appendices

- **NA7.4.5 Interior and Exterior Horizontal Slats for PAF:** The purpose of this change is to rename to "NA7.4.5 Interior and Exterior Horizontal Slats" in order to better reflect the language. The procedure for verification would not change.

4.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

This proposal would modify sections of the Nonresidential ACM Reference Manual as shown below. See Section 4.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

- **Section 3.1.10.2 Building Envelope Loads:** The purpose of this change is to add the effect of exterior horizontal slats.
- **Section 5.5.7 Fenestration:** The purpose of this change is to add horizontal slats to the "External Shading Devices" table.

4.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The window performance factors and RSHGC calculation are already included in the Nonresidential Compliance Manual. The following sections would be updated to reflect revisions to the code requirements:

- **Section 3.3.3.1.C SHGC and Overhang Factor:** The purpose of this change is to revise the formula and add exterior horizontal slats.
- **Section 3.5.1.4 Overhangs and Vertical Shading Fins:** The purpose of this change is to add exterior horizontal slats to the list of features that compliance software must be able to model.
- **Table 3-16: Window Prescriptive Requirements U-factors:** The purpose of this change is to update the U-factor values.
- **Section 11.3.2.1.5 Fenestrations in Walls and Shading:** The purpose of this change is to add exterior horizontal slats to item 5. They have the same basic inputs as overhangs and fins, except there would be an optional reflectance input that would default to a conservative value if there is no user input.

See Section 4.6.5 of this report for the detailed proposed revisions to the text of the Nonresidential Compliance Manual.

4.1.3.5 Summary of Changes to Compliance Documents

NRCI-ENV-01-E forms would need to be updated to include the proposed values for wall and roof prescriptive U-factor.

4.1.4 Regulatory Context

4.1.4.1 Existing Requirements in Title 24, Part 6

California has already set standards for window U-factor, SHGC, and VT. The tables in the code specify U-factor limits based on frame, product, and glazing type. This set of requirements was created to simplify the code. A single SHGC and VT is listed for all fenestration ratios up to the maximum fenestration ratio; a single U-factor, SHGC, and VT for all climate zones; and a single SHGC and VT for all orientations. The existing language also specifies a calculated RSHGC to account for contributions from overhangs.

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

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

4.1.4.3 Relationship to Local, State, or Federal Laws

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

4.1.4.4 Relationship to Industry Standards

The following model codes are relevant to this submeasure:

- ASHRAE 90.1-2019
- IECC 2021

- ASHRAE 189.1—2017: Design of High Performance Green Buildings / 2018 International Green Construction Code (IgCC)

IECC and ASHRAE have window characteristics broken out by climate zone, while Title 24, Part 6 does not. For some climate zones, they also have more stringent U-factors. The ASHRAE Climate Zone 6 requirements approximately reflect the 2019 Title 24, Part 6 requirements with a fixed window U-factor and SHGC of 0.34 and 0.38 respectively for California Climate Zone 6 and 0.42 and 0.25 respectively for California Climate Zone 3. Unlike Title 24, Part 6, ASHRAE does not have a category for curtain wall/storefront windows.

Window performance requirements are included in most state energy codes. The majority of states meet or exceed some version of ASHRAE 90.1/IECC standards for fenestration. As of June 30, 2020, the six states with the most stringent commercial requirements follow 2018 IECC and ASHRAE 90.1-2016 (U.S. DOE 2020).

4.1.5 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. 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 during each phase of the project are described below:

- **Design Phase:** Building designers must take prescriptive code updates for window and exterior shading credits into account in their designs. When a project intends to apply for both the RSHGC credit and the PAF, coordination between the lighting team and the envelope team would be needed.
- **Permit Application Phase:** Plans examiners must be aware of the new prescriptive windows code. They would review the compliance documents to verify that fenestration requirements are met.
- **Construction Phase:** Construction teams or their contractors install windows and exterior shading per energy documentations, plans, and/or specifications. Installers take responsibility for meeting fenestration requirements by completing compliance documentation. Multiple contractors might work together to verify compliance of site-built fenestration.
- **Inspection Phase:** The building inspector verifies that the installed fenestration characteristics meet what is listed in the energy documentation, plans, and/or specifications. Nonresidential Certificate of Installation documents and

Nonresidential Certificate of Acceptance documents are verified for nonresidential buildings.

There would be no significant changes to the compliance process for this code proposal. Market actors would work with the same compliance documents and would verify different numbers for the same U-factor, SHGC, and VT ratings. Compliance would become somewhat more complex with the breakout of window performance factors by climate zone, with other envelope requirements, such as opaque envelope assembly factors, serving as the precedent.

The field verification and acceptance testing requirements include Label Certificate Verification for Site-Built Fenestration. The fenestration acceptance test must be identified as required for site-built fenestration on the NRCC-ENV-01 document, while each factory-assembled fenestration product must have a clearly visible (temporary) label attached to it through inspection by the enforcement agency. The preferred methods for determining fenestration U-factor are those in National Fenestration Rating Council (NFRC) 100 for both manufactured and site-built windows. Designers are encouraged to obtain ratings through NFRC test procedures when available. NFRC 200 is the preferred test method for both SHGC and VT.

For the exterior shading credits, the new RSHGC formula would affect the design and permit phase verifications. In the construction and inspection phase, the procedure formerly used only for the prescriptive PAFs for horizontal slats would now also be used for the RSHGC credit for exterior horizontal slats.

Stakeholders noted that the level of compliance with the nonresidential NFRC certification requirements is, in practice, low. The updates to Title 24, Part 6 would remove the exception of using NA6 equations on vertical site-built glazing to help reduce noncompliance issues. The Statewide CASE Team has worked extensively with the Compliance Improvement Team to provide this feedback and inform their process to increase the rate of compliance with NFRC certification. NFRC is working on a more commercial approach to rating curtain walls, which will be considered for future code change cycles (Anderson and Urich 2020).

4.2 Market Analysis

The Statewide CASE Team performed a market analysis to identify current technology availability, current product availability, and market trends. This included evaluating potential impact on the market in general as well as on individual market actors and gathering information about the incremental cost of compliance. Estimates of market size and measure applicability were identified through research and outreach to stakeholders including utility staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting targeted outreach, the Statewide CASE

Team discussed the current market structure and potential barriers during public stakeholder meetings held on October 24, 2019 and March 10, 2020 (California Statewide CASE Team 2019).

The Statewide CASE Team's outreach strategy involved contacting industry stakeholders to understand current and emerging technology, study market forces and barriers, clarify industry issues, and obtain feedback from regulatory officials, fenestration technology experts, researchers, window manufacturers, fenestration designers, curtain wall and storefront manufacturers, and glazing manufacturers.

4.2.1 Market Structure

According to stakeholder conversations, the market for energy-efficient windows is expected to progress quickly along with demand for energy-efficient space heating, cooling, and lighting. Similar progression has been shown in Canada, driven by market change (Corbeil, Georges and Watson 2020). The capability of windows to increase comfort and reduce the requirement for perimeter heating and cooling is an additional driver of market growth. Heating and cooling are often applied at the exterior windows of a building to reduce the temperature differential between interior window surface and room air temperatures, as this differential greatly contributes to heat loss during the winter. Reducing the temperature differential can result in more comfort due to less radiant loss and reduced convection at the glass surface (Straube 2011). Greater comfort at an overall lower cost could be realized if higher performing windows are paired with a heating and cooling system reduced in size or distribution. Initial savings would be realized in construction and design costs and ongoing savings seen in operational costs. All of these factors would help offset additional costs from the proposed high performance windows submeasure.

The current nonresidential fenestration market comprises a wide range of market actors, including project designers and architects, component manufacturers (glazing, frame, spacers, etc.), window system manufacturers and designers, installers/contractors, plans examiners, commissioning representatives, and building inspectors. Designers plan a fenestration system for the building that would meet the project's goals and constraints, which could include budget, code requirements, performance, and aesthetics. Designers then collaborate with installers, manufacturers, or fabricators to further refine the design for construction. Designers may obtain pricing from multiple fenestration sources during this phase. When the design has been refined and a manufacturer selected, compliance documentation is completed for review by plans examiners. The compliance process is further described in Appendix E:.

Construction teams and installers are responsible for assembling and installing the fenestration systems per project construction documents and specifications. Simple projects may have the fenestration installed by the general contractor while more complex buildings may have a separate glazing installer. If a commissioning agent is involved, they are responsible for testing and verifying the installation per the requirements specified. After the fenestration has been installed, the building inspector verifies that the installed assembly meets all code requirements, including performance factors and certification requirements.

The horizontal slat market includes various manufacturers who typically supply an entire horizontal slat assembly directly to the contractor. The manufacturer typically produces the horizontal slats to the specifications given by the architect.

If the current PAF or the compliance option in the performance approach for horizontal slats is used in the design, plans examiners review construction documents to verify compliance with those requirements. Upon installation, compliance procedures are performed, and documentation completed to verify compliance with the PAF or compliance option requirements. Inspectors then verify the correct completion of compliance documentation.

The new requirements are intended to encourage new, cost-effective options in the market and would therefore have greatest impact on designers, fenestration manufacturers, and installers.

4.2.2 Technical Feasibility, Market Availability, and Current Practices

High performance windows are currently considered best practice for new construction and major renovations, and they are becoming standard practice due to recent advancements in glazing and frame technology and demand for energy-efficient building components. The Statewide CASE Team held conversations with stakeholders to first understand current practices and barriers and then identify solutions.

The paybacks for high performance fenestration, including insulated glass units (IGUs), vary with climate. The Statewide CASE Team investigated the challenges of applying a single methodology to develop prescriptive window performance requirements for the entire range of California climate zones while also achieving cost effective designs. Stakeholder conversations revealed concern over tightening existing requirements in milder climates. As a result, the Statewide CASE Team evaluated and proposed requirements that would vary by climate zone.

4.2.2.1 Technical Feasibility

No new materials or processes would be needed to comply with the proposed standards. After speaking with glazing and framing manufacturers, the Statewide CASE Team found that many technologies are currently available that would allow designers to meet the proposed requirements. These include argon and krypton gas fill, advanced low-emissivity (low-e) coatings, thermally broken frames, warm edge spacers, and triple-pane glazing. The proposed submeasure would not require a change in current design process, as per conversations with compliance experts, designers, and component manufacturers. The NFRC Component Modeling Approach Software Tool (CMAST) contains fixed window products with U-factors as low as 0.225 and SHGC as low as 0.128, and curtain wall/storefront window products with U-factors as low as 0.294 and SHGC as low as 0.222 (NFRC 2020). These values are well below the proposed Title 24, Part 6 levels, and the Statewide CASE Team verified the prevalence of both fixed and curtain wall/storefront window products that do meet the proposed requirements in CMAST.

Achieving the proposed overall U-factors may require several of these strategies to be employed together. Conversations with stakeholders indicated that while a curtain wall system with argon gas fill and a standard frame may have a U-factor of 0.41 Btu/(h/°F/ft^2), adding a warm edge spacer would decrease the U-factor to 0.39 Btu/(h/°F/ft^2). Additionally, replacing the framing system with a thermally broken one and adding a more advanced low-e coating would decrease the whole-window U-factor to U-0.36 Btu/(h/°F/ft^2). Based on the final analysis, including a fourth-surface low-e coating on the baseline technology would be sufficient to meet the updated requirements, but the proposal would not limit manufacturers to a single technology.

4.2.2.2 Current Practices

Double-pane IGUs with Low-e Coatings

By using low-e coatings and argon gas fill, the double-pane IGU market seems to have reached the technology threshold for increased thermal performance without sacrificing VT and condensation resistance. The Statewide CASE Team received feedback from manufacturers and designers that lowering the center of glass U-factor more than 0.02 – 0.03 Btu/(h/°F/ft^2) below current commonly specified glazing units would require adding warm edge spacers or even changing to triple-pane glazing.

A more recent advancement is the addition of a low-e coating to the fourth surface of a double-pane IGU. This technique places the additional coating on the interior surface of the window, facing the occupied space. These coatings can help achieve U-factors comparable to triple-glazed windows without the added cost, weight, and dimensional changes that are characteristic of triple-glazed fenestration. However, the addition of a low-e coating on the fourth and interior surface of a double-pane glazing unit has been shown to significantly lower the condensation resistance and VT in most windows, and therefore not all industry stakeholders look upon the technique favorably. In addition, some market actors, including industry associations, claim that hard-coat interior, exposed coating could be less durable than traditional window interiors.

The Statewide CASE Team is aware that the proposed submeasure may drive some projects to specify this type of coating as an inexpensive upgrade to meet the prescriptive requirements. If fourth surface low-e coatings are utilized to meet a low U-factor requirement, it would be critical to consider additional technologies, such as warm edge spacers, to reduce the risk of condensation on the internal window surface. The NFRC approved a new condensation resistance measurement and rating referred to as the Condensation Index in 2020. The new rating is undergoing ANSI balloting and NFRC estimates that the Condensation Index would not be implemented until 2021 at the earliest. The Statewide CASE Team recommends adding this requirement after NFRC's work is complete, which would likely not be prior to the project approval date for the 2022 updates to Title 24, Part 6.

Triple-pane IGUs

Significant advancements are being made in the field of thin-glass triple-pane glazing, vacuum glazing, and fiber reinforced plastic panels (Curcija, et al. 2019). Thin-glass triple-pane IGUs ("skinny triple") allow for lighter weight, thinner, higher performing windows which can work with standard double-pane framing components. While thin-glass triple-pane windows are now available for the residential market, commercial manufacturing processes are still in development. This is expected to evolve in the coming years, but most market actors view this technology as not viable for the wider commercial market due to lack of market penetration (Hart, Selkowitz and Curcija 2018). Increasing market demand for products used in skinny triple windows, such as thin glass and krypton gas, is leading to reduced product costs (Chao 2018).

Other markets have evolved to include triple-pane IGUs as a standard, including several cities in Canada, such as Vancouver. Manufacturers initially had more difficulty keeping up with the increased demand due to evolving standards, but after only a few years were able to meet demand in a manner that decreased unit costs (Georges, Watson and Corbeil 2020).

Suspended Film

With comparable if not superior insulative potential to triple-pane IGUs, suspended film is much more expensive than triple-pane IGUs and the technology has a lower life expectancy (Energy360 Solutions 2020). Suspended film provides higher window performance without the design limitations of triple-pane systems, namely weight (Alpen HPP n.d.). The technology creates multiple-chamber glass packages with the chambers increasing window insulative value. The films are internally mounted and typically combine both film and glass-based coatings to reflect heat and UV radiation while maximizing VT.

Exterior Horizontal Slats

Interviews and surveys of manufacturers and architects consistently demonstrated that exterior horizontal slats have also grown in popularity. Exterior horizontal slats are available from many manufacturers, such as Airolite, Alcoa, EFCO, Arcadia, ASCA, Construction Specialties, Industrial Louvers, LouvreTec, and Unicel. Given this, there are no foreseen impediments to supplying these products.

4.2.2.3 Persistence of Savings

There should be no change in the life span of the proposed submeasure over the current code and no change in maintenance of the fenestration—if quality, field-verified, and rated products are specified. The potential exception to this would be the use of interior low-e coating and corresponding reduction in durability, but this technology is not necessary to meet the proposed prescriptive fenestration values. The persistence of the energy savings should last through the installed life of the fenestration and submeasure analysis period. There would be no change in field testing and inspections with the proposed submeasure.

Interviews and surveys demonstrated that exterior horizontal slats generally remain on the building post-occupancy; therefore, savings persist through the life of the building.

4.2.2.4 Barriers and Solutions

The main concern that the Statewide CASE Team heard during stakeholder conversations regarded increased initial costs.

In many cases, this submeasure would involve adding higher-performing components (spacers, gas fill, thermal frames, etc.), which would add cost to the total fenestration assembly. The proposed submeasure accommodates a variety of different, currently available components. Mixing and matching these components would provide multiple ways to meet the proposed submeasure in a cost-effective manner. For example, a non-thermally broken window wall frame with triple-pane glazing could have a similar U-factor to a thermally broken frame with double-pane glazing with argon. Numerous case studies describe how high performance windows have been cost-effectively used in a variety of nonresidential project types, configurations, and climate zones (Dean 2014). The proposed submeasure continues to encourage other existing energy-saving window strategies, such as exterior shading elements, integral shading strategies, room-side low-e surface coatings, and triple-pane windows. Table 93 shows a further breakdown of barriers and solutions.

Table 93: Technical Barriers, Market Barriers, and Solutions

Potential Barrier	Solutions
SHGC and VT Ratio • SHGC is highly tunable; however, changes to SHGC directly impact VT based on climate zone, façade orientation, and building types. Stakeholders expressed concern that reducing VT has been shown to have a negative effect on daylighting and related energy, as well as human health and productivity. (Edwards and Torcellini 2002)	• The Statewide CASE Team recommends that VT not be lowered, as this would negatively impact cost effectiveness of secondary zone daylighting controls.
Cost • Triple-pane windows are more expensive. The current state of triple-pane suggests that there has not been a strong market driver, including codes, for demand despite the existing technology. Adoption has been slow. (Curcija, et al. 2019) • Stakeholders also expressed concern that the additional costs are not justified by the energy payback in most of California's warm and dry climate zones.	• Other markets have evolved to include triple-pane IGUs as a standard. After only a few years, manufacturers were able to meet demand in a manner that decreased unit costs (Georges, Watson and Corbeil 2020). • The Statewide CASE Team recommends different values by climate zone rather than a single requirement across all climate zones. Initial costs could involve a tradeoff by reducing the size of needed heating/cooling systems due to lower peak energy loads.
Weight • Design of more efficient windows is limited by weight.	• Rise of skinny triple and suspended film IGUs would increase feasibility and decrease added transportation and installation costs associated with standard triple-glazed windows.
Durability - Condensation • The addition of a low-e coating on the fourth and interior surface of a double-pane glazing unit has been shown to lower the condensation resistance in most windows. • Stakeholders have raised the importance of evaluating fenestration technology impact on condensation resistance.	• If fourth surface low-e coatings are utilized to meet a low U-factor requirement, it would be critical to consider additional technologies, such as warm edge spacers, to reduce the risk of condensation on the internal window surface. Other products exist that can also meet the proposed requirements. • Triple-pane glazing would allow performance beyond double-pane glazing with low-e coatings and minimize condensation risk, addressing durability concerns and increasing product value. The NFRC is currently working on a new condensation resistance measurement and rating. The Statewide CASE Team recommends adding this requirement after NFRC's work is complete in 2021. Since this is not likely to happen prior to May 2021, that would necessitate consideration in the following code cycle.

Potential Barrier	Solutions
Climate Zone Variation • Title 24, Part 6 currently has one set of performance ratings per product across all climate zones while other codes, such as ASHRAE and IECC, look at a breakdown of thermal factors across different climate zones.	• The Statewide CASE Team modeled and evaluated multiple window performance scenarios in all California climate zones. • The proposed changes to Title 24, Part 6 vary across all 16 California climate zones.
Market Availability • There is a limit on raw materials, including argon, most commonly used for gas fill to decrease the center of glass U-factor, as well as krypton and xenon. Additional limits for krypton and xenon exist.	• Krypton availability has increased, and cost has decreased due to recent transition of the lighting market to LEDs. Krypton has improved thermal performance over argon. Other technologies, such as glazing or additional panes, are available to decrease overall window U-factor.
Market Readiness • Larger projects tend to follow the performance path for code compliance, which allows for tradeoffs for lower performing glazing. • Smaller projects designed by smaller firms that follow the prescriptive compliance path may be penalized if the proposal is not reasonable or cost effective.	• The Statewide CASE Team has worked diligently with stakeholders to develop a cost-effective proposal that is technically feasible and market ready. Due to positive stakeholder feedback, including from various manufacturers and industry organizations, the Statewide CASE Team believes that meeting these prescriptive requirements would not be an issue.
Code Language Clarification • Curtain wall/storefront fenestration uses separate U-factors for glazing and frame.	• Current requirements are based on curtain wall/storefront with thermally broken frames, and all manufacturers who spoke with the Statewide CASE Team have thermally broken frame options available. • Appropriate glass-to-frame ratios make it easier to meet prescriptive values depending on system type.
Existing Code Stringency – Glass Entrance Doors • The Statewide CASE Team heard from several manufacturers of glass entrance doors that the current prescriptive requirement of U-0.45 already requires best in class technology and triple glazing due to high frame to glass ratio and received limited feedback that requirements should be relaxed.	• The Statewide CASE Team is not looking to update stringency for glass entrance doors. The Statewide CASE Team did work with the Compliance Improvement Team to provide updated definitions for glazed doors.

4.2.3 Market Impacts and Economic Assessments

4.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training 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 94).[21] In 2018, total payroll was $80 billion. Of these, 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 94: 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 high performance windows 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 effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 95 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report.

Builders would need to factor in higher up-front cost of window pricing to their bids. They may have to consider longer lead times when ordering if products have lower market availability. Installation process and cost would be the same as current

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

requirements. If triple-pane fenestration is selected to meet the requirements, the additional weight of the units would impact installation and transportation.

The installation of exterior horizontal slats is a relatively simple procedure of mounting pre-manufactured frames onto the building envelope. Additional training would not be necessary given this simplicity.

The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 4.2.4 Economic Impacts.

Table 95: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Commercial Building Construction	4,508	75,558	$6.9
Nonresidential Framing Contractors	148	3,991	$0.2
Nonresidential glass and glazing contractors	280	5,244	$0.4
Nonresidential Siding Contractors	25	396	$0.1
Other Nonresidential exterior contractors	277	2,879	$0.2

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

4.2.3.2 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 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 96 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for high performance windows to affect firms that focus on nonresidential construction.

There is no North American Industry Classification System (NAICS)[22] code specific for 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.[23] 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 96 provides an upper bound indication of the size of this sector in California.

The reduction in RSHGC would likely be an incentive for exterior horizontal slats to be included in more designs. Since exterior horizontal slats are a well-established technology with a long history, designers and energy consultants are already familiar with them.

Table 96: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
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.

[22] 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.

[23] 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.

4.2.3.3 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. 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.

The proposed code changes would apply to healthcare facilities. For exterior shading, there may be health and safety benefits from reduced glare through fenestration.

4.2.3.4 Impact on Building Owners and Occupants

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 warehouses) (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, more than 7.5 billion square feet of commercial floor space in California accounts for 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 4.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely. Occupants are expected to experience brighter spaces and/or less direct sunlight, which is expected to have a positive effect on mood and productivity (National Resources Canada 2019).

No maintenance is necessary for exterior horizontal slats. The technologies have no moving parts or internal resources that require replenishing, but regular cleaning would increase their effectiveness.

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

Retailers, manufacturers, and distributors who offer high performance components may see business due to proposed code modifications. Some retailers and manufacturers may need to increase production or availability of warm edge spacers, advanced thermally broken frames, low-e coatings, and gas fill.

Manufacturers and distributors of exterior horizontal slats would likely see a gradual increase in sales as this approach gains in popularity with designers.

4.2.3.6 Impact on Building Inspectors

Table 14 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 97: 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. government zoning boards and commissions are included in this industry.

4.2.3.7 Impact on Statewide Employment

As addressed in the preceding sections, the Statewide CASE Team does not anticipate significant employment or financial impacts to any specific sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In the following Section 4.2.4 on economic impacts, the Statewide CASE Team estimated the proposed change in high performance windows would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in high performance windows would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

4.2.4 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 develop estimates of the economic impacts associated with each of the proposed code changes.[24] While this is the first code cycle in which the Statewide CASE Team uses IMPLAN to develop estimates of economic impacts, 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 straightforward representation of the California economy and the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable. However, 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 aspects 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, along with architects, energy consultants, and building inspectors. 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.

[24] 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 used economic impact model in most common use due to its ease of use and extensive detailed information on output, employment, and wage information.

Table 98: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct Effects (Additional spending by Commercial Builders)	86.3	$5.71	$7.56	$12.51
Indirect Effect (Additional spending by firms supporting Commercial Builders)	18.8	$1.37	$2.18	$4.20
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	37.5	$2.11	$3.78	$6.18
Total Economic Impacts	**142.6**	**$9.19**	**$13.52**	**$22.89**

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

4.2.4.1 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 this section would lead to modest changes in employment of existing jobs.

4.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 4.2.4.1, 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 fenestration practices which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

4.2.4.3 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 located inside or outside of the state.[25] Therefore, the Statewide CASE Team does not anticipate that these measures

[25] 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.

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.

4.2.4.4 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 NPDI).[26] As Table 99 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 99: 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	$1,740.4	35%
2016	$456.0	$1,739.9	26%
2017	$509.3	$1,813.6	28%
2018	$618.3	$1,843.7	34%
2019	$580.9	$1,827.0	32%
		5-Year Average	**31%**

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

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed submeasure 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 98 through Table 99 above by 31 percent for an estimated increase of $1,359,042.

[26] 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.

4.2.4.5 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.

4.2.4.6 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. High performance windows may impact new construction of state buildings. The proposed code changes have been found to be cost effective. As an optional prescriptive compliance path, the market impact for exterior horizontal slats is not expected to significantly affect the State General Fund, State Special Funds, or local governments.

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 4.1.3 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.

4.2.4.7 Impacts on Specific Persons

While the objective of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes the potential that a proposed code change may result in unintended consequences. There are no foreseen impacts on specific persons. The technologies to meet the proposed code changes are neither proprietary nor sole-sourced so would not provide unfair advantage to individuals.

4.3 Energy Savings

4.3.1 Key Assumptions for Energy Savings Analysis

The final 2022 Time Dependent Valuation (TDV) factors were used for the analyses presented in this report (Energy + Environmental Economics 2020).

The Statewide CASE Team performed one set of analysis for the RSHGC calculation update, and another for window performance factors. The Statewide CASE Team used EnergyPlus V9.0.1 and Excel to conduct the energy savings for all code change proposals, and additionally used OpenStudio, Ruby, and Python for RSHGC evaluation. Energy models are sourced from CBECC-Com prototypical building models. These models are modified to include the proposed changes to the energy standards. All simulated results used the weather files the Energy Commission provided, which are based on historic weather.

The approaches for the RSHGC calculation update and the U-factor and SHGC update are presented separately. Three scenarios were modeled for the fixed window product category, and three scenarios were modeled for the curtain wall/storefront window category. Table 100 shows all scenarios modeled for both categories, with the ones represented in the final proposed code language and savings results highlighted in green. After these scenarios were modeled, a cost-effectiveness analysis was conducted to determine the most stringent requirements that still maintain cost effectiveness at a B/C ratio of 1.0 or greater.

Fixed windows: All climate zones were evaluated through energy modeling in CBECC-Com and are included in the cost-effective analysis. For building prototypes expected to contain curtain wall / storefront products, it was assumed that 80 percent of the building fenestration was fixed and 20 percent curtain wall / storefront. The climate zones found to be cost effective and therefore included in the proposed code changes were Climate Zones 2, 5-9, and 11-16 for Fixed Modeling Scenario 1.

Curtain wall/storefront: All climate zones were included in the curtain wall/storefront modeling evaluation. The following building prototypes are not included in the statewide results due to lack of applicability of curtain wall/storefront fenestration: OfficeSmall, OfficeMedium, OfficeMediumLab, OfficeLarge, Refrigerated warehouse, SchoolPrimary, SchoolSecondary, PublicAssembly, and Hospital. The climate zones found to be cost effective and therefore included in the proposed code changes were 1, 7, and 16.

Table 100: U-factor and SHGC Modeling Scenarios

	Fixed			Curtain wall/Storefront		
	U-Factor	SHGC	VT	U-Factor	SHGC	VT
2019 Title 24, Part 6	0.36	0.25	0.42	0.41	0.26	0.46
Modeling Scenario 1	0.34	0.22	0.42	0.38	0.26	0.46
Modeling Scenario 2	0.31	0.20	0.42	0.35	0.26	0.46
Modeling Scenario 3	0.33	0.23	0.42	0.38	0.25	0.46

4.3.2 Energy Savings Methodology

4.3.2.1 Energy Savings Methodology per Prototypical Building

Energy Savings Methodology for U-factor and SHGC Updates

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 101. The Grocery building models is sourced from the CPUC DEER because there are currently no prototype models developed in CBECC-Com for these building types. The Hospital building model is sourced from the DOE's Commercial Prototype Buildings ASHRAE 90.1-2016. The baseline model is generated for these building types by modifying the DEER models with the 2019 Title 24, Part 6 mandatory and prescriptive envelope requirements.

Table 101: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Grocery	1	50,002	6-zone grocery store DEER prototype model provided by SCE
Hospital	3	249,980	3-story hospital DEER prototype model provided by SCE
OfficeLarge	12	498,589	12-story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-40%
OfficeMedium	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeMediumLab	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeSmall	1	5,502	1-story, 5 zone office building with pitched roof and unconditioned attic. WWR-24%
RestaurantFastFood	1	2,501	Fast food restaurant with a small kitchen and dining areas. WWR-14%. Pitched roof with an unconditioned attic
RetailLarge	1	240,000	Big-box type retail building with WWR-12% and SRR-0.82%
RetailStandAlone	1	24,563	Similar to a Target or Walgreens. WWR-7% on the front façade, none on other sides. SRR-2.1%
RetailStripMall	1	9,375	Strip mall building. WWR-10%
SchoolPrimary	1	24,413	Elementary school. WWR-36%
SchoolSecondary	2	210,866	High school. WWR-35% and SRR-1.4%

CBECC-Com generates two models based on user inputs: the Standard Design and the Proposed Design. The Proposed Design represents the proposed building design described by the user inputs. The Standard Design represents a building with the same geometry as the Proposed Design, but with constructions and equipment parameters that are minimally compliant with the 2019 Title 24, Part 6 code requirements. The Standard Design is described in the 2019 Nonresidential ACM Reference Manual. To develop savings estimates for the proposed code changes, the Statewide CASE Team generated a Standard Design using the CBECC-Com prototype models and created a Proposed Design by modifying the relevant inputs in the Standard Design to reflect the submeasure. There are existing Title 24, Part 6 prescriptive fenestration requirements so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 102 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design.

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

Table 102: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change, High Performance Windows

Modeling Scenario	Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Fixed – 1	All	All	U-Factor	0.36	0.34
Fixed – 1	All	All	SHGC	0.25	0.22
Fixed – 2	All	All	U-Factor	0.36	0.31
Fixed – 2	All	All	SHGC	0.25	0.20
Fixed – 3	All	All	U-Factor	0.36	0.34
Fixed – 3	All	All	SHGC	0.25	0.22
Curtain wall / Storefront – 1	All	All	U-Factor	0.41	0.38
Curtain wall / Storefront – 1	All	All	SHGC	0.26	0.26
Curtain wall / Storefront – 2	All	All	U-Factor	0.41	0.35
Curtain wall / Storefront – 2	All	All	SHGC	0.26	0.26
Curtain wall / Storefront – 3	All	All	U-Factor	0.41	0.38
Curtain wall / Storefront – 3	All	All	SHGC	0.26	0.25

Using EnergyPlus with CBECC-Com rulesets the Statewide CASE Team determined whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). The 2022 TDV factors were then applied 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) (Energy + Environmental Economics 2020). TDV energy cost savings were calculated using the TDV energy cost impacts over the 30-year period of analysis presented in 2023 present value dollars (2023 PV$).

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

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

Energy Savings Methodology for RSHGC Calculation Update

The energy savings from exterior shading is only a function of the solar heat gain that passes through the shading and onto the window it shades. It is only affected by the geometry and solar reflectance of the shading material. It is not affected by the choice of prototype building. The interior characteristics of the building do not affect the amount of solar radiation passing through the exterior shading device. In addition, since the size of the exterior shade would be required to cover the entire window, the size of the window does not affect the relative energy savings. For these reasons, only the SmallOffice prototype was modeled.

The prototype was modeled as a baseline with no horizontal slats, then as proposed models with exterior horizontal slats. Other than the difference in exterior horizontal slats, the baseline and proposed models were identical. Various cutoff angles, tilt angles, and reflectances were modeled in the proposed cases. All models were rotated to cover a range of orientations. Table 103 lists all parametric values simulated in the models. Each parametric value was combined with every other parametric value to create a comprehensive set of data from which an appropriate new RSHGC formula could be derived.

Table 103: RSHGC Equivalent Energy Savings Simulation Parametric Values

Parameter	Simulated Values
Azimuth: The orientation of the window in degrees clockwise from north.	0, 45, 90, 135, 180, 225, 270, 315
Cutoff Angle: The degrees of solar elevation above which direct sunlight is blocked by the slat.	15, 30, 45, 60, 75
Tilt Angle: The angle of declination of the slat from horizontal as measured by the outermost edge of the slat.	0, 10, 20, 30, 40
Reflectance: The solar reflectance of the surface of the slat.	0%, 30%, 50%, 70%

The difference between cutoff angle and tilt angle is illustrated in Figure 2. Both geometries have the same projection factor (P/s) and therefore the same cutoff angle (CO). However, they have different tilt/slat angles (T).

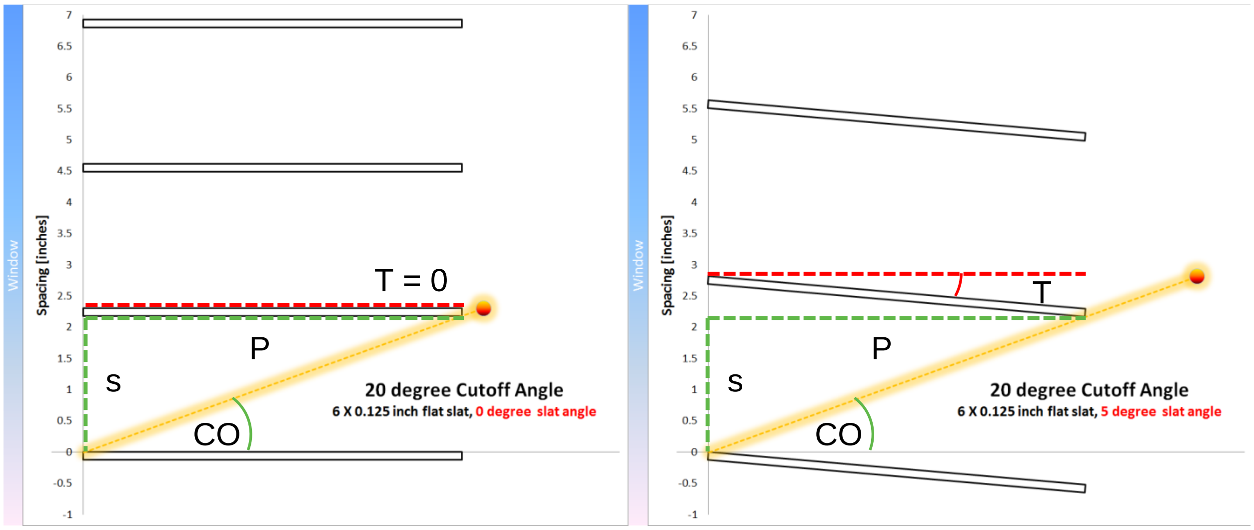

Figure 2: Cutoff angle, tilt angle, and projection factor.

The tilt of a horizontal slat determines how much indirect sunlight reaches the interior. An analogy with visible light is that the greater the tilt, the more the glowing surface of the slat can be seen from the interior. The tilt and spacing together determine a solar elevation angle above which direct sunlight is blocked. This is the cutoff angle. The cutoff angle of a horizontal slat determines how much direct sunlight reaches the interior.

4.3.2.2 Statewide Energy Savings Methodology

Methodology for U-factor and SHGC Updates

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that would 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 104 presents the prototypical buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

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

Table 104: Nonresidential Building Types and Associated Prototype Weighting, High Performance Windows

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis	Percent of Windows Assumed to be Fixed	Percent of Windows Assumed to be Curtain wall/ Storefront
Small Office	OfficeSmall	100%	100%	0%
Large Office	OfficeMedium	50%	100%	0%
	OfficeLarge	50%	100%	0%
Restaurant	RestaurantFastFood	100%	80%	20%
Retail	RetailStandAlone	10%	80%	20%
	RetailLarge	75%	80%	20%
	RetailStripMall	5%	80%	20%
	RetailMixedUse	10%	80%	20%
Grocery Store	Grocery	100%	80%	20%
Non-Refrigerated Warehouse	Warehouse	100%	0%	0%
Refrigerated Warehouse	RefrigWarehouse	N/A	100%	0%
Schools	SchoolPrimary	60%	100%	0%
	SchoolSecondary	40%	100%	0%
Colleges	OfficeSmall	5%	80%	20%
	OfficeMedium	15%	80%	20%
	OfficeMediumLab	20%	100%	0%
	SchoolSecondary	30%	100%	0%
	ApartmentHighRise	25%	0%	0%
Hospitals	Hospital	100%	100%	0%

Methodology for RSHGC Calculation Update

The shading factor (SHF) is the factor multiplied by a window's SHGC to reduce the RSHGC when shading is present (i.e., RSHGC = Window SHGC * SHF). The simulated SHFs were calculated per Equation 1. For each climate zone, the TDV-weighted sum of solar gains through the windows for all hours in the proposed model was divided by that of the baseline model. This was then weighted by that climate zone's fraction of all forecasted nonresidential construction; then all climate zones were summed. This data set represented the statewide simulated SHF as a function for each combination of parameters in Table 103.

Equation 1: Calculation of statewide shading factors

$$SHF_{proposed} = \sum_{CZ=1}^{16} \frac{NRC_{CZ}}{NRC_{CA}} \times \frac{\sum_{h=1}^{8760} WSG_{CZ,h,proposed} \times TDV_{CZ,h}}{\sum_{h=1}^{8760} WSG_{CZ,h,baseline} \times TDV_{CZ,h}}$$

Where:

$SHF_{proposed}$	=	The shading factor for a specific combination of horizontal slat geometry and reflectance
NRC	=	Nonresidential forecasted construction
CZ	=	Climate zone
h	=	The hour of the year
WSG	=	The total simulated solar gain through the window for the hour
TDV	=	The time dependent valuation of energy for the hour

The zero tilt, zero reflectance SHF results were used to determine the savings from an overhang. As described above, horizontal slats transmit indirect solar gains into the space. But since overhangs do not have interreflection between slats, they don’t transmit indirect solar gains. Their reflectance was considered virtually zero.

Calculating overhang SHF in this way created consistency with the horizontal slat calculations so that a single formula for both overhangs and horizontal slats could be more readily developed.

For horizontal slats, the physics is more complex. As expected, higher reflectance resulted in more interior solar gains. But, for a given cutoff angle, there is a tilt angle of maximum solar gain. This is illustrated in Figure 3. At low tilt angles, the slats mostly inter-reflect between themselves and not into the interior space. At high tilt angles, the slats mostly bounce sunlight back out to the exterior. Somewhere in between these points there is a maximum solar gain point. To be conservative, this maximum point was used for determining the SHF formula.

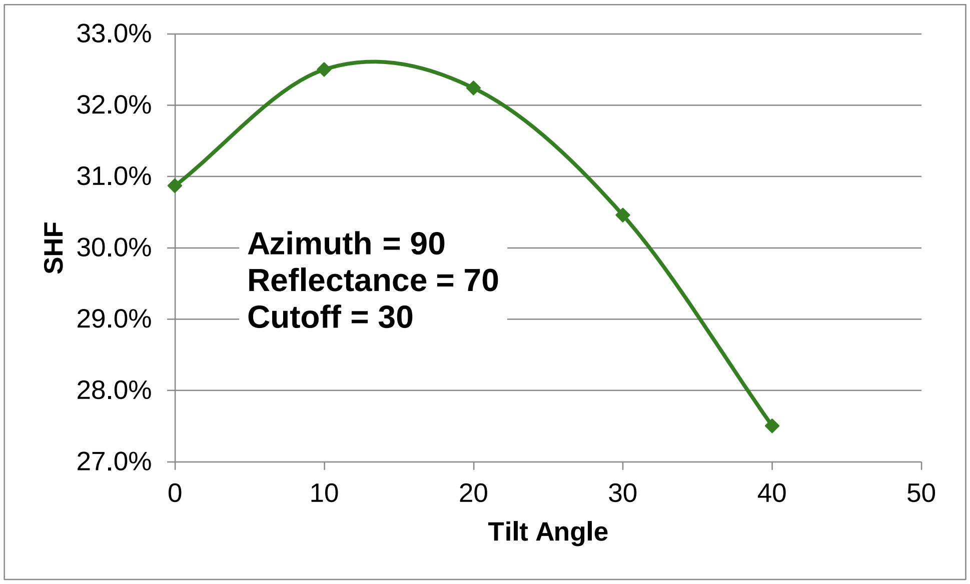

Figure 3: Shading factor as a function of tilt angle for a horizontal slat.

The current RSHGC formula uses the term H/V which is equivalent to the daylighting projection factor introduced in the 2019 code cycle. To unify these two formulae, the H/V in the RSHGC was replaced by the term projection factor. The relationship between cutoff angle and projection factor is given in Equation 2.

Equation 2: Relationship between cutoff angle and projection factor

$$\tan(CO) = \frac{1}{PF}$$

Where:

CO	=	The cutoff angle
PF	=	The projection factor

Finally, Equation 3 represents the regression curve fit of SHF that was derived for the final RSHGC. The format of the equation results in an SHF that is 1.0 when PF = 0.0 and reaches a minimum near a 180-degree azimuth.

The regression curves (solid lines) are plotted with the simulated values (dots) for various cutoff angles and azimuth in Figure 4. The correlation between simulated and calculated savings, along with a line of perfect correlation, is given in Figure 5. As can be seen in both figures, the overhang regression is conservative and slightly overestimates the SHF while the horizontal slat regression matches the simulated results closely.

Equation 3: Proposed RSHGC formula

$$RSHGC = SHGC_{win}[1 + a(2.72^{-PF} - 1)(\sin(b \times Az) - c)]$$

Where:

RSHGC = Relative Solar Heat Gain Coefficient

$SHGC_{win}$ = The NFRC SHGC of the window

Az = The azimuth (orientation) of the window in degrees clockwise from north

PF = The projection factor of the exterior shade

a, b, c = Coefficients shown in Table 105: Best Fit RSHGC Formula Coefficients

Table 105: Best Fit RSHGC Formula Coefficients

	a	b	c
Overhang	0.150	0.130	5.67
Horizontal Slat	0.144	0.133	5.13

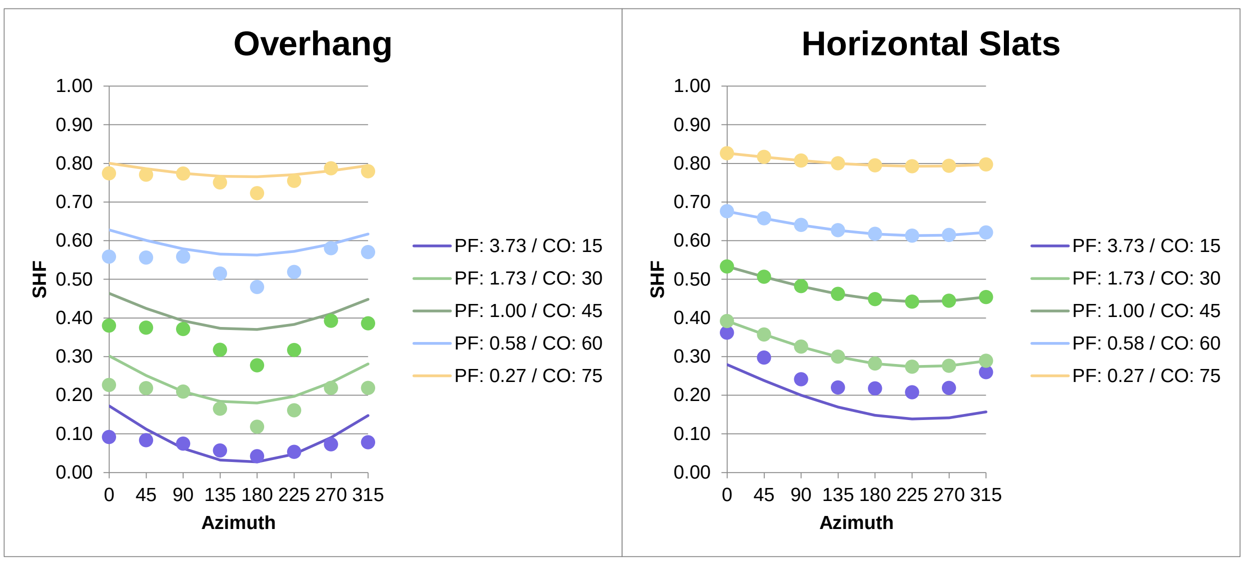

Figure 4: Shading factor regression curve with simulated values.

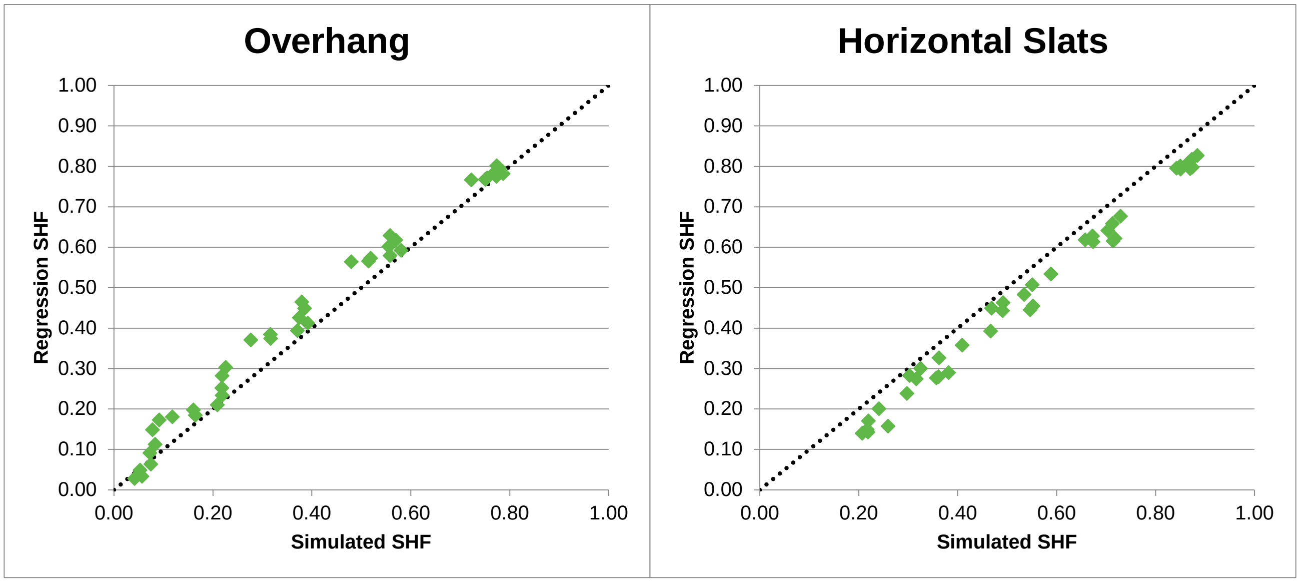

Figure 5: Shading factor regression curve versus simulated values.

Stakeholders suggested that the existing RSHGC formula can be used with horizontal slats. However, further justification for changing the existing formula is presented in Figure 6. The existing shading factor increases at projection factors greater than 1.0, effectively penalizing longer projections when in fact longer projections shade windows more than shorter projections. For overhangs this may be acceptable as longer overhangs, although they do exist, are not common. But projection factors greater than 1.0 are more common with horizontal slats. Furthermore, some of the solar energy enters the space because of the inter-reflectance of slats, resulting in a higher shading factor than an overhang of the same projection factor.

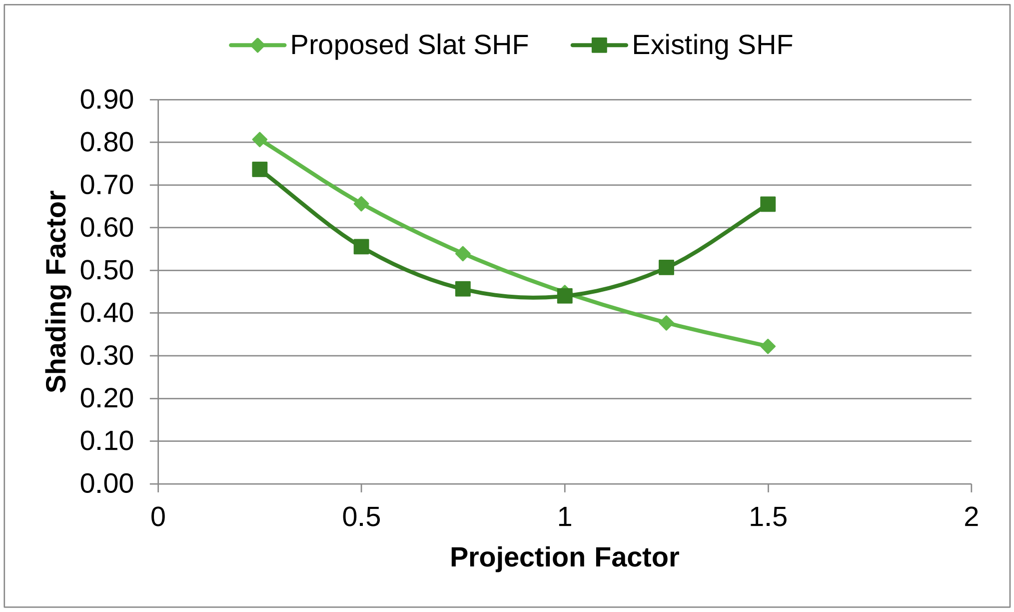

Figure 6: Comparison of the existing shading factor and proposed shading factor for a south-facing horizontal slat.

4.3.3 Per-Unit Energy Impacts Results

Energy savings per building prototype square foot unit are presented in Table 106 through Table 111. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

As described in Section 4.3.1, the Statewide CASE Team simulated the energy impacts of three potential stringency levels for both fixed and curtain wall/storefront. The results presented in this section and the results presented throughout this report represent the stringency levels that the Statewide CASE Team is recommending. That is, for fixed windows modeling scenario 1 (U-factor of 0.34 and SHGC of 0.22) and for curtain wall / storefront modeling scenario 3 (U-factor of 0.38 and SHGC of 0.25). These scenarios were selected based on both cost effectiveness and modeled energy savings, across all modeled scenarios. The energy models were run across all climate zones using the prototypical buildings identified in Table 101. Results are only presented for climate zones where changes are recommended.

Energy savings per square foot of total building square footage are presented in the tables below. Electricity savings are shown in kWh/ft^2. Natural gas savings are shown in millitherm/ft^2. Total TDV energy savings are shown in TDV kBtu/ft^2. When the proposed code change would increase energy use, the energy savings are negative and depicted in red font and in parentheses ( ). The Statewide CASE Team evaluated the energy savings of all prototypical buildings in all climate zones and reviewed results to inform recommended code changes.

The electricity savings are greater than the gas savings for fixed windows due to the impact of increased overall envelope efficiency in cooling-dominated versus heating-dominated climate zones. The fixed window energy modeling shows positive electricity savings in kWh/ft^2 in almost all combinations of climate zone and building prototype.

Table 106: High Performance Windows Electricity Savings Per Square Foot (kWh/ft²) by Climate Zone and Prototype Building – Fixed

Prototype / **Climate Zone**	**2**	**5**	**6**	**7**	**8**	**9**	**11**	**12**	**13**	**14**	**15**
Grocery	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02
Hospital	0.02	0.04	0.03	0.03	0.03	0.03	0.05	0.02	0.05	0.04	0.04
OfficeLarge	0.03	0.03	0.03	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.06
OfficeMedium	0.05	0.04	0.06	0.06	0.07	0.07	0.07	0.06	0.08	0.09	0.11
OfficeMediumLab	0.03	0.02	0.04	0.04	0.05	0.05	0.05	0.04	0.06	0.06	0.09
OfficeSmall	0.09	0.09	0.12	0.10	0.10	0.11	0.12	0.10	0.12	0.12	0.14
RestaurantFastFood	0.13	0.12	0.15	0.14	0.16	0.16	0.15	0.19	0.14	0.13	0.16
RetailLarge	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.03
RetailMixedUse	0.02	0.02	0.02	(0.01)	0.05	0.04	0.04	0.00	0.02	0.04	0.07
RetailStandAlone	0.05	0.02	0.04	0.04	0.06	0.01	0.01	0.05	0.03	0.04	0.07
RetailStripMall	0.03	0.00	0.04	0.02	0.03	0.00	0.02	0.04	0.02	0.06	0.01
SchoolPrimary	0.10	0.12	0.12	0.11	0.14	0.14	0.15	0.12	0.15	0.14	0.18
SchoolSecondary	0.02	0.02	0.02	0.02	0.03	0.03	0.05	0.02	0.05	0.04	0.04
Warehouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 107: High Performance Windows Natural Gas Savings Per Square Foot (millitherm/ft^2) by Climate Zone and Prototype Building – Fixed

Prototype / Climate Zone	2	5	6	7	8	9	11	12	13	14	15
Grocery	(1.32)	(1.70)	(1.25)	(1.22)	(1.15)	(1.14)	(0.89)	(1.01)	(0.72)	(1.31)	(0.66)
Hospital	1.00	1.96	1.62	0.53	0.76	0.66	1.81	0.32	1.73	1.25	0.40
OfficeLarge	0.30	0.00	(0.48)	0.73	(0.04)	0.81	0.55	0.36	0.42	0.60	0.09
OfficeMedium	(1.12)	(1.16)	(0.08)	(0.02)	(0.16)	(0.26)	(0.35)	(0.57)	(0.43)	(0.75)	(0.06)
OfficeMediumLab	(2.44)	(2.91)	(2.98)	(2.96)	(3.12)	(3.16)	(2.56)	(2.69)	(3.37)	(3.20)	(3.80)
OfficeSmall	(1.49)	(1.44)	(0.45)	(0.39)	(0.50)	(0.60)	(1.26)	(1.12)	(1.04)	(1.67)	(0.30)
RestaurantFastFood	(6.98)	(7.64)	(3.58)	(3.34)	(3.31)	(3.94)	(4.36)	(4.72)	(3.93)	(5.49)	(1.93)
RetailLarge	(0.28)	(0.26)	(0.13)	(0.09)	(0.11)	(0.12)	(0.22)	(0.23)	(0.16)	(0.29)	(0.05)
RetailMixedUse	(1.19)	(1.01)	(0.27)	(0.23)	(0.29)	(0.45)	(1.07)	(0.92)	(0.78)	(1.42)	(0.26)
RetailStandAlone	(1.02)	(0.76)	(0.43)	(0.33)	(0.39)	(0.39)	(0.66)	(0.64)	(0.60)	(0.91)	(0.24)
RetailStripMall	(1.61)	(1.49)	(0.68)	(0.61)	(0.71)	(0.83)	(1.40)	(1.34)	(1.23)	(1.99)	(0.45)
SchoolPrimary	(3.20)	(3.57)	(1.24)	(1.10)	(1.33)	(1.42)	(2.61)	(2.43)	(2.19)	(3.14)	(0.80)
SchoolSecondary	(0.92)	(1.36)	(0.96)	(0.93)	(0.71)	(0.90)	(0.49)	(0.71)	(0.73)	(1.06)	(0.70)
Warehouse	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)	(0.04)

Table 108: High Performance Windows TDV Energy Savings Per Square Foot (TDV kBtu/ft²) by Climate Zone and Prototype Building – Fixed

Prototype / Climate Zone	2	5	6	7	8	9	11	12	13	14	15
Grocery	(0.04)	(0.29)	(0.08)	(0.08)	0.04	0.15	0.23	0.20	0.31	0.19	0.40
Hospital	1.14	1.58	1.35	0.91	1.09	0.94	2.32	0.69	1.60	1.56	1.18
OfficeLarge	1.00	0.53	0.52	1.06	1.20	1.58	1.31	1.13	1.42	1.75	1.42
OfficeMedium	1.07	0.58	1.60	1.42	1.93	2.07	2.02	1.54	2.10	2.44	2.74
OfficeMediumLab	0.41	(0.42)	0.16	0.09	0.65	0.69	0.90	0.57	0.74	0.99	1.55
OfficeSmall	2.19	1.91	2.94	2.48	2.68	2.87	3.04	2.49	2.88	2.87	3.89
RestaurantFastFood	1.67	1.04	2.98	2.62	3.45	3.24	2.86	11.67	2.70	2.04	3.75
RetailLarge	0.03	0.31	0.27	0.10	(0.21)	0.28	(0.01)	0.23	0.48	(0.12)	0.62
RetailMixedUse	(0.20)	(0.81)	0.75	(0.82)	0.03	0.22	0.77	(0.39)	0.69	0.55	1.54
RetailStandAlone	1.04	0.17	0.46	0.30	1.49	0.15	0.08	1.02	2.89	0.99	1.52
RetailStripMall	0.29	(1.15)	0.74	0.21	(1.13)	(0.17)	0.03	0.53	(0.08)	0.81	0.48
SchoolPrimary	2.26	2.00	3.08	2.78	3.44	3.48	3.46	2.65	3.51	3.24	4.81
SchoolSecondary	0.30	0.10	0.32	0.15	0.66	0.61	1.10	0.40	1.08	0.75	0.94
Warehouse	0.00	(0.00)	(0.02)	0.01	(0.01)	0.06	0.02	(0.00)	(0.01)	0.04	0.02

Table 109: High Performance Windows Electricity Savings Per Square Foot (kWh/ft^2) by Climate Zone and Prototype Building – Curtain wall/Storefront

Prototype **Climate Zone**	**1**	**7**	**16**
Grocery	0.00	0.00	0.01
Hospital	(0.00)	0.03	(0.00)
OfficeLarge	(0.00)	(0.01)	(0.00)
OfficeMedium	(0.01)	(0.01)	(0.01)
OfficeSmall	(0.01)	(0.00)	(0.01)
RestaurantFastFood	(0.01)	(0.03)	(0.05)
RetailLarge	0.00	0.00	(0.00)
RetailMixedUse	(0.01)	0.01	(0.01)
RetailStandAlone	(0.01)	0.05	0.01
RetailStripMall	(0.01)	(0.00)	(0.00)

Table 110: High Performance Windows Natural Gas Savings Per Square Foot ($millitherms/ft^2$) by Climate Zone and Prototype Building – Curtain wall/Storefront

Prototype **Climate Zone**	**1**	**7**	**16**
Grocery	0.77	0.29	0.84
Hospital	1.84	5.54	0.77
OfficeLarge	2.98	0.93	3.63
OfficeMedium	4.02	0.93	4.66
OfficeSmall	3.08	0.25	3.35
RestaurantFastFood	5.30	0.98	4.79
RetailLarge	0.46	0.05	0.61
RetailMixedUse	1.49	0.10	1.90
RetailStandAlone	1.09	0.12	0.96
RetailStripMall	1.89	0.22	2.06

Table 111: High Performance Windows TDV Energy Savings Per Square Foot ($TDV\ kBtu/ft^2$) by Climate Zone and Prototype Building – Curtain wall/Storefront

Prototype **Climate Zone**	**1**	**7**	**16**
Grocery	0.34	0.11	0.42
Hospital	0.53	1.80	0.57
OfficeLarge	0.87	0.22	1.16
OfficeMedium	1.04	0.09	1.28
OfficeSmall	0.65	0.00	0.84
RestaurantFastFood	1.51	(0.31)	0.54
RetailLarge	0.27	0.40	0.20
RetailMixedUse	0.22	0.68	0.38
RetailStandAlone	(0.12)	1.95	0.64
RetailStripMall	0.37	0.61	0.53

4.4 Cost and Cost Effectiveness

4.4.1 Energy Cost Savings Methodology

The proposed code change applies to new construction. Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.3.2. 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 nonresidential envelope measures). In this case, the period of analysis used is 30 years. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years. Appendix K: presents the energy cost savings in nominal dollars.

4.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings that are realized over the 30-year period of analysis are presented in 2023 dollars in the following section for both fixed and curtain wall/storefront windows, respectively. Appendix K: presents the energy cost savings in nominal dollars.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. The savings represent the same scenarios listed in the previous section.

For fixed windows, the full breakdown by both climate zone and building prototype can be seen below.

The curtain wall/storefront PV TDV energy savings per square foot are shown for all building prototypes that were processed into the energy modeling for this product within the high performance windows submeasure.

Table 112: 2023 PV TDV Energy Cost Savings per Square Foot (2023PV $/ft^2) Over 30-Year Period of Analysis – Per Square Foot – New Construction –High Performance Windows (Fixed)

Prototype / **Climate Zone**	**2**	**5**	**6**	**7**	**8**	**9**	**11**	**12**	**13**	**14**	**15**
Grocery	($0.01)	($0.05)	($0.01)	($0.01)	$0.01	$0.02	$0.03	$0.03	$0.05	$0.03	$0.06
Hospital	$0.18	$0.24	$0.21	$0.14	$0.17	$0.14	$0.36	$0.11	$0.25	$0.24	$0.18
OfficeLarge	$0.15	$0.08	$0.08	$0.16	$0.18	$0.24	$0.20	$0.17	$0.22	$0.27	$0.22
OfficeMedium	$0.16	$0.09	$0.25	$0.22	$0.30	$0.32	$0.31	$0.24	$0.32	$0.38	$0.42
OfficeMediumLab	$0.06	($0.06)	$0.02	$0.01	$0.10	$0.11	$0.14	$0.09	$0.11	$0.15	$0.24
OfficeSmall	$0.34	$0.29	$0.45	$0.38	$0.41	$0.44	$0.47	$0.38	$0.44	$0.44	$0.60
Restaurant FastFood	$0.26	$0.16	$0.46	$0.40	$0.53	$0.50	$0.44	$1.80	$0.42	$0.31	$0.58
RetailLarge	$0.01	$0.05	$0.04	$0.01	($0.03)	$0.04	($0.00)	$0.04	$0.07	($0.02)	$0.09
RetailMixedUse	($0.03)	($0.13)	$0.12	($0.13)	$0.00	$0.03	$0.12	($0.06)	$0.11	$0.09	$0.24
RetailStandAlone	$0.16	$0.03	$0.07	$0.05	$0.23	$0.02	$0.01	$0.16	$0.44	$0.15	$0.23
RetailStripMall	$0.04	($0.18)	$0.11	$0.03	($0.17)	($0.03)	$0.00	$0.08	($0.01)	$0.13	$0.07
SchoolPrimary	$0.35	$0.31	$0.48	$0.43	$0.53	$0.54	$0.53	$0.41	$0.54	$0.50	$0.74
SchoolSecondary	$0.05	$0.02	$0.05	$0.02	$0.10	$0.09	$0.17	$0.06	$0.17	$0.12	$0.14
Warehouse	$0.00	($0.00)	($0.00)	$0.00	($0.00)	$0.01	$0.00	($0.00)	($0.00)	$0.01	$0.00

Table 113: 2023 PV TDV Energy Cost Savings per Square Foot (2023PV $/ft²) Over 30-Year Period of Analysis – Per Square Foot – New Construction –High Performance Windows (Curtain wall/Storefront)

Prototype / **Climate Zone**	**1**	**7**	**16**
Grocery	$0.05	$0.02	$0.07
HotelSmall	$0.09	($0.00)	$0.07
OfficeMedium	$0.16	$0.01	$0.20
OfficeSmall	$0.10	($0.00)	$0.13
Restaurant FastFood	$0.23	($0.05)	$0.08
RetailLarge	$0.04	$0.06	$0.03
RetailMixedUse	$0.03	$0.11	$0.06
RetailStandAlone	($0.02)	$0.30	$0.10
RetailStripMall	$0.06	$0.09	$0.08

4.4.3 Incremental First Cost

4.4.3.1 Cost Information for U-factor and SHGC Updates

The baseline for this submeasure is a window that is minimally compliant with 2019 Title 24, Part 6. This minimally compliant window is double-pane, argon-filled, hybrid steel spacer, poured and debridged thermal break, high performance tint, and triple-silver low-e.

The incremental cost for the high performance windows submeasure includes labor and material costs. The incremental labor cost is assumed to remain the same. The incremental cost was determined based on the additional cost for adding a fourth surface low-e coating, as well as the spacer type used for the window. Over a dozen stakeholders provided cost and product data as well as feedback on models, aligning with ASHRAE working group estimates. These stakeholders provided incremental cost above the baseline products. The final incremental cost is based on evaluation of this information, averaging the difference in cost between baseline and proposed products, with assistance from a professional cost estimator.

Table 114 shows the cost information used as modeling input for the fixed window scenarios that is reflected in the updated code language, while Table 115 shows the cost information for the curtain wall/storefront window scenarios used as the modeling input for the cost-effective scenario that is reflected in the updated code language.

Table 114: High Performance Windows – Fixed Window Scenario 1 Cost per Building Prototype

Building Prototype	Net Window Area (ft^2)	Window-to-Wall Ratio	Percent of Window Included in Scenario	Incremental Cost per ft^2 of Window	Total Cost	Building Area (ft^2)	Total Cost per Square Foot of Building Area ($/$ft^2$)
Grocery	1,587	7%	80%	$1.75	$2,777.30	50,002	$0.06
Hospital	4,280	0%	80%	$1.75	$7,490.61	249,985	$0.03
HotelSmall	1,983	11%	80%	$1.75	$3,470.44	42,554	$0.08
OfficeLarge	48,134	52%	80%	$1.75	$84,234.19	498,589	$0.17
OfficeMedium	7,027	33%	80%	$1.75	$12,297.62	53,628	$0.23
OfficeMediumLab	7,027	33%	100%	$1.75	$12,297.62	53,628	$0.23
OfficeSmall	642	21%	80%	$1.75	$1,124.36	5,502	$0.20
RestaurantFastFood	280	14%	80%	$1.75	$490.25	2,501	$0.20
RetailLarge	5,881	12%	80%	$1.75	$10,291.03	240,000	$0.04
RetailMixedUse	558	10%	80%	$1.75	$976.31	9,375	$0.10
RetailStandAlone	904	7%	80%	$1.75	$1,581.25	24,563	$0.06
RetailStripMall	558	8%	80%	$1.75	$976.31	9,375	$0.10
SchoolPrimary	4,964	36%	100%	$1.75	$8,686.77	24,413	$0.36
SchoolSecondary	22,162	34%	100%	$1.75	$38,783.34	210,866	$0.18
Warehouse	190	1%	80%	$1.75	$332.73	49,495	$0.01

Table 115: High Performance Windows – Curtain wall/Storefront Window Scenario 3 Cost per Building Prototype

Building Prototype	Net Window Area (ft^2)	Window-to-Wall Ratio	Percent of Window Included in Scenario	Incremental Cost per ft^2 of Window	Total Cost	Building Area (ft^2)	Total Cost per Square Foot of Building Area ($\$/ft^2$)
Grocery	1,587	7%	20%	$1.00	$1,587.03	50,002	$0.03
OfficeLarge	48,134	52%	20%	$1.00	$48,133.82	498,589	$0.10
OfficeMedium	7,027	33%	20%	$1.00	$7,027.21	53,628	$0.13
OfficeSmall	642	21%	20%	$1.00	$642.49	5,502	$0.12
RestaurantFastFood	280	14%	20%	$1.00	$280.14	2,501	$0.11
RetailLarge	5,881	12%	20%	$1.00	$5,880.59	240,000	$0.02
RetailMixedUse	558	10%	20%	$1.00	$557.89	9,375	$0.06
RetailStandAlone	904	7%	20%	$1.00	$903.57	24,563	$0.04
RetailStripMall	558	8%	20%	$1.00	$557.89	9,375	$0.06

4.4.3.1.1 Cost Information for RSHGC Calculation Update

The RSHGC update is an alternative compliance path, so no cost-effectiveness calculation is necessary. Projects do not have to use Equation 140.3-A if windows have overhangs or horizontal slats; rather the equation is an option to use if the project is looking for further SHGC credit to meet Title 24, Part 6 requirements. However, research indicates that horizontal slat assemblies ranged from $20 to $100 per square meter (Alibaba n.d.).

4.4.4 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 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 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:

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

The expected useful life of this submeasure is 30 years (California Utilities Statewide Codes and Standards Team 2011), based on the assumption of window replacements every 30 years. No additional maintenance or replacement costs are anticipated for this submeasure. Performance of fenestration depends on the component properties, such as the argon fill and various potential coatings. Since these elements are protected within the product or on the building interior, there is little to no expected degradation within and even beyond the 30-year lifetime. The persistence of energy savings should therefore last through the entire installed life of the fenestration, which is beyond the 30-year expected useful life of this submeasure.

4.4.5 Cost Effectiveness

This submeasure proposes a prescriptive requirement. As such, a cost analysis is required to demonstrate that the submeasure is cost effective over the 30-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 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas 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 30 years by the total incremental costs, which includes maintenance costs for 30 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 116 and Benefits: **TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis. 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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

a. **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 and 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 B/C ratio is infinite.

Table 117 for the new construction OfficeLarge building prototype. As this single table is not representative of all building prototypes, the full range of B/C Ratios for all building prototypes in all climate zones shown in Table 118 and Table 119.

Table 116: 30-Year Cost-Effectiveness Summary– New Construction Per-unit OfficeLarge, High Performance Windows (Fixed)

Climate Zone	**Benefits**: 2023 PV$ Energy Cost Savings + Other PV Savings[a] per ft^2	**Costs**: Total Incremental PV Costs[b]	Benefit-to-Cost Ratio	Modeling Scenario
2	$0.15	$0.18	0.84	Fixed – 1
3	N/A	N/A	N/A	Fixed – 1
5	$0.08	$0.18	0.45	Fixed – 1
6	$0.08	$0.18	0.44	Fixed – 1
7	$0.16	$0.18	0.89	Fixed – 1
8	$0.18	$0.18	1.01	Fixed – 1
9	$0.24	$0.18	1.33	Fixed – 1
11	$0.20	$0.18	1.10	Fixed – 1
12	$0.17	$0.18	0.95	Fixed – 1
13	$0.22	$0.18	1.20	Fixed – 1
14	$0.27	$0.18	1.47	Fixed – 1
15	$0.22	$0.18	1.19	Fixed – 1

b. **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. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

c. **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 and 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 B/C ratio is infinite.

Table 117: 30-Year Cost-Effectiveness Summary– New Construction Per-unit RetailLarge, High Performance Windows (Curtain wall/Storefront)

Climate Zone	Benefits: 2023 PV$ Energy Cost Savings + Other PV Savings[a] per ft^2	Costs: Total Incremental PV Costs[b]	Benefit-to-Cost Ratio	Modeling Scenario
1	$0.04	$0.02	1.68	Curtain wall/Storefront – 3
7	$0.06	$0.02	2.54	Curtain wall/Storefront – 3
16	$0.03	$0.02	1.26	Curtain wall/Storefront – 3

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. Includes PV maintenance cost savings 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 and 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 B/C ratio is infinite.

Table 118: High Performance Windows - Fixed, Benefit-to-Cost Ratio by Climate Zone and Building Prototype

Prototype / Climate Zone	2	5	6	7	8	9	11	12	13	14	15
Grocery	(0.12)	(0.82)	(0.22)	(0.24)	0.12	0.41	0.63	0.56	0.86	0.53	1.10
Hospital	2.66	3.70	3.14	2.12	2.55	2.19	5.43	1.61	3.73	3.64	2.76
OfficeLarge	0.84	0.45	0.44	0.89	1.01	1.33	1.10	0.95	1.20	1.47	1.19
OfficeMedium	0.72	0.39	1.07	0.95	1.29	1.39	1.36	1.04	1.41	1.64	1.84
OfficeMediumLab	0.27	(0.28)	0.11	0.06	0.44	0.46	0.60	0.38	0.49	0.66	1.04
OfficeSmall	1.65	1.44	2.21	1.87	2.02	2.16	2.29	1.87	2.17	2.16	2.93
RestaurantFastFood	1.31	0.82	2.34	2.06	2.71	2.55	2.25	9.17	2.12	1.60	2.95
RetailLarge	0.12	1.12	0.97	0.34	(0.75)	1.01	(0.05)	0.83	1.72	(0.44)	2.21
RetailMixedUse	(0.29)	(1.20)	1.11	(1.21)	0.04	0.32	1.13	(0.57)	1.02	0.82	2.28
RetailStandAlone	2.50	0.41	1.10	0.71	3.57	0.37	0.20	2.44	6.90	2.37	3.64
RetailStripMall	0.43	(1.70)	1.09	0.31	(1.68)	(0.25)	0.04	0.79	(0.12)	1.20	0.71
SchoolPrimary	0.98	0.87	1.34	1.20	1.49	1.51	1.50	1.15	1.52	1.40	2.08
SchoolSecondary	0.25	0.09	0.27	0.13	0.55	0.51	0.92	0.33	0.90	0.63	0.78
Warehouse	0.07	(0.05)	(0.57)	0.30	(0.18)	1.33	0.47	(0.08)	(0.21)	0.88	0.52

Table 119: High Performance Windows – Curtain wall/Storefront, Benefit-to-Cost Ratio by Climate Zone and Building Prototype

Prototype / Climate Zone	1	7	16
Grocery	1.64	0.54	2.05
HotelSmall	1.90	(0.02)	1.57
OfficeMedium	1.22	0.11	1.50
OfficeSmall	0.85	0.00	1.11
Restaurant FastFood	2.08	(0.43)	0.75
RetailLarge	1.68	2.54	1.26
RetailMixedUse	0.56	1.77	0.99
RetailStandAlone	(0.50)	8.17	2.69
RetailStripMall	0.95	1.58	1.36

a. The proposed code change would not impact this climate zone.

4.5 First-Year Statewide Impacts

4.5.1 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, presented in Section 4.3.3, 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 first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 120 and Table 121 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone, as broken out by window product type. There are no savings for additions/alterations since this submeasure does not apply to those construction types.

Table 120: Statewide Energy and Energy Cost Impacts – New Construction, High Performance Windows (Fixed)

Climate Zone	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 (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)	Modeling Scenario
2	3,.37	0.11	0.01	0.00	$0.40	Fixed – 1
5	1.59	0.05	0.00	0.00	$0.14	Fixed – 1
6	10.96	0.44	0.02	0.00	$1.53	Fixed – 1
7	8.08	0.34	0.01	0.00	$1.16	Fixed – 1
8	15.83	0.66	0.05	(0.01)	$2.45	Fixed – 1
9	26.41	1.14	0.04	(0.01)	$4.82	Fixed – 1
11	3.18	0.15	0.01	0.00	$0.59	Fixed – 1
12	17.43	0.69	0.04	(0.01)	$3.01	Fixed – 1
13	6.25	0.32	0.02	0.00	$1.26	Fixed – 1
14	3.41	0.15	0.01	0.00	$0.56	Fixed – 1
15	2.05	0.11	0.00	0.00	$0.44	Fixed – 1
TOTAL	**98.80**	**4.16**	**0.21**	**(0.04)**	**$16.37**	

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

Table 121: Statewide Energy and Energy Cost Impacts – New Construction, High Performance Windows (Curtain wall/Storefront)

Climate Zone	Construction Impacted by Proposed Change in 2023 (million square feet)	First-Year[a] Electricity Savings (kWh)	First-Year Peak Electrical Demand Reduction (W)	First-Year Natural Gas Savings (therms)	30-Year Present Valued Energy Cost Savings (2023 PV$)	Modeling Scenario
1	0.07	17.74	4.14	70.59	$3,333	curtain wall /storefront – 3
7	1.0	977.27	1,298.28	170.29	$32,141	curtain wall /storefront – 3
16	0.15	(511.69)	37.97	151.98	$5,517	curtain wall /storefront – 3
Total	**1.22**	**483.32**	**1,340.39**	**392.86**	**$40,991**	

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

Table 122: Statewide Energy and Energy Cost Impacts – New Construction Summary, High Performance Windows

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (PV$ million)
Fixed	4.16	0.21	(0.04)	$16.37
Curtain wall/Storefront	0.00	0.00	0.00	$0.04
TOTAL	**4.16**	**0.21**	**(0.03)**	**$16.41**

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

4.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the U.S. EPA eGRID for the 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 factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 123 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 790 metric tons of CO2e would be avoided.

Table 123: First-Year Statewide GHG Emissions Impacts, High Performance Windows

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Fixed	4.16	1,000.73	(0.04)	(211.28)	787.99
Curtain wall/Storefront	0.00	0.12	0.00	2.14	2.26
TOTAL	**4.16**	**1,000.85**	**(0.04)**	**(209.14)**	**790.25**

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

b. Assumes the following emission factors: 240 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

4.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

4.5.4 Statewide Material Impacts

The proposed code change does not require any new equipment or materials that do not already exist on the market. Stakeholders raised concerns about the amount of argon available to fill windows to meet the code requirements, but as the baseline from the previous code language was evaluated as argon-fill, this material impact would be minimal. Popular construction materials such as mercury, lead, copper, steel, plastic, and others would not be impacted.

4.5.5 Other Non-Energy Impacts

The proposed submeasure does not affect the installation, operation, or maintenance of the fenestration at the site, so additional environmental impacts should be nonexistent. The environmental impact associated with the manufacture of the products is related to the material increase required with added higher-performing fenestration components. This submeasure would have a positive impact on occupancy comfort, as well as providing benefits through daylighting. On-site emissions, air quality, and health and safety benefits would likely not be impacted.

4.6 Proposed Revisions to Code Language

4.6.1 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).

4.6.2 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

AZIMUTH is the degrees of clockwise rotation from absolute north.

~~**OVERHANG PROJECTION** is the horizontal distance, measured outward horizontally from the surface of exposed exterior glazing at the head of a window to the outward edge of an overhang.~~

~~**OVERHANG RISE** is the vertical distance between the projected edge of an overhang and the sill of the vertical fenestration below it.~~

CURTAIN WALL/STOREFRONT is an external nonbearing wall intended to separate the exterior nonconditioned and interior conditioned spaces. It also consists of any combination of framing materials, fixed glazing, opaque glazing, operable windows, glazed doors within storefront systems, or other in-fill materials.

GLAZED DOOR is an exterior door having a glazed area of 25 percent or greater of the area of the door. Glazed doors shall meet fenestration product requirements. Glazed doors within storefront systems shall meet the curtain wall/storefront requirements, See: Door.

SITE-BUILT is fenestration designed to be field-glazed or field assembled units using specific factory cut or otherwise factory formed framing and glazing units, that are manufactured with the intention of being assembled at the construction site. These include storefront systems, glazed doors within storefront systems, curtain walls, and atrium roof systems.

SECTION 110.6 – MANDATORY REQUIREMENTS FOR FENESTRATION PRODUCTS AND EXTERIOR DOORS

(a)**Certification of Fenestration Products and Exterior Doors other than Field-fabricated.** Any fenestration product and exterior door, other than field-fabricated fenestration products and field-fabricated exterior doors, may be installed only if the manufacturer has certified to the Commission, or if an independent certifying organization approved by the Commission has certified that the product complies with all of the applicable requirements of this subsection.

1. **Air leakage.** Manufactured fenestration products and exterior doors shall have air infiltration rates not exceeding 0.3 cfm/ft² of window area, 0.3 cfm/ft² of door area for residential doors, 0.3 cfm/ft² of door area for nonresidential single doors (swinging and

sliding), and 1.0 cfm/ft² for nonresidential double doors (swinging), when tested according to NFRC-400 or ASTM E283 at a pressure differential of 75 pascals (or 1.57 pounds/ft²), incorporated herein by reference.

NOTES TO SECTION 110.6(a)1:Pet doors must meet 0.3 cfm/ft² when tested according to ASTM E283 at 75 pascals (or 1.57 pounds/ft²). AAMA/WDMA/CSA 101/I.S.2/A440-2011 specification is equivalent to ASTM E283 at a pressure differential of 75 pascals (or 1.57 pounds/ft²) and satisfies the air leakage certification requirements of this section.

EXCEPTION to Section 110.6(a)1: Field-fabricated fenestration and field-fabricated exterior doors.

2. **U-factor.** The fenestration product and exterior door's U-factor shall be rated in accordance with NFRC 100, or use the applicable default U-factor set forth in TABLE 110.6-A.

   EXCEPTION 1 to Section 110.6(a)2: If the fenestration product is a skylight, ~~or a vertical site-built fenestration product in a building covered by the nonresidential standards with less than 200 square feet of site-built fenestration,~~ the default U-factor may be calculated as set forth in Reference Nonresidential Appendix NA6.

   EXCEPTION 2 to Section 110.6(a)2: If the fenestration product is an alteration consisting of any area replacement of glass in a skylight product, ~~or in a vertical site-built fenestration product,~~ in a building covered by the nonresidential standards, the default U-factor may be calculated as set forth in Reference Nonresidential Appendix NA6.

3. **Solar Heat Gain Coefficient (SHGC).** The fenestration product's SHGC shall be rated in accordance with NFRC 200, or use the applicable default SHGC set forth in TABLE 110.6-B.

   EXCEPTION 1 to Section 110.6(a)3: If the fenestration product is a skylight ~~or a vertical site-built fenestration product in a building covered by the nonresidential standards with less than 200 square feet of site-built fenestration~~, the default SHGC may be calculated as set forth in Reference Nonresidential Appendix NA6.

   EXCEPTION 2 to Section 110.6(a)3: If the fenestration product is an alteration consisting of any area replacement of glass in a skylight product ~~or in a vertical site-built fenestration product~~, in a building covered by the nonresidential standards, the default SHGC may be calculated as set forth in Reference Nonresidential Appendix NA6.

4. **Visible Transmittance (VT).** The fenestration product's VT shall be rated in accordance with NFRC 200 or ASTM E972, for tubular daylighting devices VT shall be rated using NFRC 203**.**

EXCEPTION 1 to Section 110.6(a)4: If the fenestration product is a skylight ~~or a vertical site-built fenestration product~~ , the default VT may be calculated as set forth in Reference Nonresidential Appendix NA6.

EXCEPTION 2 to Section 110.6(a)4: If the fenestration product is an alteration consisting of any area; replacement of glass in a skylight product ~~or in a vertical site-built fenestration product~~ in a building covered by the nonresidential standards, the default VT may be calculated as set forth in Reference Nonresidential Appendix NA6.

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

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

EXCEPTION 2 to Section 130.1(d): Areas adjacent to vertical glazing below an overhang, where the overhang covers the entire width of the vertical glazing, no vertical glazing is above the overhang, and the ~~ratio of the overhang projection to the overhang rise~~ projection factor as calculated by Equation 140.3-D is greater than 1.5 for South, East and West orientations or greater than 1.0 for North orientations.

4.6.2.1.1 SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

5. Exterior Windows. Vertical windows in exterior walls shall:

A. Percent window area shall be limited in accordance with the applicable requirements of i and ii below:

i. a west-facing area no greater than 40 percent of the gross west-facing exterior wall area, or 6 feet times the west-facing display perimeter, whichever is greater; and

ii. a total area no greater than 40 percent of the gross exterior wall area, or 6 feet times the display perimeter, whichever is greater; and

NOTE: Demising walls are not exterior walls, and therefore demising wall area is not part of the gross exterior wall area or display perimeter, and windows in demising walls are not part of the window area.

B. Have an area-weighted average U-factor no greater than the applicable value in TABLE140.3-B, C or D.

EXCEPTION to Section 140.3(a)5B: For vertical windows containing chromogenic type glazing:

i. The lower-rated labeled U-factor shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

ii. Chromogenic glazing shall be considered separately from other glazing; and

iii. Area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

C. Have an area-weighted average Relative Solar Heat Gain Coefficient, RSHGC, excluding the effects of interior shading, no greater than the applicable value in TABLE 140.3-B, C or D.

For purposes of this paragraph, the Relative Solar Heat Gain Coefficient, RSHGC, of a vertical window is:

i. The Solar Heat Gain Coefficient of the window; or

ii. Relative Solar Heat Gain Coefficient is calculated using EQUATION 140.3-A, if the window has an overhang <u>or exterior horizontal slats</u> that extend~~s~~ beyond each side of the window jamb by a distance equal to the overhang's horizontal projection.

EXCEPTION 1 to Section 140.3(a)5C: An area-weighted average Relative Solar Heat Gain Coefficient of 0.56 or less shall be used for windows:

a. That are in the first story of exterior walls that form a display perimeter; and
b. For which codes restrict the use of overhangs to shade the windows.

EXCEPTION 2 to Section 140.3(a)5C: For vertical windows containing chromogenic type glazing:

i. the lower-rated labeled RSHGC shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

ii. chromogenic glazing shall be considered separately from other glazing; and

iii. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

NOTE: Demising walls are not exterior walls, and therefore windows in demising walls are not subject to SHGC requirements.

D. Have an area-weighted average Visible Transmittance (VT) no less than the applicable value in TABLE 140.3-B and C, or EQUATION 140.3-B, as applicable.

EXCEPTION 1 to Section 140.3(a)5D: When the window's primary and secondary sidelit daylit zones are completely overlapped by one or more skylit daylit zones, then the window need not comply with Section 140.3(a)5D.

EXCEPTION 2 to Section 140.3(a)5D: If the window's VT is not within the scope of NFRC 200, or ASTM E972, then the VT shall be calculated according to Reference Nonresidential Appendix NA6.

EXCEPTION 3 to Section 140.3(a)5D: For vertical windows containing chromogenic type glazing:

i. The higher rated labeled VT shall be used with automatic controls to modulate the amount of light transmitted into the space in multiple steps in response to daylight levels or solar intensity; and

ii. Chromogenic glazing shall be considered separately from other glazing; and

iii. Area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

NOTE: Demising walls are not exterior walls, and therefore windows in demising walls are not subject to VT requirements.

EQUATION 140.3-A RELATIVE SOLAR HEAT GAIN COEFFICIENT, RSHGC

~~RSHGC = SHGCwin × [1 + aH/V + b (H/V)2]~~

$$RSHGC = SHGC \times [1 + a(2.72^{-PF} - 1)(\sin(b \times Az) - c)]$$

WHERE:

RSHGC	=	Relative Solar Heat Gain Coefficient.
SHGC~~win~~	=	Solar Heat Gain Coefficient of the vertical fenestration ~~window~~.
Az	=	Azimuth of the vertical fenestration in degrees.
PF	=	Projection factor as calculated by Equation 140.3-D.
~~H~~	~~=~~	~~Horizontal projection of the overhang from the surface of the window in feet, but no greater than V.~~
~~V~~	~~=~~	~~Vertical distance from the window sill to the bottom of the overhang in feet.~~
~~a~~	~~=~~	~~-0.41 for north-facing windows, -1.22 for south-facing windows, and -0.92 for east and west-facing windows.~~
~~b~~	~~=~~	~~0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east and west-facing windows.~~

	a	b	c
Overhang	0.150	0.130	5.67
Exterior Horizontal Slat	0.144	0.133	5.13

EQUATION 140.3-B VERTICAL FENESTRATION MINIMUM VT

$VT \geq 0.11/ WWR$

WHERE:

WWR	=	Window Wall Ratio, the ratio of (i) the total window area of the entire building to (ii) the total gross exterior wall area of the entire building. If the WWR is greater than 0.40, then 0.40 shall be used as the value for WWR in EQUATION 140.3-B.
VT	=	Visible Transmittance of framed window.

6. **Skylights.** Skylights shall:

   A. Have an area no greater than 5 percent of the gross exterior roof area Skylight Roof Ratio (SRR); and

   EXCEPTION to Section 140.3(a)6A: Buildings with an atria over 55 feet high shall have a skylight area no greater than 10 percent of the gross exterior roof area.

   B. Have an Area-Weighted Performance Rating U-factor no greater than the applicable value in
   TABLE 140.3-B, C or D.

   EXCEPTION to Section 140.3(a)6B: For skylights containing chromogenic type glazing:

   i. the lower-rate labeled U-factor shall be used with automatic controls to modulate the amount of U-factor heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

   ii. chromogenic glazing shall be considered separately from other glazing; and

   iii. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

   C. Have an area-weighted performance rating Solar Heat Gain Coefficient no greater than the applicable value in TABLE 140.3-B, C or D.

   EXCEPTION to Section 140.3(a)6C: For skylights containing chromogenic type glazing:

   i. the lower-rated labeled SHGC shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

   ii. chromogenic glazing shall be considered separately from other glazing; and

   iii. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

   D. Have an Area-Weighted Performance Rating VT no less than the applicable value in TABLE 140.3-B or C; and

EXCEPTION to Section 140.3(a)6D: For skylights containing chromogenic type glazing:

i. the higher-rated labeled VT shall be used with automatic controls to modulate the amount of light transmitted into the space in multiple steps in response to daylight levels or solar intensity and;

ii. chromogenic glazing shall be considered separately from other glazing; and

iii. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

E. Have a glazing material or diffuser that has a measured haze value greater than 90 percent, determined according to ASTM D1003, or other test method approved by the Energy Commission.

EXCEPTION to Section 140.3(a)6E: Skylights designed and installed to exclude direct sunlight entering the occupied space by the use of fixed or automated baffles or the geometry of the skylight and light well.

EQUATION 140.3-D PROJECTION AND DISTANCE FACTOR CALCULATION

Projection Factor = Projection / Spacing

Distance Factor = D / (H_{AS} x Projection Factor)

WHERE:

Projection = The horizontal distance between the base edge and the projected edge of the overhang, slat, or light shelf.

Spacing = For overhangs, the vertical distance between the projected edge of the overhang and sill of the vertical fenestration below it.

For horizontal slats, the vertical distance between the projected edge of a slat to the base edge of the slat below it.

For interior light shelves, the vertical distance between the projected edge of the light shelf and head of the clerestory fenestration above it.

For exterior light shelves, the vertical distance between the projected edge of the light shelf and sill of the vertical fenestration below it.

D = Distance between the existing structure or nature object and the fenestration

H_{AS} = Height difference between the top of the existing structure or nature object and the bottom of the fenestration

NOTE: The base edge is the edge of ~~a~~ an overhang, slat~~,~~ or light shelf that is adjacent to the vertical fenestration. The projected edge is the opposite edge from the base edge.

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS ~~AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)~~

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	**Maximum U-factor**	**Roofs/ Ceilings**	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
			Wood Framed and Other	0.034	0.034	0.034	0.034	0.034	0.049	0.049	0.049	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
		Walls	Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
			Metal-framed	0.069	0.062	0.082	0.062	0.062	0.069	0.069	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
			Mass Light[1]	0.196	0.170	0.278	0.227	0.440	0.440	0.440	0.440	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
		Floors/ Soffits	Raised Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
			Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
	Roofing Products	**Low-sloped**	Aged Solar Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		Steep-Sloped	Aged Solar Reflectance	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0. 75	0.75	0.75	0.75	0.75	0.75	0.75
	Air Barrier			NR	NR	NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Exterior Doors, Maximum U-factor		Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
			Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

CONTINUED: TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS ~~AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS~~)

					Climate Zone															
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Fenestration	Vertical			Fixed Window															
			Area-weighted Performance Weighting	Max U-factor	0.36	0.34 ~~0.36~~	0.36	0.36	0.34 ~~0.36~~	0.34 ~~0.36~~	0.34 ~~0.36~~	0.34 ~~0.36~~	0.34 ~~0.36~~	0.36	0.34 ~~0.36~~	0.34 ~~0.36~~	0.34 ~~0.36~~	0.34 ~~0.36~~	0.34 ~~0.36~~	0.36
				Max RSHGC	0.25	0.22 ~~0.25~~	0.25	0.25	0.22 ~~0.25~~	0.22 ~~0.25~~	0.22 ~~0.25~~	0.22 ~~0.25~~	0.22 ~~0.25~~	0.25	0.22 ~~0.25~~	0.22 ~~0.25~~	0.22 ~~0.25~~	0.22 ~~0.25~~	0.22 ~~0.25~~	0.25
				Min VT	0.42															
					Curtain wall or Storefront															
				Max U-factor	0.38 ~~0.41~~	0.41	0.41	0.41	0.41	0.41	0.38 ~~0.41~~	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.38 ~~0.41~~
				Max RSHGC	0.25 ~~0.26~~	0.26	0.26	0.26	0.26	0.26	0.25 ~~0.26~~	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25 ~~0.26~~
				Min VT	0.46															
					Operable Window															
				Max U-factor	0.46															
				Max RSHGC	0.22															
				Min VT	0.32															
					Glazed Doors[2]															
				Max U-factor	0.45															
				Max RSHGC	0.23															
				Min VT	0.17															
				Maximum WWR%	40%															

					All Climate Zones			
					Glass, Curb Mounted	Glass, Deck Mounted	Plastic, Curb Mounted	Tubular Daylighting Devices (TDDs)
Envelope	Fenestration	Skylights	Area-Weighted Performance Rating	Max U-factor	0.58	0.46	0.88	0.88
				Max SHGC	0.25	0.25	NR	NR
				Min VT (Min VT_{annual} for TDDs)	0.49	0.49	0.64	0.38
			Maximum SRR%		5%			

4.6.3 Reference Appendices

NA7.4.5 Interior and Exterior Horizontal Slats ~~for PAF~~

NA7.4.5.1 Procedures

These procedures detail the installation and verification protocols necessary to meet acceptance requirements of interior and exterior horizontal slats ~~for PAF~~. In addition, the responsible person shall fill out Certificate of Acceptance. The responsible person shall verify the horizontal slat to be installed matches the energy compliance documentation (Certificate of Compliance) and building plans. A copy of the Installation and Acceptance certificate shall be given to the building owner and the enforcement agency for their records.

For buildings with up to and including seven (7) horizontal slat assemblies that claim the Interior and Exterior Horizontal Slats for PAF or RSHGC for exterior horizontal slats, all horizontal slat assemblies shall be tested by the person responsible for the Certificate of Acceptance. For buildings with more than seven (7) horizontal slat assemblies ~~claiming the PAF~~, random sampling may be done to select the seven horizontal slat assemblies. If any of the horizontal slat assemblies in the sample group or seven horizontal slat assemblies fails the acceptance test, another group of seven horizontal slat assemblies must be tested.

4.6.4 ACM Reference Manual

3.1.10.2 Building Envelope Loads

- The effect of shading from overhangs ~~or~~, side fins, or exterior horizontal slats.

5.5.7 Fenestration

External Shading Devices	
Applicability	All fenestration
Definition	Devices or building features that are documented in the construction documents and shade the glazing, such as overhangs, fins, shading screens, and setbacks of windows from the exterior face of the wall. The Title 24 compliance software shall be capable of modeling vertical fins, horizontal slats, and overhangs. Recessed windows may also be modeled with side fins, horizontal slats, and overhangs.
Units	Data structure: surface

Input Restrictions	No restrictions other than that the inputs must match the construction documents
Standard Design	The Standard Design building is modeled without external shading devices.
Standard Design: *Existing Buildings*	No shading devices

4.6.5 Compliance Manuals

Sections 3.3, 3.5, and 11.3 of the Nonresidential Compliance Manual would need to be revised. The default values for U-factor and RSHGC in the Energy Standards would be updated so the copies of those tables in the Nonresidential Compliance Manual would be revised to reflect those changes.

4.6.6 Compliance Documents

NRCI-ENV-01-E forms would need to be updated to include the proposed values for wall and roof prescriptive U-factor.

5. Opaque Envelope

5.1 Submeasure Description

5.1.1 Measure Overview

The opaque envelope of a building refers to all aspects of the envelope that are not transparent. This submeasure proposes increasing existing insulation requirements for walls and roofs. Cool roofs and roof alterations have their own proposed standards (see Sections 2 and 3 of this report). Better insulation reduces demand on HVAC equipment and increases comfort, with zero or minimal impact to building aesthetics.

The rate of heat transfer though the envelope is determined by its U-factor. This proposal would lower existing U-factor requirements, taking climate zone into account to ensure cost effectiveness. Like the existing requirements, these new requirements would be prescriptive and impact nonresidential new construction and additions. The wall insulation requirements would also be applicable to alterations whereas the roof alterations recommendations are described in Section 3 of this report. This proposal would not add or modify field verification or acceptance tests or require any technology not previously regulated. See Table 124 for a summary of the proposed scope. It would require a software update to account for the new standard design.

Currently, hotel/motel buildings are subject to two different sets of envelope requirements. Requirements in Table 140.3-B apply to nonresidential spaces and requirements in Table 140.3-C apply to guestroom spaces. This proposal would simplify requirements for hotel/motel by removing requirements that only apply to guestroom space. Requirements in Table 140.3-B, which would be updated by this proposal, would apply to the entire hotel/motel building. See Appendix M: for recommendations for hotel / motel.

Table 124: Scope of Code Change Proposal – Opaque Envelope

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)
Opaque Envelope	Prescriptive	140.0, 140.3	N/a	Yes	N/A

5.1.2 Measure History

Opaque envelope requirements were first evaluated for inclusion in Title 24, Part 6 in 2008, and most recently updated in 2016. Due to then-current envelope technologies, other measures were prioritized throughout the 2019 code change cycle. Other codes, such as ASHRAE 90.1, also evaluate assembly U-factors and have been updated since. Like Title 24, Part 6, ASHRAE 90.1 recommends different values for different climate zones. With the most recent ASHRAE 90.1 updates as well as advancing envelope technologies, opportunity exists to update Title 24, Part 6 to reflect the current market capabilities and increase building envelope efficiency. Updates to the 2022 Title 24, Part 6 language include separating the multifamily high-rise language from the nonresidential language, so this section only applies to nonresidential buildings.

This proposal is based on updated cost parameters and builds off of the Opaque Envelope CASE Report from the 2016 code cycle (California Statewide Codes and Standards Team 2014). The energy impact of U-factors can be modeled in building energy modeling software, and the optimized results feed directly into the proposed code changes.

5.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 5.6 of this report for the detailed revisions to code language being proposed.

5.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 1.1.1 of this report for marked-up code language.

— **SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES**

The purpose of the proposed prescriptive regulation is to update assembly U-factors, specifically for walls and roof, to increase overall building envelope efficiency. This change is necessary to prevent significant energy consumption from building cooling and heating loads. The prescriptive compliance approach remains the same, using updated U-factor criteria.

- **Table 140.3-B:** The purpose of this change is to increase stringency of prescriptive envelope U-factor criteria.
- **Table 140.3-C:** The purpose of this change is to remove the table and simplify the code. The Statewide CASE Team is proposing to split out the multifamily code language into its own section, as described in the multifamily restructuring CASE Report. The hotel/motel guest room requirements would be the same as the rest of the nonresidential requirements included in Table 140.3-B.

5.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the reference appendices.

5.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would modify Section 5.5 of the Nonresidential ACM Reference Manual. Other than updating the standard design construction assemblies to prescriptive requirements outlined in Title 24, Part 6 Tables 140.3B and 140.3-C, no changes are expected.

5.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

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

- Table 3-6: Roof/Ceiling U-Factor Requirements
- Table 3-8: Wall U-Factor Requirements

5.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would not modify the compliance documents.

5.1.4 Regulatory Context

5.1.4.1 Existing Requirements in Title 24, Part 6

The existing maximum assembly U-factor requirements in Title 24, Part 6 are listed in Tables 140.3-B and 140.3-C. These values vary by climate zone, envelope component (roof, wall, floor, door) and material. This proposal does consider the tradeoff to the cool roof requirements that allows for additional roof/ceiling insulation rather than cool roof installation, and the Statewide CASE Team intends this tradeoff to remain. This tradeoff would be updated so that additional insulation tradeoff achieves energy performance similar to cool roofs (Section 2) while changes to the roof recovers and alterations code language is described in Section 3. The tradeoff is further detailed in Appendix J:

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

Chapter 12 of the California Building Code (Title 24, Part 2) includes insulation requirements for condensate control that apply to unvented enclosed wood frame assemblies. Section 1203.2: Ventilation Required and Section 1203.3: Unvented Attic and Unvented Enclosed Rafter Assemblies have a relationship with this section of the code. These sections contain R-value requirements for the insulation, and information on permeability of the insulation on the underside of the roof deck. This is specifically seen in Climate Zone 14 and Climate Zone 16.

Relationship to Local, State, or Federal Laws

Assembly U-factors are required in most national and state energy codes.

5.1.4.3 Relationship to Industry Standards

ASHRAE 90.1 also includes opaque envelope standards that vary by climate zone. IECC has U-factor requirements that are based on assembly type and insulation placement. The proposed changes to Title 24, Part 6 are based on cost-optimized values for California climate zones developed using California prototype buildings and the Title 24, Part 6 compliance software ruleset, and therefore may not match ASHRAE 90.1 stringency.

5.1.5 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. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E: presents the impact proposed changes may have on various market actors.

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

- **Design Phase:** Building designers must be aware of the code changes to the envelope U-factors. The qualified design reviewer, per commissioning requirements, as well as energy consultants and compliance documentation authors must verify that plans and specifications match, and therefore meet the requirements of Title 24, Part 6.
- **Permit Application Phase:** Plans examiners would verify that the project meets new envelope U-factor requirements by ensuring that the compliance documentation (NRCC) matches the plan and specifications.
- **Construction Phase:** Envelopes would be built to new U-factor requirements per energy documentations and/or specifications. Installers need to complete the required installation certificates (NRCI).
- **Inspection Phase:** Building inspectors would verify that the U-factor meets what is listed on energy documentation, plans, and/or specifications.

The compliance process would not vary from the current compliance process, with designers, builders, and compliance officials referencing the same tables with updated values.

5.2 Market Analysis

5.2.1 Market Structure

The Statewide CASE Team performed a market analysis to identify current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Researchers gathered information regarding the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors including roofing manufacturers, industry advocates, and building consultants. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings held on October 24, 2019, and April 23, 2020.

The nonresidential building envelope market involves many market actors in a variety of roles. This includes designers, architects, component manufacturers (shell, insulation, etc.), installers, construction companies, and certification/compliance specialists. The opaque envelope submeasure would have some impact on all of these market actors. Designers and architects would have to be aware of the new code changes and then design to those requirements. Examiners would need to verify that the project meets new envelope U-factor requirements; builders would need to build to the correct specifications; and inspectors would need to verify that the assembly U-factor meets what is listed in the specifications.

The market actors most impacted by this submeasure would likely be designers and architects. This submeasure does not consider new technologies, so component manufacturers would not be greatly impacted. This proposal would necessitate that designers learn the new U-factor requirements and factor those into their designs. This could be accomplished with current techniques and materials. Compliance specialists would need to learn the new standards and verify building compliance if those buildings were created following the prescriptive path.

Component manufacturers, design-build consultants, and industry organizations have been the most vocal actors for this code cycle. The most common feedback for the opaque envelope submeasure has highlighted the necessity for cost effectiveness, since the submeasure considers the entirety of the building envelope.

5.2.2 Technical Feasibility, Market Availability, and Current Practices

No new materials or processes would need to be developed for submeasure success. There are different requirements for different construction materials and methods, such as wood-framed, metal-framed, and mass walls, and many products are available to enable designers to meet or exceed the proposed standards. Best practices of installation and maintenance are well understood.

Common types of wall insulation for commercial buildings include rigid continuous insulation, polyisocyanurate, and expanded polystyrene foam. Thicker studs (2 x 6) are commonly used to create room for additional cavity insulation. When continuous insulation is specified, one to three inches of rigid insulation are applied as an additional layer to increase efficiency. For mass walls, common practice is to partially grout concrete masonry unit (CMU) walls to allow more cavities to be filled with insulation, while reduced webbed CMUs are sometimes employed. Wood-framed, metal-framed, and mass walls remain techniques used in nonresidential construction.

The Statewide CASE Team held two separate stakeholder meetings, and conducted general and envelope-specific outreach in preparation, to ensure participation. Solid support for updating assembly U-factors in the prescriptive path was found, along with acceptance that the nonresidential market description is valid.

Stakeholders indicated that assemblies that could meet the requirements included 2 x 8 studs, staggered 2 x 4 studs on 2 x 8 plate, or 2 x 10 plate. Additional insulation to meet the proposed requirements could range between 0.5-2.0 inches in thickness, depending on the material. Concerns were raised regarding fasteners for thicker continuous insulation. Further stakeholder discussion indicated that fasteners are feasible for the proposed assemblies. The assemblies described do not require exterior rigid insulation, and there is no single design required by the language in Title 24, Part 6.

5.2.2.1 Fire Safety

The issue of flammability was raised during the second stakeholder meeting. Some stakeholders indicated that they were able to avoid flammable exterior insulation. To meet these concerns, there is no single exterior insulation technology recommended by the Statewide CASE Team.

One stakeholder stated that materials that could fit the proposed values include Cascadia clip, Smart Continuous Insulation (CI) fiberglass girts, Knight CI, and mineral fiber insulation (MFI). Another stakeholder raised the point that no single material should be required, which aligns with the Statewide CASE Team's proposal that recommends a more stringent assembly U-factor rather than requiring a specific assembly. Stakeholders expressed support for this approach, and the stakeholder that presented a list of materials that could fit the proposed values stated that their work has been in high-rise multifamily projects that are able to avoid flammable exterior insulation (Statewide CASE Team 2020).

Following these comments, the Statewide CASE Team reached out to additional wall industry stakeholders. One of these conversations highlighted expanded polystyrene foam, a lightweight foam insulation, as a cost-effective solution for more stringent U-factors. This insulation is used with all framing types. The Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components (NFPA 285) becomes relevant for buildings with multiple stories. The standard provides a test method for determining the fire propagation characteristics of exterior wall assemblies and panels used as components of curtain wall assemblies that are constructed using combustible materials or that incorporate combustible components (NFPA 285). As discussed with multiple stakeholders who work on relevant projects, NFPA 285 is often triggered for buildings with three or more stories (Brown 2020).

Polyisocyanurate was mentioned by multiple stakeholders as a viable option for higher performing insulation. The material has seen widespread usage and, as with all plastic insulative materials, must achieve the minimum requirements specified in the building codes (Polyisocyanurate Insulation Manufacturers Association n.d.).

The Statewide CASE Team engaged with the North American Building Alliance (NAMBA) which is an alliance of trade associations and companies that represents the plastics industry in the building sector with a mission to promote fire-safety policies to support the use of these materials in the construction sector. Their representatives stated that there should be no difference in the application of NFPA 285 for the compliance of the proposed wall factors. While other stakeholders had focused on mineral wool as a non-combustible insulation option, this is not the only option. With additional thickness of continuous insulation, presented by NAMBA as 0.6-1.25 inches of foam plastic insulation for the proposed U-factors, there might be need for additional testing, but this would not negatively impact fire safety. NAMBA stated that more stringent U-factors do not mean a fire or combustibility issue (Banks and Greenwald 2020). Additionally, the Statewide CASE Team met with a representative from the California Office of the State Fire Marshal who was in agreement that the proposed U-factors would not be a fire safety issue but might necessitate additional testing.

5.2.3 Market Impacts and Economic Assessments

5.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. However, it is standard practice for these businesses to continually adjust to changes in design practices and building codes, which may include engaging in continuing education and training to remain compliant.

California's construction industry is made up of about 80,000 business establishments and 860,000 employees (see Table 125).[27] In 2018, total payroll was $80 billion. Of these, 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in residential, industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 125: 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 opaque envelope 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 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 126 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report.

Builders would need to factor in higher up-front costs of envelope assembly pricing to their bids. They may have to consider longer lead times when ordering if products have lower market availability. Installation processes and costs would be the same as current requirements.

The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 5.2.4 Economic Impacts.

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

Table 126: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Commercial building construction	4,508	75,558	$6.9
Nonresidential poured foundation contractors	504	14,917	$1.1
Nonresidential structural steel contractors	318	12,044	$0.9
Nonresidential Framing Contractors	148	3,991	$0.2
Nonresidential Masonry Contractors	254	5,121	$0.3
Nonresidential Roofing Contractors	347	8,939	$0.6
Nonresidential Siding Contractors	25	396	$0.0
Other Nonresidential exterior contractors	277	2,879	$0.2
Nonresidential Drywall Contractors	625	22,704	$1.7

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

5.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes 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 to remain compliant with these changes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (NAICS 541310). Table 127 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for opaque envelope to affect firms that focus on nonresidential construction.

There is no NAICS code specifically for energy consultants.[28] Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is composed of firms primarily

[28] 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 developed 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.

engaged in the physical inspection of residential and nonresidential buildings.[29] It is not possible to determine which business establishments in the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 127 provides an upper bound indication of the size of this sector in California..

Table 127: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (millions $)
Architectural Services [a]	3,704	29,611	$2,906.7
Building Inspection Services [b]	824	3,145	$223.9

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

Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;

a. 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.

5.2.3.3 Impact on Occupational Safety and Health

The proposed code changes would apply to healthcare facilities. 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. 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.

5.2.3.4 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, mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial

[29] 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 contaminants, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas is consumed primarily for heating water and for space heating. According to the 2019 California Energy Efficiency Action Plan, more than 7.5 billion square feet of commercial floor space in California accounts for 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 5.3, when building occupants save on energy bills, they tend to spend it elsewhere in the economy, thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

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

Retailers, manufacturers, and distributors who offer higher performing wall and roof assemblies could have increased business from proposed code modifications. Some retailers and manufacturers may need to increase production or availability of these lower U-factor technologies.

5.2.3.6 Impact on Building Inspectors

Table 128 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 128: 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.

5.2.3.7 Impact on Statewide Employment

As described in Sections 5.2.3.1 through 5.2.3.7, 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 5.2.4, the Statewide CASE Team estimates how the proposed change in opaque envelope would affect statewide employment and economic output, both directly and indirectly, through its impact on builders, designers, energy consultants, and building inspectors. In addition, the Statewide CASE Team estimates how energy savings associated with the proposed change in opaque envelope would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

5.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN modelling software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes.[30] While this is the first code cycle in which the Statewide CASE Team use IMPLAN to develop estimates of economic impacts, 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. The Statewide CASE Team is

[30] 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.

confident that direction and approximate magnitude of the estimated economic impacts are reasonable. However, it is important to understand that the IMPLAN model provides a relatively simple representation of the California economy—i.e., it is a simplification of extremely complex actions and interactions of individuals, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspects 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, architects, energy consultants, and building inspectors. 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 129: Estimated Impact that Adoption of the Proposed Submeasure Would Have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct Effects (Additional spending by commercial builders)	249	$16.49	$21.84	$36.14
Indirect Effect (Additional spending by firms supporting commercial builders)	54	$3.95	$6.29	$12.13
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	109	$6.11	$10.93	$17.84
Total Economic Impacts	**412**	**$26.55**	**$39.06**	**$66.11**

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

5.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the submeasure 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 this section would lead to modest changes in employment of existing jobs.

5.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 5.2.4.1, 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 building assembly practices which would not excessively burden or competitively disadvantage California businesses, nor necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created nor think any existing businesses would be eliminated due to the proposed code change.

5.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code change would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[31] Therefore, the Statewide CASE Team does not anticipate that this submeasure would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate that businesses located outside of California would be advantaged or disadvantaged.

5.2.4.4 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 NPDI).[32] As Table 130 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.

[31] 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.

[32] Net private domestic investment (NPDI) is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

Table 130: 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	$609.25	$1,740.35	35%
2016	$455.98	$1,739.84	26%
2017	$509.28	$1,813.55	28%
2018	$618.25	$1,843.71	34%
2019	$580.85	$1,826.97	32%
		5-Year Average	**31%**

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

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed submeasure 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 was able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 129 through Table 130 above by 31 percent for an estimated increase of $140,313.

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

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

5.2.4.6 Cost of Enforcement

Cost to the State

State government already has budgets 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 cost savings and policy benefits associated with the code change proposals. Opaque envelope may impact new construction state buildings. The proposed code changes have been found to be cost effective.

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 retraining 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. Numerous resources are 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 5.1.5 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.

5.2.4.7 Impacts on Specific Persons

While the objective of any Statewide CASE Team proposal is to promote energy efficiency, the Statewide CASE Team recognizes the potential that a proposed code change may result in unintended consequences. There are no foreseen impacts on specific persons or groups. The technologies to meet the proposed code changes are neither proprietary nor sole-sourced.

5.3 Energy Savings

5.3.1 Key Assumptions for Energy Savings Analysis

The final 2022 Time Dependent Valuation (TDV) factors were used for the analyses presented in this report (Energy + Environmental Economics 2020). The Energy Commission developed a source energy metric (energy design rating or EDR 1) for the 2022 code cycle.

The Statewide CASE Team used EnergyPlus v9.0.1 to conduct the energy savings calculations for all code change proposals. Energy models are sourced from the CBECC-Com prototypical building models. These models are modified to include the proposed changes to the energy standards. The 2019 Standard Design also serves as the baseline, a conservative assumption. This proposal is evaluating changes to new construction.

The modeling evaluated an additional R-4 for new construction for both roof and walls. All 16 climate zones were included in the modeling evaluation and statewide results for both the roof and wall components of this submeasure.

5.3.2 Energy Savings Methodology

5.3.2.1 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 prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 131. The Grocery building model is sourced from the CPUC DEER because there are currently no prototype models developed in CBECC-Com for these building types. The Hospital building model is sourced from the DOE's Commercial Prototype Buildings ASHRAE 90.1-2016. The RetailMixedUse prototype was used to estimate impacts of revised wall insulation requirements, but since the prototype does not have a roof it was not used to simulate impacts of changes to the roof insulation requirements.

The baseline model is generated for these building types by modifying the models with the 2019 Title 24, Part 6 mandatory and prescriptive envelope requirements. The submeasure applies to new construction.

The Statewide CASE Team modeled energy and cost savings for two scenarios: an additional R-2 and an additional R-4. It is conventional to model these values in increments. Both scenarios proved to be cost effective, so the results for the additional R-4 are included in this report as they are more stringent. The further breakdowns of corresponding U-factors from this scenario by climate zone for roof and wall are listed in Table 132.

Table 131: Opaque Envelope Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)	Description
Grocery	1	50,002	6-zone Grocery Store DEER prototype model provided by SCE
Hospital	3	249,980	3-story hospital DEER prototype model provided by SCE
OfficeLarge	12	498,589	12-story + 1 basement office building with 5 zones and a ceiling plenum on each floor. WWR-40%
OfficeMedium	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeMediumLab	3	53,628	3-story office building with 5 zones and a ceiling plenum on each floor. WWR-33%
OfficeSmall	1	5,502	1-story, 5 zone office building with pitched roof and unconditioned attic. WWR-24%
RestaurantFastFood	1	2,501	Fast food restaurant with a small kitchen and dining areas. WWR-14%. Pitched roof with an unconditioned attic
RetailLarge	1	240,000	Big-box type retail building with WWR -12% and SRR-0.82%
RetailMixedUse	1	9,375	Retail building with WWR -10%. Roof is adiabatic
RetailStandAlone	1	24,563	Similar to a Target or Walgreens. WWR-7% on the front façade, none on other sides. SRR-2.1%.
RetailStripMall	1	9,375	Strip mall building. WWR-10%
SchoolPrimary	1	24,413	Elementary school. WWR-36%
SchoolSecondary	2	210,866	High school. WWR-35% and SRR-1.4%
Warehouse	1	49,495	Single story high ceiling warehouse. Includes one office space. WWR-0.7%,SRR-5%

CBECC-Com generates two models based on user inputs: the Standard Design and the Proposed Design. The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Nonresidential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building. There are existing requirements for building envelopes in Title 24, Part 6 which apply to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 132 presents how the parameter “U-Factor (without air film)” was modified for both roof and wall components, and which values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume more stringent U-factors.

Hotels and motels currently have to comply with requirements in Table 140.3-B for nonresidential spaces and requirements in Table 140.3-C for guestroom spaces. Appendix M: further details the recommended simplifications for hotel/motel envelope prescriptive requirements.

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

Table 132: U-Factor Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Roof Standard Design Parameter Value	Roof Proposed Design Parameter Value	Wall Standard Design Parameter Value	Wall Proposed Design Parameter Value
All	1	0.035	0.031	0.073	0.057
All	2	0.035	0.031	0.065	0.052
All	3	0.035	0.031	0.088	0.065
All	4	0.035	0.031	0.065	0.052
All	5	0.035	0.031	0.065	0.052
All	6	0.051	0.042	0.073	0.057
All	7	0.051	0.042	0.073	0.057
All	8	0.051	0.042	0.065	0.052
All	9	0.035	0.031	0.065	0.052
All	10	0.035	0.031	0.065	0.052
All	11	0.035	0.031	0.065	0.052
All	12	0.035	0.031	0.065	0.052
All	13	0.035	0.031	0.065	0.052
All	14	0.035	0.031	0.065	0.052
All	15	0.035	0.031	0.065	0.052
All	16	0.035	0.031	0.065	0.052

Using EnergyPlus with CBECC-Com rulesets the Statewide CASE Team determined whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). The 2022 TDV factors were then applied 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) (Energy + Environmental Economics 2020). TDV energy cost savings were calculated using the TDV energy cost impacts over the 30-year period of analysis presented in 2023 present value dollars (2023 PV$).

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

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

5.3.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that would 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 133 presents the prototypical buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

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

Table 133: Nonresidential Building Types and Associated Prototype Weighting, Opaque Envelope

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%
	SchoolSecondary	30%
	ApartmentHighRise	25%
Hospitals	Hospital	100%

5.3.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit for new construction are presented in Table 134 through

Table 136, reflecting the savings for updates to roof and wall new construction requirements. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. The energy models were run across all climate zones, and results are only shown for cost effective scenarios. All simulated results used the weather files the Energy Commission provided, which are based on historic weather.

Energy savings per square foot of total building square footage are presented in the tables below. Electricity savings are shown in Wh/ft^2. Natural gas savings are shown in millitherm/ft^2. Total TDV energy savings are shown in TDVKBtu/ft^2. When the proposed code change would increase energy use, the energy savings are negative and savings are shown as negative, depicted in red font and in parentheses ( ). The Statewide CASE Team evaluated the energy savings of all prototypical buildings in all climate zones and reviewed results to inform recommended code changes.

The gas savings for both the roof and wall energy modeled savings are more positive than the electricity savings, with the only negative savings in Climate Zone 5 for the hospital building prototype. Overall TDV savings range from 03.44 to 14.44 per square foot.

Table 134: Opaque Envelope Electricity Savings Per Square Foot (Wh/ft²) by Climate Zone and Prototype Building

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	93.9	93.8	92.2	94.1	75.4	92.6	93.3	130.1	86.1	95.0	114.3	108.5	126.2	148.0	124.2	78.0
Hospital	(18.7)	(10.2)	(24.2)	(6.6)	(22.6)	(3.7)	(3.2)	9.8	218.6	9.9	(13.9)	(2.6)	16.1	(12.9)	24.2	(1.1)
OfficeLarge	(3.9)	3.2	(3.7)	1.8	11.7	21.3	5.5	8.9	4.1	13.2	5.5	3.3	24.1	16.8	11.4	(6.0)
OfficeMedium	(0.3)	5.2	1.2	5.2	1.0	7.3	6.1	14.1	11.5	12.4	18.6	10.8	23.6	19.6	38.0	5.9
OfficeMediumLab	(1.1)	6.2	2.0	3.8	2.0	7.3	6.1	14.3	10.3	11.4	16.5	10.1	20.2	16.0	38.6	4.6
OfficeSmall	14.0	78.1	57.7	67.9	40.9	122.2	96.9	141.5	88.3	111.0	126.0	91.1	126.4	110.2	209.4	91.1
Restaurant FastFood	50.5	109.9	92.2	126.3	81.8	158.0	118.1	147.2	133.6	147.8	146.5	127.1	155.6	137.6	335.3	96.5
RetailLarge	(1.9)	4.1	8.8	(23.4)	(1.6)	(12.1)	(14.9)	(21.0)	(22.6)	(20.7)	3.7	21.5	8.5	(11.9)	(13.6)	9.2
RetailMixedUse	(23.4)	(10.0)	(17.5)	3.7	(27.4)	(26.3)	(13.1)	14.6	(18.9)	(28.2)	8.7	0.4	9.1	85.2	69.0	(12.9)
RetailStandAlone	(16.6)	15.9	2.6	(11.4)	(6.3)	13.4	(6.8)	98.9	(18.9)	39.3	0.7	(29.4)	53.2	35.7	73.5	21.5
RetailStripMall	(24.1)	154.3	33.6	(25.3)	24.6	(52.8)	(15.8)	(1.9)	(1.9)	(54.1)	(1.5)	7.5	28.2	(6.9)	159.8	9.1
SchoolPrimary	(0.4)	64.9	24.2	24.5	(9.6)	25.7	17.2	43.9	31.3	44.3	42.7	40.1	46.9	38.3	83.7	31.2
SchoolSecondary	4.9	7.8	2.8	7.4	10.9	6.5	4.4	18.4	9.8	13.6	32.8	12.5	37.3	21.2	33.1	19.1
Warehouse	(0.8)	(1.1)	(0.8)	(2.5)	(3.0)	0.1	0.9	(1.3)	(1.1)	(5.3)	(1.8)	(0.7)	(2.1)	(0.5)	(2.1)	(0.5)

Table 135: Opaque Envelope Natural Gas Savings Per Square Foot (millitherm/ft^2) by Climate Zone and Prototype Building

Prototype Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	7.87	3.85	3.99	2.82	3.22	2.35	1.89	2.15	1.99	2.06	4.00	3.40	2.78	3.02	1.21	7.86
Hospital	3.22	2.06	1.73	2.16	(0.17)	0.27	1.82	1.49	3.06	1.57	1.69	2.60	2.93	3.67	1.18	2.68
OfficeLarge	2.76	1.99	2.29	1.28	1.84	2.39	1.51	1.19	1.22	1.28	1.58	1.44	1.87	2.19	0.56	2.57
OfficeMedium	5.51	3.57	3.70	2.32	2.72	2.19	1.88	2.03	1.69	1.81	2.80	2.82	2.36	2.74	1.09	5.33
OfficeMediumLab	7.67	4.90	6.32	4.49	4.76	4.08	3.56	3.37	2.73	2.64	3.37	4.12	2.12	3.20	0.09	6.33
OfficeSmall	8.42	3.86	3.79	2.39	2.91	1.04	0.91	1.23	1.15	1.52	3.62	3.54	2.82	3.49	0.39	8.14
Restaurant FastFood	15.71	9.82	13.10	7.43	9.18	6.56	5.62	5.55	5.29	5.72	8.16	8.29	6.37	7.66	3.09	10.27
RetailLarge	9.50	5.38	5.05	3.64	4.14	3.19	2.83	3.21	2.24	2.58	4.92	4.64	3.95	4.53	1.15	9.48
RetailMixedUse	6.63	2.95	3.38	1.75	1.96	0.67	0.51	0.60	0.88	1.18	3.24	2.73	2.47	2.41	0.43	6.63
RetailStandAlone	13.62	7.77	8.53	5.31	6.10	4.16	3.63	4.07	3.47	3.83	7.34	7.03	5.73	6.60	1.91	13.06
RetailStripMall	14.42	6.43	7.54	4.96	5.15	2.98	2.57	3.06	2.89	3.54	7.57	7.05	6.12	6.41	1.30	14.44
SchoolPrimary	9.95	4.48	5.01	3.28	4.38	2.55	2.11	2.53	1.97	2.37	4.64	4.48	3.66	4.35	0.95	9.05
SchoolSecondary	7.18	4.84	5.05	3.62	4.22	3.80	3.35	3.93	2.74	2.94	4.22	4.32	3.44	4.13	1.62	7.57
Warehouse	10.71	5.38	5.85	3.85	4.15	2.88	2.78	2.89	2.26	2.64	5.35	4.93	4.05	4.34	1.32	9.36

Table 136: Opaque Envelope - TDV Energy Savings Per Square Foot (TDVKBtu/ft^2) by Climate Zone and Prototype Building

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	4.88	4.15	3.89	3.91	3.01	3.47	3.22	4.69	3.37	3.55	4.93	4.53	4.89	5.55	4.20	4.54
Hospital	0.61	0.62	0.08	0.62	(0.61)	0.14	0.40	0.88	6.92	1.00	0.52	0.89	1.22	1.27	1.32	0.95
OfficeLarge	0.69	0.75	0.63	0.51	0.87	1.38	0.59	0.67	0.52	0.78	0.67	0.62	1.39	1.37	0.52	0.57
OfficeMedium	1.61	1.37	1.21	1.04	0.84	0.90	0.73	1.15	1.09	1.02	1.64	1.35	1.64	1.68	1.53	1.81
OfficeMediumLab	2.21	1.80	1.98	1.76	1.44	1.46	1.24	1.59	1.37	1.27	1.64	1.68	1.32	1.70	1.70	1.98
OfficeSmall	2.92	3.61	2.88	2.88	1.92	3.62	2.77	4.50	3.04	3.62	4.95	3.88	4.71	4.43	6.09	4.78
Restaurant FastFood	6.02	6.30	6.56	10.78	4.82	6.29	4.64	5.72	5.60	5.98	6.74	6.35	6.38	6.34	14.44	5.61
RetailLarge	2.86	0.32	2.40	(1.29)	1.23	(3.44)	(0.70)	0.36	(0.65)	0.63	1.07	3.49	1.08	0.02	(0.04)	3.15
RetailMixedUse	1.43	0.93	2.55	(0.26)	(0.86)	0.30	(0.15)	0.80	0.14	0.05	1.97	1.19	2.77	1.03	2.32	1.76
RetailStandAlone	3.60	3.85	1.60	2.16	1.23	1.95	0.54	5.60	2.39	(0.09)	2.72	(1.75)	6.75	3.84	11.04	4.44
RetailStripMall	3.74	6.64	3.34	1.32	1.96	(0.27)	0.68	1.65	2.01	(1.65)	2.26	3.69	2.62	2.63	5.31	4.74
SchoolPrimary	2.95	3.53	2.29	1.88	1.05	1.62	1.08	2.15	1.74	2.20	2.90	2.71	2.80	2.76	2.87	3.56
SchoolSecondary	2.26	1.71	1.58	1.37	1.50	1.33	1.11	1.81	1.24	1.33	2.25	1.64	2.15	2.00	1.51	2.84
Warehouse	3.16	1.68	1.78	1.16	1.23	0.93	0.90	0.90	0.70	0.69	1.64	1.54	1.25	1.37	0.39	2.85

5.4 Cost and Cost Effectiveness

5.4.1 Energy Cost Savings Methodology

The proposed code change applies to new construction only. 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 5.3.2. 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 nonresidential envelope measures). In this case, the period of analysis used is 30 years. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years. Appendix K: presents the energy cost savings in nominal dollars.

5.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed that are realized over the 30-year period of analysis are presented in 2023 dollars in the following tables. Appendix K: presents the energy cost savings in nominal dollars.

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

Table 137: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – OfficeLarge, Opaque Envelope

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($0.02)	$0.12	$0.11
2	$0.02	$0.09	$0.12
3	($0.01)	$0.10	$0.10
4	$0.02	$0.06	$0.08
5	$0.05	$0.08	$0.13
6	$0.10	$0.11	$0.21
7	$0.02	$0.07	$0.09
8	$0.05	$0.05	$0.10
9	$0.02	$0.06	$0.08
10	$0.06	$0.06	$0.12
11	$0.03	$0.07	$0.10
12	$0.03	$0.07	$0.10
13	$0.12	$0.09	$0.21
14	$0.11	$0.11	$0.21
15	$0.05	$0.03	$0.08
16	($0.03)	$0.12	$0.09

5.4.3 Incremental First Cost

The incremental costs include the incremental material cost of additional insulation. This cost information was gathered through calls to distributors, 2020 RS Means, and internet sales information. The cost associated with each R-value represents the incremental cost for an approximate range that includes additional R-4 (Arup 2020). The final model reflects the cost of adding an additional R-4 insulative value to both roof ($0.288/square foot roof) and wall ($0.10/square foot wall). Installation costs were assumed to remain the same, with a corresponding incremental first cost of $0 for labor. The R-4 costs for new construction roof continuous insulation align with the additions and alterations costs presented in Appendix O:.

Table 138 and Table 139 show the details of incremental first cost for each building prototype. The model input was the incremental cost per building square foot, calculated from the wall area and building areas shown in the following tables.

Table 140 shows the combined roof and wall costs that went into the cost and savings evaluation.

Table 138: Cost per Building Prototype, Opaque Envelope – Roof

Building Prototype	Building Area (ft²)	Measure Component Area (Roof, Area ft²)	Total Incremental Cost	Per Unit Incremental First Cost (2023 PV$/building area)
Grocery	50,002	50,002	$14,400.53	$0.29
Hospital	241,374	40,253	$11,592.90	$0.05
OfficeLarge	460,281	38,357	$11,046.74	$0.02
OfficeMedium	53,633	17,878	$5,148.77	$0.10
OfficeMediumLab	53,633	17,878	$5,148.77	$0.10
OfficeSmall	5,503	6,446	$1,856.34	$0.34
RestaurantFastFood	2,501	2,787	$802.54	$0.32
RetailLarge	240,023	236,647	$68,154.36	$0.28
RetailMixedUse	9,376	0	N/A	N/A
RetailStandAlone	24,566	24,183	$0.00	$0.00
RetailStripMall	9,376	9,376	$6,964.60	$0.28
SchoolPrimary	24,415	24,415	$2,700.26	$0.29
SchoolSecondary	210,907	126,277	$7,031.53	$0.29
Warehouse	52,050	47,025	$36,367.75	$0.17

Table 139: Cost per Building Prototype, Opaque Envelope – Wall

Building Prototype	Building Area (ft²)	Measure Component Area (Wall, Area ft²)	Total Incremental Cost	Per Unit Incremental First Cost (2023 PV$/building area)
Grocery	50,002	20,775	$2,077.52	$0.04
Hospital	241,374	46,709	$4,670.93	$0.02
OfficeLarge	460,281	76,604	$7,660.40	$0.02
OfficeMedium	53,633	14,262	$1,426.23	$0.03
OfficeMediumLab	53,633	14,262	$1,426.23	$0.03
OfficeSmall	5,503	2,388	$238.80	$0.04
RestaurantFastFood	2,501	1,721	$172.09	$0.07
RetailLarge	240,023	44,124	$4,412.43	$0.02
RetailMixedUse	9,376	4,966	$496.60	$0.05
RetailStandAlone	24,566	11,767	$1,176.70	$0.05
RetailStripMall	9,376	6,241	$624.07	$0.07
SchoolPrimary	24,415	8,988	$898.76	$0.04
SchoolSecondary	210,907	42,083	$4,208.33	$0.02

Table 140: Cost per Building Prototype, Opaque Envelope – Combined

Building Prototype	Building Area (ft^2)	Total Incremental Cost ($/building	Per Unit Incremental First Cost (2023 PV$/ ft^2 building area)
Grocery	50,002	$16,478.04	$0.33
Hospital	241,374	$16,263.83	$0.07
OfficeLarge	460,281	$18,707.13	$0.04
OfficeMedium	53,633	$6,575.00	$0.12
OfficeMediumLab	53,633	$6,575.00	$0.12
OfficeSmall	5,503	$2,095.15	$0.38
RestaurantFastFood	2,501	$974.63	$0.39
RetailLarge	240,023	$72,566.79	$0.30
RetailMixedUse	9,376	$496.60	$0.05
RetailStandAlone	24,566	$8,141.30	$0.33
RetailStripMall	9,376	$3,324.33	$0.35
SchoolPrimary	24,415	$7,930.29	$0.32
SchoolSecondary	210,907	$40,576.08	$0.19
Warehouse	52,050	$16,212.20	$0.31

5.4.4 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 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 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 expected useful life of building envelope insulation is 30 years per Energy Commission guidelines. Therefore, the opaque envelope submeasure is modeled and evaluated for a 30-year period. In many cases the insulation lifetime extends far beyond 30 years, with performance potentially degrading over time due to moisture accumulation within the envelope assembly (California Statewide Codes and Standards Team 2014).

There are no anticipated incremental maintenance and replacement costs that would result from maintenance varied from the baseline. Through a combination of public stakeholder meetings and targeted outreach, the Statewide CASE Team heard a mix of feedback both supporting this assumption and claiming that there could be added labor cost or material fastener cost due to increased thickness. With the release of the Draft CASE Report, the Statewide CASE Team specifically requested incremental cost information for maintenance and did not receive any additional data.

5.4.5 Cost Effectiveness

This submeasure proposes a prescriptive requirement. As such, a cost analysis is required to demonstrate that the submeasure is cost effective over the 30-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 to include in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas 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 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-unit cost-effectiveness analysis are presented in Table 141 for new construction with the updated roof and wall parameters. All B/C ratios under 1.0 are indicated in red, while parentheses indicate negative numbers.

The proposed submeasure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in all climate zones except Climate Zone 7 for both the wall and roof requirements, and has a construction forecast weighted average B/C Ratio of 1.37.

Table 141: Benefit-to-Cost Ratio by Climate Zone and Building Prototype, Opaque Envelope

Prototype / Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	2.28	1.94	1.82	1.83	1.41	1.62	1.51	2.19	1.57	1.66	2.31	2.12	2.28	2.59	1.96	2.12
Hospital	1.40	1.43	0.19	1.41	(1.38)	0.33	0.92	2.01	15.82	2.29	1.20	2.04	2.78	2.89	3.02	2.16
OfficeLarge	2.62	2.85	2.39	1.94	3.28	5.24	2.25	2.55	1.96	2.97	2.53	2.36	5.27	5.20	1.98	2.14
OfficeMedium	2.02	1.72	1.52	1.30	1.05	1.13	0.91	1.45	1.37	1.28	2.06	1.69	2.06	2.11	1.92	2.28
OfficeMediumLab	2.78	2.26	2.49	2.21	1.81	1.83	1.56	1.99	1.73	1.59	2.06	2.11	1.66	2.13	2.13	2.48
OfficeSmall	1.18	1.46	1.16	1.17	0.78	1.47	1.12	1.82	1.23	1.46	2.00	1.57	1.91	1.79	2.46	1.93
RestaurantFastFood	2.38	2.49	2.59	4.26	1.90	2.48	1.83	2.26	2.21	2.36	2.66	2.51	2.52	2.50	5.71	2.22
RetailLarge	1.46	0.16	1.22	(0.65)	0.62	(1.75)	(0.36)	0.18	(0.33)	0.32	0.55	1.78	0.55	0.01	(0.02)	1.61
RetailMixedUse	4.17	2.70	7.41	(0.76)	(2.50)	0.86	(0.44)	2.33	0.41	0.13	5.71	3.46	8.04	2.99	6.75	5.12
RetailStandAlone	1.67	1.79	0.75	1.00	0.57	0.90	0.25	2.60	1.11	(0.04)	1.26	(0.81)	3.14	1.79	5.13	2.07
RetailStripMall	1.62	2.89	1.45	0.58	0.85	(0.12)	0.30	0.72	0.87	(0.72)	0.98	1.60	1.14	1.14	2.31	2.06
SchoolPrimary	1.40	1.68	1.09	0.89	0.50	0.77	0.51	1.02	0.83	1.04	1.38	1.29	1.33	1.31	1.36	1.69
SchoolSecondary	1.81	1.37	1.26	1.10	1.20	1.06	0.88	1.45	0.99	1.06	1.80	1.31	1.72	1.60	1.21	2.27
Warehouse	1.56	0.83	0.88	0.57	0.61	0.46	0.45	0.45	0.35	0.34	0.81	0.76	0.62	0.68	0.19	1.41

5.5 First-Year Statewide Impacts

5.5.1 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 5.3.2, 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 first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 142 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. First-year statewide savings for additions and alterations were not evaluated.

Table 142: Statewide Energy and Energy Cost Impacts – New Construction, Opaque Envelope

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 (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.61	0.00	0.00	0.00	$0.23
2	3.61	0.08	0.01	0.02	$1.04
3	17.02	0.19	0.02	0.08	$4.90
4	8.75	0.09	0.00	0.03	$1.58
5	1.70	0.01	0.00	0.01	$0.32
6	11.71	0.25	0.01	0.03	$1.43
7	8.62	0.18	0.01	0.02	$1.38
8	16.91	0.44	0.02	0.04	$4.18
9	28.10	0.74	0.00	0.06	$6.18
10	15.75	0.36	0.04	0.04	$3.60
11	3.41	0.11	0.01	0.01	$1.21
12	18.54	0.47	0.04	0.07	$6.34
13	6.72	0.28	0.02	0.02	$2.54
14	3.67	0.11	0.02	0.01	$1.15
15	2.20	0.13	0.01	0.00	$0.82
16	1.18	0.03	0.00	0.01	$0.55
TOTAL	**148.50**	**3.46**	**0.20**	**0.46**	**$37.42**

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

Table 143: Statewide Energy and Energy Cost Impacts – New Construction Summary, Opaque Envelope

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (PV$ million)
New Construction - Total	3.46	0.20	0.46	37.42

5.5.2 Statewide Greenhouse Gas (GHG) Emissions Reduction

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the U.S. EPA eGRID for the 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 factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 144 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 3,330 metric tons of CO2e would be avoided.

Table 144: First-Year Statewide GHG Emissions Impacts, Opaque Envelope

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (million therms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Opaque Envelope (Wall and Roof)	3.46	830.82	0.46	2,499.14	3,329.96

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

b. Assumes the following emission factors: 240 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

5.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

5.5.4 Statewide Material Impacts

The material impacts of this submeasure would potentially include an increase in the use of continuous insulation products, such as rigid polyisocyanurate. There are no significant anticipated statewide impacts on material use.

5.5.5 Other Non-Energy Impacts

Increased insulation would improve occupancy comfort by regulating indoor temperature.

5.6 Proposed Revisions to Code Language

5.6.1 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).

5.6.2 Standards

SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE~~; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS~~)

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Maximum U-factor	Roofs/ Ceilings	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
			Wood Framed and Other	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.042 ~~0.049~~	0.042 ~~0.049~~	0.042 ~~0.049~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~	0.030 ~~0.034~~
		Walls	Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
			Metal-framed	0.060 ~~0.069~~	0.055 ~~0.062~~	0.071 ~~0.082~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.060 ~~0.069~~	0.060 ~~0.069~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~	0.055 ~~0.062~~
			Mass Light[1]	0.196	0.170	0.278	0.227	0.440	0.440	0.440	0.440	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
		Floors/ Soffits	Raised Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
			Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
	Roofing Products	Low-sloped	Aged Solar Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		Steep-sloped	Aged Solar Reflectance	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0. 75	0.75	0.75	0.75	0.75	0.75	0.75
	Air Barrier			NR	NR	NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Exterior Doors, Maximum U-factor		Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
			Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

5.6.3 Reference Appendices

The proposed code change would not modify the Reference Appendices.

5.6.4 ACM Reference Manual

This measure would impact the Standard Design construction assemblies, in Sections 5.5.3 of the Nonresidential ACM Reference Manual. The U-factors would be adjusted to reflect the more stringent, proposed values.

Section 5.5.3 Roofs, Page 5-68

<table>
<tr>
<td>Standard Design</td>
<td>
Roofs in the standard design are of the type “insulation entirely above deck.” The insulation requirement is determined by climate zone. The standard design building roof construction shall be modeled as layers defined. See Appendix 5.5B for details.
For new construction, the standard design roof type is wood-framed and other, and the roof is a standing seam metal roof, with the R-value of continuous insulation adjusted to match the prescriptive standards for wood-framed and other roofs. The U-factor required for roof construction is defined in Table 140.3-B, C, or D of the standards. Programs that model a U-factor shall include an exterior and interior air film resistance.
The standard design construction is based on JA4-10 Table 4.2.7 and assumes an exterior air film of R-0.17 and an interior air film of R-0.61.
The Standard design construction shall include the following Layers:
<table>
<tr><td>Layer 1</td><td>Metal Standing Seam 1/16 in.</td><td>R – 0.00</td></tr>
<tr><td>Layer 2</td><td>Continuous Insulation</td><td>R – Based on Climate Zone</td></tr>
<tr><td>Layer 3</td><td>Open Framing + No Insulation</td><td>R – 0.00</td></tr>
</table>
The value of the continuous insulation layer entirely above framing shall be set to achieve the following R-values:
Nonresidential Buildings: Continuous Insulation
<table>
<tr><td>Climate Zones 2, 3, 4, 9-16</td><td>R – ~~28.63~~ 32.63 (U-~~0.034~~0.030)</td></tr>
<tr><td>Climate Zones 1, 5</td><td>R – ~~28.63~~ 32.63 (U-~~0.034~~0.030)</td></tr>
<tr><td>Climate Zones 7, 8</td><td>R – ~~19.62~~ 23.62 (U-~~0.049~~0.042)</td></tr>
<tr><td>Climate Zones 6</td><td>R – ~~19.62~~ 23.62 (U-~~0.049~~0.042)</td></tr>
</table>
</td>
</tr>
</table>

Section 5.5.4 Exterior Walls, Page 5-72

Standard Design: Existing Buildings	The U-factor required for wall construction of the standard design building is defined in Table 140.3-B, C, or D of the

<table>
<tr><td></td><td>standards. Programs that model a U-factor shall use an extior and interior air film resistance. The standard design construction is based on JA4-10 Table 4.3.3 and assumes an exterior air film of R-0.17 and an exterior air film of R-0.68.

For metal framed walls, the standard design construction shall include the following layers:

<table><tr><td>Climate Zones 1, 6, and 7</td><td>R – ~~12.30~~ 16.30</td></tr><tr><td>Climate Zones 2, 4, 5, and 8 – 16</td><td>R – ~~13.94~~ 17.94</td></tr><tr><td>Climate Zone~~s~~ 3</td><td>R – ~~10.01~~ 14.01</td></tr></table></td></tr>
</table>

5.6.5 Compliance Manuals

Chapter 3 of the Nonresidential Compliance Manual would need to be revised to include the updated assembly U-factor requirements.

5.6.6 Compliance Documents

NRCI-ENV-01-E forms would need to be updated to include the proposed values for wall and roof prescriptive U-factor.

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Appendix A: Statewide Savings Methodology

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards would be in effect (2023). 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://ww2.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 19, Table 91, Table 104, and Table 133. These tables also identify the prototypical buildings that were used to model the energy use of the proposed code changes. This mapping was required because the building types the Energy Commission defined in the construction forecast are not identical to the prototypical building types that the Energy Commission requested that the Statewide CASE Team use to model energy use. This mapping is consistent with the mapping that the Energy Commission used in the Final Impacts Analysis for the 2019 code cycle (California Energy Commission 2018).

The Energy Commission's forecast allocated 19 percent of the total square footage of new construction in 2023 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings would be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types so that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, would remain constant. See Table 145 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

After the miscellaneous floorspace was redistributed, the Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. Table 158 presents the assumed percentage of floorspace that would be impacted by the proposed code change by building type and the percentage of floorspace assumed to be impacted by the proposed change by climate zone. 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.

Although the proposed code changes for this CASE Report will apply to the food, small school, and public assembly building categories, the Statewide CASE Team did not simulate energy impacts from the associated prototypical buildings and for this analysis no savings were attributed to these building types. In reality, there will be savings from these building types, so the statewide energy savings are likely understated for all submeasures.

Cool Roofs

Only steep-sloped changes are presented in this section since a low-sloped proposed is not made for Title 24, Part 6.

To calculate statewide savings for the cool roof submeasure, Climate Zones 1 and 3 were not included in the steep-sloped proposal. As noted in Section 2.3.2, hotels, high-rise apartments, retail buildings, groceries, and warehouses buildings are not included in these statewide results.

80 percent of the square footage of the small office and restaurant fast food and 20 percent of retail stand alone and retail strip mall prototypes were assumed to located in buildings with steep-sloped roofs.

Roof Alterations

The Statewide CASE Team assumed that roofs were either replaced or recovered after 15 years, with an even split based on feedback from PIMA. However, roofs that had previously been recovered would be replaced at the 30 year mark. The Statewide CASE Team therefore assumed that 2.5 percent of roofs were recovered every year and 4.2 percent were replaced every year – 6.7 percent of roofs are either recover or replaced each year, with 38 percent of them recovered and 62 percent of them replaced. All climate zones were included in the statewide savings analysis. As noted in Section 3.5.6, the following prototypes were excluded: Hospital and RetailMixedUse,.

High Performance Windows

Fixed windows: All Climate Zones were evaluated through energy modeling in CBECC-Com and are included in the cost-effective analysis. For building prototypes expected to contain curtain wall/storefront products, it was assumed that 80 percent of the building fenestration was fixed and 20 percent curtain wall/storefront. The climate zones found to be cost effective were 2, 5-9, and11 -15. The final results represent Fixed Modeling Scenario 1.

Curtain wall/storefront: All climate zones were included in the curtain wall/storefront modeling evaluation. The following building prototypes are not included in the statewide results due to lack of applicability of curtain wall/storefront fenestration: OfficeSmall, OfficeMedium, OfficeMediumLab, OfficeLarge, Refrigerated warehouse, SchoolPrimary, SchoolSecondary, and Hospital. The climate zones found to be cost effective were 1, 7, and 16. The final results represent Curtain wall/Storefront Scenario 3.

Opaque Envelope

All 16 climate zones and building prototypes were included in the modeling evaluation and statewide results for both the roof and wall components of this submeasure.

Impacted Buildings

Table 145: 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	---	---	---
TOTAL	0.686	100%	0.147	0.686

Table 146: Percent of Floorspace Impacted by Proposed Measure, by Building Type, Cool Roofs, Steep-Slope

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		80%	4%
Restaurant		80%	4%
Retail		12%	1%
Stand-Alone Retail	10%	20%	1%
Large Retail	75%	0%	0%
Strip Mall	5%	20%	1%
Mixed-Use Retail	10%	0%	0%
Food		0%	0%
Non-Refrigerated Warehouse		0%	0%
Refrigerated Warehouse		0%	0%
Schools		0%	0%
Small School	60%	0%	0%
Large School	40%	0%	0%
College		0%	0%
Small Office	5%	80%	4%
Medium Office	15%	0%	0%
Medium Office/Lab	20%	0%	0%
Public Assembly	5%	0%	0%
Large School	30%	0%	0%
High-Rise Apartment	25%	0%	0%
Hospital		0%	0%
Hotel/Motel		0%	0%
Offices		0%	0%
Medium Office	50%	0%	0%
Large Office	50%	0%	0%

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 147: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone, Cool Roofs, Steep-Slope

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	0%	0%
2	100%	100%
3	0%	0%
4	100%	100%
5	100%	100%
6	100%	100%
7	100%	100%
8	100%	100%
9	100%	100%
10	100%	100%
11	100%	100%
12	100%	100%
13	100%	100%
14	100%	100%
15	100%	100%
16	100%	100%

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

Table 148: Percent of Floorspace Impacted by Proposed Measure, by Building Type, Roof Replacements

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		0%	0.8%
Restaurant		0%	0.8%
Retail		0%	3.7%
Stand-Alone Retail	10%	0%	3.4%
Large Retail	75%	0%	4.2%
Strip Mall	5%	0%	3.4%
Mixed-Use Retail	10%	0%	0.0%
Food		0%	4.2%
Non-Refrigerated Warehouse		0%	4.2%
Refrigerated Warehouse		0%	0.0%
Schools		0%	4.2%
Small School	60%	0%	4.2%
Large School	40%	0%	4.2%
College		0%	1.9%
Small Office	5%	0%	0.8%
Medium Office	15%	0%	4.2%
Medium Office/Lab	20%	0%	0.0%
Public Assembly	5%	NA	NA
Large School	30%	0%	4.2%
High-Rise Apartment	25%	0%	0.0%
Hospital		NA	NA
Hotel/Motel		0%	0.0%
Large Offices		0%	4.2%
Medium Office	50%	0%	4.2%
Large Office	50%	0%	4.2%

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 149: Percent of Floorspace Impacted by Proposed Measure, by Building Type, Roof Recovers

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		0%	0.5%
Restaurant		0%	0.5%
Retail		0%	2.2%
Stand-Alone Retail	10%	0%	2.0%
Large Retail	75%	0%	2.5%
Strip Mall	5%	0%	2.0%
Mixed-Use Retail	10%	0%	0.0%
Food		0%	2.5%
Non-Refrigerated Warehouse		0%	2.5%
Refrigerated Warehouse		0%	0.0%
Schools		0%	2.5%
Small School	60%	0%	2.5%
Large School	40%	0%	2.5%
College		0%	1.2%
Small Office	5%	0%	0.5%
Medium Office	15%	0%	2.5%
Medium Office/Lab	20%	0%	0.0%
Public Assembly	5%	NA	NA
Large School	30%	0%	2.5%
High-Rise Apartment	25%	0%	0.0%
Hospital		NA	NA
Hotel/Motel		0%	0.0%
Offices		0%	2.5%
Medium Office	50%	0%	2.5%
Large Office	50%	0%	2.5%

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 150: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone, Roof Alterations (Replacements and Recovers)

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	0%	100%
2	0%	100%
3	0%	100%
4	0%	100%
5	0%	100%
6	0%	100%
7	0%	100%
8	0%	100%
9	0%	100%
10	0%	100%
11	0%	100%
12	0%	100%
13	0%	100%
14	0%	100%
15	0%	100%
16	0%	100%

a. Percent of existing floorspace

Table 151: Percent of Floorspace Impacted by Proposed Measure within Impacted Climate Zones, by Building Type, High Performance Windows - Fixed

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		80%	0%
Restaurant		80%	0%
Retail		100%	0%
Stand-Alone Retail	10%	80%	0%
Large Retail	75%	80%	0%
Strip Mall	5%	80%	0%
Mixed-Use Retail	10%	80%	0%
Food		80%	0%
Non-Refrigerated Warehouse		80%	0%
Refrigerated Warehouse		0%	0%
Schools		100%	0%
Small School	60%	100%	0%
Large School	40%	100%	0%
College		90%	0%
Small Office	5%	80%	0%
Medium Office	15%	80%	0%
Medium Office/Lab	20%	100%	0%
Public Assembly	5%	100%	0%
Large School	30%	80%	0%
High-Rise Apartment	25%	100%	0%
Hospital		80%	0%
Hotel/Motel		80%	0%
Offices		80%	0%
Medium Office	50%	80%	0%
Large Office	50%	80%	0%

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 152: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone, High Performance Windows - Fixed

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	0%	0%
2	100%	0%
3	0%	0%
4	0%	0%
5	100%	0%
6	100%	0%
7	100%	0%
8	100%	0%
9	100%	0%
10	0%	0%
11	100%	0%
12	100%	0%
13	100%	0%
14	100%	0%
15	100%	0%
16	0%	0%

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

Table 153: Percent of Floorspace Impacted by Proposed Measure, by Building Type, High Performance Windows - Curtain wall/Storefront

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		20%	0%
Restaurant		20%	0%
Retail		18%	0%
Stand-Alone Retail	10%	20%	0%
Large Retail	75%	20%	0%
Strip Mall	5%	20%	0%
Mixed-Use Retail	10%	0%	0%
Food		0%	0%
Non-Refrigerated Warehouse		0%	0%
Refrigerated Warehouse		0%	0%
Schools		0%	0%
Small School	60%	0%	0%
Large School	40%	0%	0%
College		10%	0%
Small Office	5%	20%	0%
Medium Office	15%	20%	0%
Medium Office/Lab	20%	20%	0%
Public Assembly	5%	0%	0%
Large School	30%	20%	0%
High-Rise Apartment	25%	0%	0%
Hospital		0%	0%
Hotel/Motel		0%	0%
Offices		20%	0%
Medium Office	50%	20%	0%
Large Office	50%	20%	0%

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 154: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone, High Performance Windows – Curtain wall/Storefront

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	100%	0%
2	0%	0%
3	0%	0%
4	0%	0%
5	0%	0%
6	0%	0%
7	100%	0%
8	0%	0%
9	0%	0%
10	0%	0%
11	0%	0%
12	0%	0%
13	0%	0%
14	0%	0%
15	0%	0%
16	100%	0%

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

Table 155: Percent of Floorspace Impacted by Proposed Measure, by Building Type, Opaque Envelope - Roof

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		100%	0%
Restaurant		100%	0%
Retail		100%	0%
Stand-Alone Retail	10%	100%	0%
Large Retail	75%	100%	0%
Strip Mall	5%	100%	0%
Mixed-Use Retail	10%	100%	0%
Food		100%	0%
Non-Refrigerated Warehouse		0%	0%
Refrigerated Warehouse		100%	0%
Schools		100%	0%
Small School	60%	100%	0%
Large School	40%	100%	0%
College		100%	0%
Small Office	5%	100%	0%
Medium Office	15%	100%	0%
Medium Office/Lab	20%	100%	0%
Public Assembly	5%	0%	0%
Large School	30%	100%	0%
High-Rise Apartment	25%	0%	0%
Hospital		100%	0%
Hotel/Motel		0%	0%
Offices		100%	0%
Medium Office	50%	100%	0%
Large Office	50%	100%	0%

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 156: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone, Opaque Envelope - Roof

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	100%	0%
2	100%	0%
3	100%	0%
4	100%	0%
5	100%	0%
6	100%	0%
7	100%	0%
8	100%	0%
9	100%	0%
10	100%	0%
11	100%	0%
12	100%	0%
13	100%	0%
14	100%	0%
15	100%	0%
16	100%	0%

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

Table 157: Percent of Floorspace Impacted by Proposed Measure, by Building Type, Opaque Envelope - Wall

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		100%	0%
Restaurant		100%	0%
Retail		100%	0%
Stand-Alone Retail	10%	100%	0%
Large Retail	75%	100%	0%
Strip Mall	5%	100%	0%
Mixed-Use Retail	10%	100%	0%
Food		100%	0%
Non-Refrigerated Warehouse		0%	0%
Refrigerated Warehouse		100%	0%
Schools		100%	0%
Small School	60%	100%	0%
Large School	40%	100%	0%
College		100%	0%
Small Office	5%	100%	0%
Medium Office	15%	100%	0%
Medium Office/Lab	20%	100%	0%
Public Assembly	5%	0%	0%
Large School	30%	100%	0%
High-Rise Apartment	25%	0%	0%
Hospital		100%	0%
Hotel/Motel		0%	0%
Offices		100%	0%
Medium Office	50%	100%	0%
Large Office	50%	100%	0%

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 158: Percent of Floorspace Impacted by Proposed Measure, by Climate Zone, Opaque Envelope - Wall

Climate Zone	Percent of Square Footage Impacted	
	New Construction	Existing Building Stock (Alterations)[a]
1	100%	0%
2	100%	0%
3	100%	0%
4	100%	0%
5	100%	0%
6	100%	0%
7	100%	0%
8	100%	0%
9	100%	0%
10	100%	0%
11	100%	0%
12	100%	0%
13	100%	0%
14	100%	0%
15	100%	0%
16	100%	0%

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

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with this Final CASE Report.

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric 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 million therms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). 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.

Water Use and Water Quality Impacts Methodology

There are no associated impacts on water use or water quality.

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

Introduction

The purpose of this appendix is to present proposed revisions to CBECC for commercial (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.

All four submeasures in this proposal would entail software changes. However, only high performance windows would require new software, because of the updated RSHGC calculation. Cool roofs, roof alterations, and opaque envelopes just change the stringency of existing requirements, which would only require modifying certain parameters.

The high-level specifications for changes due to the high performance windows submeasure are described below.

Technical Basis for Software Change

Per surveys and interviews conducted by the Statewide CASE Team, exterior horizontal slats are becoming increasingly common in high-performance building designs. The new prescriptive criteria RSHGC formula established in this Final CASE Report allows projects to take credit for this technology in the prescriptive path. Modeling exterior horizontal slats in the compliance software would allow projects to take more accurate credit in the performance approach.

Description of Software Change

Exterior horizontal slats block direct solar heat gain. CBECC-Com is not currently capable of modeling exterior horizontal slats. The Statewide CASE Team recommends that CBECC-Com be updated so that the reduction in solar gain from exterior horizontal slats can be accounted for.

As described in Section 4 of this report, exterior horizontal slats can be installed on all nonresidential building types in all California climate zones. The CBECC-Com feature proposed in this appendix would also be available for use in all nonresidential building types and climate zones.

Note that this software change would only account for solar heat gain credits. The daylighting credits are being discussed through the Code Cleanup effort, but it may be pertinent for the horizontal slat PAF to be linked to the RSHGC inputs to ease the burden on users (i.e., relieve them of specifying slats in two places).

Existing CBECC-Com Modeling Capabilities

CBECC-Com currently models overhangs and fins to evaluate solar heat gain reduction from these technologies. The user inputs the overhang and fin geometry, such as height, distance from the window, and angle. These are translated into coordinates in space that define an external shading surface in EnergyPlus.

The inputs for exterior horizontal slats would be spacing, tilt, and reflectance. Reflectance would be defaulted, or, if the user has ASTM E903 test data, they may specify the reflectance.

Using the current overhang shading calculation in CBECC-Com for exterior horizontal slats is not valid because exterior horizontal slats do not block all solar heat gain like overhangs. Instead, they redirect some solar heat gain into the space because of the interreflection between slats.

Summary of Proposed Revisions to CBECC-Com

This section describes how exterior horizontal slats can be implemented in CBECC-Com. Exterior horizontal slats would act on individual windows from a modeling perspective. EnergyPlus has a blind object that can be placed on the exterior of windows. This object would be used to model the horizontal slats. Although this object can be used in EnergyPlus to model the opening and closing of manual blinds in response to glare or high solar heat gain, CBECC-Com is not currently using this object and so it is available for modeling exterior horizontal slats.

CBECC-Com currently provides shading over windows. These are overhangs and fins. A new type of shading system, *Exterior Horizontal Slats*, would be added. Overhangs and fins in CBECC-Com are defined as zone shades. Horizontal slats would instead be defined as fixed exterior blinds as shading control objects.

For exterior horizontal slats, the user inputs would be placed in the same subsection as overhangs and fins under the Define Window Shade(s) subsection of the Window Data tab. Here the user would enter the Depth, Spacing, Angle, and Solar Reflectance.

The user may only specify the Solar Reflectance if they have ASTM E903 test results for the surface material of the exterior horizontal slats. If this test data is not available, CBECC-Com would default to a Solar Reflectance of 0.70.

Table 159 lists the CBECC-Com user inputs for horizontal slats.

Table 159: User Inputs Relevant to Exterior Horizontal Slats

Input Screen	Variable Name	Data Type	Units	User Editable	Default	Restrictions	Recommended Label
Window Data/ Define Window Shade(s)/ Horizontal Slats	Depth	Float	Inches	Yes	None	None	Horizontal Slat Depth
Window Data/ Define Window Shade(s)/ Horizontal Slats	Spacing	Float	Inches	Yes	None	No larger than the window height	Horizontal Slat Spacing
Window Data/ Define Window Shade(s)/ Horizontal Slats	Angle	Float	degrees	Yes	None	0 - 90	Horizontal Slat Angle
Window Data/ Define Window Shade(s)/ Horizontal Slats	Solar Reflectance Test Results	Fraction	None	Yes	0.70	Notify user there must be ASTM E903 test results to change this field	Horizontal Slat Solar Reflectance Test Results

User Inputs to CBECC-Com

There is no change to user input required.

Simulation Engine Inputs

Table 160 provides recommended translation information for generating EnergyPlus inputs from CBECC-Com generated data. In EnergyPlus, the horizontal slats are modeled as exterior blinds at a fixed angle that do not retract or rotate for the entire year.

Table 160: CBECC-Com Horizontal Slats Translation to EnergyPlus Input

Target EnergyPlus Object = WindowMaterial:Blind							
CBECC-Com				**EnergyPlus**			**Notes**
Field	**Data Type**	**Limit**	**Units**	**Field**	**Value**[i]	**Units**	
				Name	Created by OS		
				Slat Orientation	Horizontal		
Depth	Float		Inches	Slat Width	Convert	m	
Spacing	Float	Window height	Inches	Slat Separation	Convert	m	
				Slat Thickness	0.003175	M	1/8 inch is common
Angle	Float	0 to 90	Degrees	Slat Angle	90 - Angle	Degrees	
				Slat Conductivity	160	W/m-K	From Window7. No impact.
				Slat Beam Solar Transmittance	0		Opaque, solid slat
Solar Reflectance Test Results	Float	0 to 0.99		Front Side Slat Beam Solar Reflectance			
Solar Reflectance Test Results	Float	0 to 0.99		Back Side Slat Beam Solar Reflectance			
				Slat Diffuse Solar Transmittance	0		Opaque, solid slat
Solar Reflectance Test Results	Float	0 to 0.99		Front Side Slat Diffuse Solar Reflectance			
Solar Reflectance Test Results	Float	0 to 0.99		Back Side Slat Diffuse Solar Reflectance			
				Slat Beam Visible Transmittance	0		Opaque, solid slat
				Front Side Slat Beam Visible Reflectance	0		No impact
				Back Side Slat Beam Visible Reflectance	0		No impact
				Slat Diffuse Visible Transmittance	0		Opaque, solid slat
				Front Side Slat Diffuse Visible Reflectance	0		No impact

Target EnergyPlus Object = WindowMaterial:Blind							
CBECC-Com				**EnergyPlus**			**Notes**
Field	**Data Type**	**Limit**	**Units**	**Field**	**Value[i]**	**Units**	
				Back Side Slat Diffuse Visible Reflectance	0		No impact
				Slat Infrared Hemispherical Transmittance	0		Opaque, solid slat
				Front Side Slat Infrared Hemispherical Emissivity	0.9		Typical for many materials. Small impact.
				Back Side Slat Infrared Hemispherical Emissivity	0.9		Typical for many materials. Small impact.
				Blind to Glass Distance	0.2032	m	8 inches. Assumed.
				Blind Top Opening Multiplier	Default		
				Blind Bottom Opening Multiplier	Default		
				Blind Left Side Opening Multiplier	Default		
				Blind Right Side Opening Multiplier	Default		
				Minimum Slat Angle	0		Unused
				Maximum Slat Angle	180		Unused

a. Values for the baseline are denoted "B" and for the proposed "P". For information on why slats are needed in the baseline, see Calculated Values, Fixed Values, and Limitations.

Target EnergyPlus Object = WindowShadingControl							
CBECC-Com				**EnergyPlus**			**Notes**
Field	**Data Type**	**Limit**	**Units**	**Field**	**Value**	**Units**	
				Name	Created by OS		
				Layer 1	WindowMaterial:Blind Name		
				Layer 2	WindowMaterial:SimpleGlazing Name		

Target EnergyPlus Object = Construction							
CBECC-Com				**EnergyPlus**			**Notes**
Field	Data Type	Limit	Units	Field	Value	Units	
				Name	Created by OS		
				Zone Name	Zone Name		
				Shading Control Sequence Number	1		
				Shading Type	ExteriorBlind		
				Construction with Shading Name	Construction Name		
				Shading Control Type	AlwaysOn		
				Schedule Name			
				Setpoint			
				Shading Control Is Scheduled	No		
				Glare Control Is Active	No		
				Shading Device Material Name			
				Type of Slat Angle Control for Blinds			
				Slat Angle Schedule Name			
				Setpoint 2			
				Daylighting Control Object Name			
				Multiple Surface Control Type	Group		
				Fenestration Surface Name #	FenestrationSurface: Detailed Name		

Compliance Report

The window performance factors and RSHGC calculation are already included in the Nonresidential Compliance Manual NRCC-ENV-01 (Envelope Components) in the Fenestration schedule and would be updated there. Nonresidential Compliance Manual NRCC-ENV-02 (Fenestration Worksheet) compares information of proposed fenestration with Table 140.3-B, including the maximum RSHGC. The information provided in NRCC-ENV-02 should match the information in NRCC-ENV-01. While updates have been proposed to the RSHGC calculation, the output would be the same.

Description of Changes to ACM Reference Manual

Cool Roofs

No changes required.

Roof Alterations

No changes required.

High Performance Windows

See Section 4.6.4 of this report.

Opaque Envelope

See Section 5.6.4 of this report.

Appendix E: Impacts of Compliance Process on Market Actors

This appendix summarizes how the recommended compliance process, which is described in Section X.1.5 of each submeasure, could impact various market actors.

To summarize, the submeasures in this proposal would primarily increase stringency of existing requirements. No new skills would be required, and the only changes to workflow would be to add inspections for roof alterations. The key issues related to compliance and enforcement are summarized below:

- To receive a permit, a Nonresidential Code Compliance Envelope (NRCC-ENV-E) form for roof replacements must be filled out. However, if the user mistakenly checks "Roof Material" and not "Roof Assembly" and the Statewide CASE Team is proposing that either trigger the alterations requirements. The Statewide CASE Team is also proposing documentation requirements if an exception is used.
- Currently, there is no nonresidential registry or project status report that would allow a building inspector to verify the insulation while it is being installed for a roof alteration. The Statewide CASE Team recommends including roof alterations if a nonresidential registry is forthcoming and providing training for counter technicians and building officials.
- The Statewide CASE Team heard from stakeholders that there is not enough support for compliance and enforcement for roof alterations. The Statewide CASE Team is therefore proposing verifications of existing conditions and insulation installation.

Table 161 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 that negative impacts could be mitigated. The information in Table 161 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.

Table 161: 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
Owners / Tenants	Understand options and negotiate design, materials and orientation.	Provide direction to architects.	Owners would have to account for cost differences for time and materials.	Show cost effectiveness of each measure in CASE Report.
Architect	• Design the building envelope according to relevant Title 24, Part 6 Standards. • Fill out certificate of compliance from NRCC-ENV-01-E.	• Comply with the energy efficiency standards. • Provide plans to building owners. • Show compliance on the building plans.	Roof Alterations & Cool Roofs: • Roofs would need to be designed to meet updated reflectance standards or the relevant insulation tradeoff metrics. High Performance Windows: • Windows would need to be designed to meet updated requirements for SHGC-VT, which impacts building design. Opaque Envelope: • Properly document envelope assemblies.	Clear code language and compliance documents.
Energy Consultants	Opaque Envelope: • Read drawing and complete prescriptive compliance documents (prescriptive path).	Opaque Envelope: • Properly document assemblies and quickly generate compliance forms.	Opaque Envelope: • Account for new code requirements in documentation.	Opaque Envelope: • Clear compliance documents. • Clear and accessible educational materials.
Plans Examiner	Read drawings and confirm compliance with forms and standards.	Correctly fill out compliance forms and be able to quickly verify that the plans meet requirements.	Verify in plans and NRCC that the new requirements were properly designed.	Clear code language and compliance documents.

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
General Contractor	• Adhere to current Title 24, Part 6 requirements. • Constructing building in accordance with building plans. Roof Alterations & Cool Roofs: • Coordinate with roofing contractor on any specific roofing needs and completing of compliance documents. High Performance Windows: • Coordinate installation of windows that meet requirements, which in some cases includes heavier windows. • Verify NFRC certification and window performance factor adherence to code.	• Follow requirements in Title 24, Part 6 to meet compliance. • Ensure a quick and efficient completion of compliance documents. • Coordinate a quick and efficient building construction.	Coordinate with the architect and subcontractors to ensure the new requirements are being built to code.	Clear code language and compliance documents.
Roofing Contractor	Roof Alterations & Cool Roofs: • Install roof in accordance with design plans. • Coordinate with design team to understand appropriate roofing needs and reflectance levels and/or insulation levels desired. • Coordinate with general contractor to plan out the specifics of the roofing construction.	Roof Alterations & Cool Roofs: • Construct a Title 24, Part 6 compliant roof in timely manner.	Roof Alterations & Cool Roofs: • Roofing contractor would have to adhere to the updated cool roof and insulation standards. • Roofing contractor would need to document moisture level of wood decks	Clear code language and compliance documents.
Manufacturers	Design and build envelope parts.	Manufacture envelope components that are up to code.	Provide cut sheets of products that meet the new code requirements.	Easy to understand code language and compliance documents.

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
Enforcement Agency Field Inspector	Conduct site visits to verify code compliance and proper installation of approved plans.	Coordinate with general contractor to conduct visits. Roof Alterations & Cool Roofs: • Confirm reflectance levels of roof and/or insulation levels meet the proposed Title 24, Part 6 Standards.	No major changes to workflow.	Clear and easy to understand code language and compliance documents.

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders who 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.

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 high performance envelope via webinar. 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.

Table 162: Summary of Stakeholder Meetings

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential High Performance Envelope Utility-Sponsored Stakeholder Meeting	October 24, 2019	https://title24stakeholders.com/event/nonresidential-envelope-utility-sponsored-stakeholder-meeting/
Second Round of Nonresidential High Performance Envelope Utility-Sponsored Stakeholder Meeting	April 23, 2020	https://title24stakeholders.com/event/nonresidential-envelope-part-1-high-performance-envelope-utility-sponsored-stakeholder-meeting/

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 May 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com 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[33] (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,

[33] Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/.

and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. In most cases, these efforts were broken out by the four submeasures discussed in this Final CASE Report due to the limited overlap between interested stakeholder groups. This list is not exhaustive; the Statewide CASE Team has communicated with other stakeholders not included in this report.

Cool Roofs

In 2019, a survey was distributed over email to hundreds of members of the roofing market to gather their feedback and experience with current cool roof code requirements; respondents to this survey included architects, roofing contractors, manufacturers, energy consultants, and building owners. The goal of this survey was to get an overview of the cool roofing market in California as well as potential technical issues to consider as the Statewide CASE Team began to draft this report. A second survey has been crafted and is current open for public response. This survey has more focused questions, and seeks to understand what roofing products are commonly used in the commercial market and common insulation values in existing roofs. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on October 24, 2019, and April 23, 2020.

Various roofing manufacturers, contractors, suppliers, researchers, and trade groups provided essential comments and feedback that helped inform this Final CASE Report.

Particular focus was placed on the roofing product market to ensure that there would be many cost-effective products available to meet the proposed reflectivity standards for both low- and steep-sloped roofs.

Market Overview

To assess the market for cool roof products, the Statewide CASE met numerous times with the Cool Roof Rating Council (CRRC), an educational organization that rates roofing products to be used in California. The CRRC provided general guidance as to the best ways to navigate its Rated Product Directory as well as organizations and individuals to contact regarding the cool roof submeasure. Additionally, the CRRC clarified concerns that the rated product database is not an accurate representation of roofing products available the market. The vast majority of CRRC rated products are available on the market. See Appendix G: for more information.

Additionally, trade groups, such as the Asphalt Roofing Manufacturers Association (ARMA), Single-Ply Roofing Industry, and Metal Construction Association, gave useful feedback on how best to craft this code change proposal so as to not present difficulties for the market. The Statewide CASE Team was encouraged to ensure building owners still have flexibility when choosing how best to design a high performance envelope for their specific building. Additionally, it was noted that increasing rates of compliance with cool roof requirements would lead to increased savings.

The Global Cool Cities Alliance, a cool urban surface advocate, provided background on the state of cool roof efforts across the country and reiterated that the Statewide CASE Team should pursue the highest level of reflectivity that provides cost savings. Furthermore, the Statewide CASE Team has been and is contacting roofing suppliers across California to understand what products are typically in inventory that can meet these proposed changes.

Savings Benefits of Cool Roofs

Researchers at Concordia University, Lawrence Berkeley National Lab, and Oak Ridge National Lab provided background on previous cool roof CASE reports and recommended best practices. More specifically, the Statewide CASE Team received more information about the SRI levels as well as the roof/ceiling insulation among other topics.

Staff at Kynar Coatings provided insights about the technical make-up of coating products and pointed the Statewide CASE Team towards research showing the savings potential of cool roofs. See Section 2.3.4 more information.

Impacts on Contractors

Roofing contractor group Commercial Waterproofing and the Roofing Contractors Association of California provided background information as to the impacts of cool roof legislation on contractors. It was noted that the reflectivity of a roofing product does not change contractor costs so long as the type of roofing product does not change.

Moisture Accumulation

The Statewide CASE Team discussed moisture accumulation concerns with individuals from Oak Ridge National Lab; Wiss, Janney, Elstner Associates; Lawrence Berkeley National Lab; the Single-Ply Roofing Industry; and ARMA. Through these interactions and online research, the Statewide CASE Team determined that the addition of above deck insulation is a method to mitigate any potential moisture concerns.

Cost information

The table below provides an overview of the sources used for cost information.

Table 163: Summary of Cool Roof Cost Information

Roofing Type	Shingle	Single-Ply	Coating	Mod-Bit
Unique Cost Estimates	60	22	22	7
Individual Products (same products of different colors were considered the same)	9	12	10	5
Retailer/Supplier Location from Which Costs Were Collected	7	16	11	4
Different Retailers/Suppliers from Which Costs Were Collected	4	5	3	3
Separate Manufacturers	3	5	5	4

Suppliers such as ABC Roofing Supply, Elite Roofing, Pacific Roofing, Beacon Supply, and United Roofing Supply were contacted to get cost estimates and other estimates were gathered from prior CASE reports.

Roof Alterations

The Statewide CASE Team reached out to both insulation manufacturers and installers as well as roofing contractors for feedback on the roof alterations code change proposal, cost information, and market trends. The Statewide CASE Team also sought feedback from mechanical contractors on the price of lifting mechanical equipment. The Statewide CASE Team had multiple conversations with the Polyisocyanurate Insulation Manufacturers Association, Roofing Contractors Association of California, Asphalt Roofing Manufacturers Association, and Associated Roofing Contractors of the Bay Area Counties. The Statewide CASE Team also engaged with individual contractors and spent a day roof walk with a contractor to get a firsthand look at existing conditions. It was through these discussions that the Statewide Case Team decided to include insulation requirements for roof recovers, include inspections of below deck roof insulation, and modify the existing exceptions.

After the Draft CASE Report was released for public review, the Statewide CASE Team circulated a survey to stakeholders to collect additional cost information. The Statewide CASE Team also met another two times with ARCBAC, RCAC, PIMA, as well as other stakeholders to get feedback on the proposed requirements and decided to revise the proposed insulation requirements for replacements and recovers, add a minimum insulation requirement regardless of existing conditions, and rewrite the exception for mechanical equipment.

High Performance Windows

The National Fenestration Rating Council (NFRC), provider of fenestration performance energy ratings, participated in the development of this submeasure starting in August 2019. NFRC provided input on market trends and scope of the window categories covered by Title 24, Part 6. RDH Building Science presented the impact that updating the prescriptive requirements would have on commercial projects, as well as relevant issues with current glass technologies, such as triple-glazing and market-ready center of glass values. Lawrence Berkeley Lab discussed the variety of current market technologies and stressed the importance of considering comfort level in California's solar load-dominated climate zones. Throughout the code change cycle, a variety of stakeholders including manufacturers, glaziers, architects, industry organizations, and consultants provided input. This list includes but is not limited to: Kawneer, Oldcastle Building Envelope, Arcadia, Saint-Gobain, Vitro, Alpen, Loewen, New Buildings Institute, Birch Point Consulting, NRDC, Bagatelos Architectural Glass Systems, the National Glass Association (NGA), Aluminum Extruders Council (AEC), Northern California Glass Management Association, and Technoform engaged in the conversation surrounding feasibility of meeting the proposed standards and provided both product and costing information.

Opaque Envelope

Unlike the other submeasures, opaque envelope involved the simple update of cost-effective analyses for envelope components based on current market costs and past CASE Report evaluations. The National Resources Defense Council (NRDC) was engaged from the beginning of the code change cycle, starting with the September 2019 discussion of evaluating cost-effectiveness using the prescriptive path. Previous envelope CASE Authors, including NORESCO, were consulted to understand the context of the measure and guide development for the 2022 code change cycle. Various manufacturers and industry organizations were contacted for participation in the utility-sponsored stakeholder meetings, while engagement during those meetings included industry advocates and energy consulting companies. Several stakeholders continued to engage with the proposal beyond the stakeholder meetings and throughout the code change cycle.

Appendix G: Cool Roof Surveys

First Cool Roof Survey

Introduction

The purpose of the initial cool roof survey was to gain a better understanding of the cool roof landscape in California. In particular, the Statewide CASE Team sought to understand how popular cool roof products are, what products are used most frequently, and what maintenance and technical concerns to consider. The survey was sent over email to hundreds of members of the roofing industry. Respondents include roof contractors, energy consultants, architects, manufacturers and others. Responses were gathered throughout the month of January 2020.

Survey Questions

The survey questions are presented below.

1. Which of the following best describes your current job?
2. Which of the following building types do you typically work on?
3. In the last five years, which of the following types of projects have you done work on? Check all that apply. New Construction, Existing Building Roof Alteration, Repair Only, All Roofing Project Types.
4. In the past 12 months, roughly how many nonresidential roofing projects have you done in California?
5. What percentage of those nonresidential California roofing projects were roof replacement projects?
6. What percentage of those nonresidential California roofing projects were roof repair?
7. What percentage of those nonresidential California roofing projects were roof recovering?
8. What percentage of those nonresidential California roofing projects were cool roof projects?
9. In the past five years, in which climate zones have you installed a cool roof? Map of climate zones is here https://ww2.energy.ca.gov/maps/renewable/BuildingClimateZonesMap.png
10. What percentage of all nonresidential cool roof projects were mainly nonresidential steep-sloped roofs?

11. Thinking about your cool roof projects, did you use (select all that apply): Built-up roofs, single-ply, metal, asphalt shingle, asphaltic membrane, concrete or clay, coatings, tile.
12. Compared to five years ago, do you think the cost to install a cool roof has increased, decreased or stayed the same?
13. In your experience, how do the installation costs (including labor) of cool roofs and standard roofs relate, assuming the type of roofing is the same?
14. In 2014, Title 24 changes took affect regarding cool roofs. In your experience, have those changes increased, decreased, or had no effect on the number of cool roofs installed in California?
15. Compared to standard steep-sloped products, would you say that cool steep-sloped roofs are much more expensive, more expensive, about the same, less expensive, or much less expensive?
16. Compared to standard low-sloped products, would you say that low-sloped cool roofs are much more expensive, more expensive, about the same, less expensive, or much less expensive?
17. When implementing a cool roof for a built-up roof, do you most often use asphalt products with coating, a white granulated cap sheet, an even mix of both or are you unsure?
18. In general, what type of nonresidential buildings use steep-sloped roofs?
19. In general, what type of nonresidential buildings use low-sloped roofs?
20. Think about your recent cool roof projects. What is the typical aged solar reflectance levels for low-sloped non-residential buildings?
21. Think about your recent cool roof projects. What is the typical aged solar reflectance levels for steep-sloped nonresidential buildings?
22. With one being always, two being sometimes, and three being never, how often do you work with asphaltic membrane for low-sloped cool roofs?
23. With one being always, two being sometimes, and three being never, how often do you work with single-ply for low-sloped cool roofs?
24. With one being always, two being sometimes, and three being never, how often do you work with coating for low-sloped cool roofs?
25. With one being always, two being sometimes, and three being never, how often do you work with fluid applied membrane for low-sloped cool roofs?
26. With one being always, two being sometimes, and three being never, how often do you work with tile for steep-sloped cool roofs?

27. With one being always, two being sometimes, and three being never, how often do you work with metal roofing products for steep-sloped cool roofs?
28. With one being always, two being sometimes, and three being never, how often do you work with asphalt shingles for steep-sloped cool roofs?
29. With one being always, two being sometimes, and three being never, how often do you work with polymer/composite for steep-sloped cool roofs?
30. Have you ever encountered the following maintenance issues with cool roofs (select all that apply)? Moisture build up, cleaning, added inspections, roof decay, glare.
31. Do you think that maintenance for cool roofs costs more, costs less or is about the same as maintenance costs for standard roofs?
32. With one being the most important and five being the least important, please rank "Product Availability" in terms of its impact on cool roof installation.
33. With one being the most important and five being the least important, please rank "Costs" in terms of its impact on cool roof installation.
34. With one being the most important and five being the least important, please rank "Rejection in value engineering" in terms of its impact on cool roof installation.
35. With one being the most important and five being the least important, please rank "Lack of demand from building owners" in terms of its impact on cool roof installation.
36. With one being the most important and five being the least important, please rank "Maintenance Concerns" in terms of its impact on cool roof installation.
37. With one being very, two being somewhat, three a bit, and four being not at all, how important do you think 'cost savings' is as a factor for customers who choose to install cool roofs?
38. With one being very, two being somewhat, three a bit, and four being not at all, how important do you think 'energy savings' is as a factor for customers who choose to install cool roofs?
39. With one being very, two being somewhat, three a bit, and four being not at all, how important do you think 'environmental benefits' is as a factor for customers who choose to install cool roofs?
40. With one being very, two being somewhat, three a bit, and four being not at all, how important do you think 'consumer demand' is as a factor for customers who choose to install cool roofs?
41. Do you ever receive an incentive for installing a cool roof?

42. Do cool roofs require more, less, or about the same amount of cleaning compared to standard roofs?

Survey 2

The Statewide CASE Team developed a second survey in lead up to the Draft CASE Report to address more specific concerns raised by stakeholders. The survey was conducted independently by the third-party survey expert, Evergreen Economics. Specifically, most questions in this survey sought to understand the costs for the most popular roofing products in the California commercial market and the ability of contractors to get products that meet the proposed reflectance levels. Seven respondents were able to provide cost estimates for roofing products and an overview of results is presented below in Table 164. Once received, the Statewide CASE Team ran a statistical analysis to account for the wide variance in responses; some respondents reported only working on a few nonresidential projects while others have worked on hundreds of projects. Responses from individuals having worked on more commercial projects with a high percentage of low-sloped projects were given the most weight. Results reflecting this weight are shown in

Table 165. Additional questions in the survey asked about insulation levels in existing buildings, as well as other concerns related to the roof alterations, high performance windows, and opaque envelope proposals.

Evergreen Economics recommended using the results qualitatively due to limited responses and a wide range of results rather than using the precise results of this survey. Although the low-sloped proposal is no longer proposed for Title 24, Part 6, but may be proposed for CALGreen, the Statewide CASE Team is still including the information in this Final CASE Report.

Table 164: Cost Estimates to Replace a 40,000 ft^2 Low-Sloped Roof for Various Scenarios

Scenario	Type	Median	Minimum	Maximum
Scenario 1: Single-ply product with aged solar reflectance of at least 0.63	Material cost	$120,000	$100,000	$150,000
	Labor cost	$200,000	$30,000	$280,000
	Shipping cost	$3,000	$0	$30,000
Scenario 2: Single-ply product with aged solar reflectance of at least 0.70	Material cost	$130,000	$120,000	$160,000
	Labor cost	$220,000	$30,000	$300,000
	Shipping cost	$3,000	$0	$40,000
Scenario 3: Mod Bit Cap Sheet product with aged solar reflectance of at least 0.63	Material cost	$120,000	$80,000	$200,000
	Labor cost	$200,000	$28,000	$360,000
	Shipping cost	$20,000	$0	$20,000
Scenario 4: Mod Bit Cap Sheet product with aged solar reflectance of at least 0.70	Material cost	$130,000	$10,000	$200,000
	Labor cost	$250,000	$20,000	$380,000
	Shipping cost	$3,000	$0	$25,000
Scenario 5: Reflective Coating product with aged solar reflectance of at least 0.63	Material cost	$80,000	$70,000	$140,000
	Labor cost	$200,000	$40,000	$220,000
	Shipping cost	$10,000	$0	$15,000
Scenario 6: Reflective Coating product with aged solar reflectance of at least 0.70	Material cost	$80,000	$10,000	$140,000
	Labor cost	$210,000	$40,000	$220,000
	Shipping cost	$10,000	$0	$18,000

Table 165: Final Cost Estimates Following Statistical Analysis

Scenario	Type	Estimated Cost ($)
Scenario 1: Single-ply product with aged solar reflectance of at least 0.63	Material cost	127,454
	Labor cost	192,958
	Shipping cost	2,887
Scenario 2: Single-ply product with aged solar reflectance of at least 0.70	Material cost	130,649
	Labor cost	193,833
	Shipping cost	3,066
Scenario 3: Mod Bit Cap Sheet product with aged solar reflectance of at least 0.63	Material cost	134,519
	Labor cost	194,258
	Shipping cost	9,839
Scenario 4: Mod Bit Cap Sheet product with aged solar reflectance of at least 0.70	Material cost	97,213
	Labor cost	241,986
	Shipping cost	10,743
Scenario 5: Reflective Coating product with aged solar reflectance of at least 0.63	Material cost	76,798
	Labor cost	134,098
	Shipping cost	8,313
Scenario 6: Reflective Coating product with aged solar reflectance of at least 0.70	Material cost	58,973
	Labor cost	138,120
	Shipping cost	9,519

The Statewide CASE Team also asked respondents for the labor cost installing insulation and the cost of lifting mechanical equipment. The Statewide CASE Team had five respondents to these questions and included the median, minimum, and maximum results in Table 166 and Table 167.

Table 166: Cost of Lifting Mechanical Equipment – Survey Results

Scenario	Median	Minimum	Maximum
Half-day rental of crane	$2,800	$600	$3,000
Labor for lifting and replacing the RTU	$2,500	$200	$3,500
Preparing and inserting a curb and securing ductwork	$850	$50	$2,500
The cost of a curb adapter	$300	$250	$750
Installing an extended gas supply line	$700	$250	$4,000
Installing an extended supply cable	$600	$100	$3,500
Total Costs	**$7,825**	**$1,650**	**$17,250**

Table 167: Labor Costs for Installing Insulation - Survey Results

R-value	Median	Minimum	Maximum
R-8	$1.50	$1	$4
R-11	$1.50	$1	$6
R-14	$1.75	$1	$7
R-19	$2.10	$1	$8
R-29	$3.21	$2	$11

Appendix H: Cool Roof Product Availability Analysis

Methodology

CRRC Rated Products Directory

The Cool Roof Rating Council (CRRC) maintains a Rated Products Directory (CRRC Directory) containing roughly 3,000 roofing products. The Statewide CASE Team leveraged this database to evaluate listed products relative to the existing and proposed cool roof requirements and determine a proposed standard that could be met by a variety of products from numerous manufacturers. As discussed below, only products in the CRRC directory can be used to meet prescriptive cool roof requirements in California. Thus, the CRRC Directory is the best available data source, and the CRRC has several processes in place to limit discrepancies between listed products and products that are available in the market. The next subsections address this topic in detail.

Products in the CRRC Directory Represent Those that Can be Used to Comply With Prescriptive Cool Roof Requirements

While manufacturers may choose to not list all their products in the CRRC Directory, the CRRC Directory does represent a comprehensive set of products available to meet the prescriptive cool roof requirements in California. Section 10-113(b) specifies,

> *"Every roofing product installed in construction to take compliance credit or meet the prescriptive requirements for reflectance and emittance under Sections 140.1, 140.2, 140.3(a)1, 141.0(b)2B, 150.1(c)11, 150.2(b)1H or 150.2(b)2 shall be rated by CRRC or another supervisory entity approved by the Commission pursuant to Section 10-113(c)."*

As the supervisory entity for roofing products designated by the Commission, only the products in the CRRC Directory can be used to fulfill prescriptive cool roof requirements. However, some buildings use roofing products that are not listed in the CRRC Directory to comply with code requirements. Through the performance approach, designers may opt to meet the required energy budget without cool roof products, or use the default aged solar reflectance and thermal emittance values listed in Exception 1 to Section 110.8(i)1, allowing them to use a product that is not rated by the CRRC.

If a manufacturer elects not to submit products to the CRRC for rating and listing, their products cannot be used to meet the prescriptive requirements. The proposed changes will only impact the manufacturers who have elected to rate products with the CRRC.

Manufacturers who choose not to rate products with the CRRC can continue to have their products used in California buildings if designers follow the performance path.

CRRC Processes to Inactivate Products that are Unavailable

The CRRC seeks to ensure that information in the CRRC Directory is accurate and consistent with what is available in the marketplace. The CRRC staff highlighted three elements of their program that allow the CRRC Directory to remain accurate as the roofing marketplace evolves and matures:

- **Annual renewals process.** The CRRC has an annual product rating renewal process wherein "Licensees" (manufacturers) must pay an annual fee for each rated product listed in the CRRC Directory. Annual fees are based on the number of rated products, so it benefits the manufacturer to inactivate products that are no longer available (i.e., their annual fee is reduced). CRRC staff indicated that the annual renewals process does result in products being removed from the CRRC Directory (CRRC 2018) (Schneider and Egolf 2020).
- **Random testing.** Through the CRRC Random Testing program, the CRRC conducts periodic testing of products with active ratings. The purpose of this testing is to verify product rating accuracy, but it is also a method to confirm availability of rated products. Each year, approximately 100 to 150 products are randomly selected for testing. Manufacturers have two weeks to provide the CRRC with information on how the selected products can be procured. If products are made-to-order or not produced regularly, manufacturers have the option of deferring testing for one year, but then are required to supply the product in the following Random Testing program year. If the CRRC cannot procure a product, the product is inactivated. CRRC staff indicated that approximately 10 products are inactivated each year because they cannot be obtained for Random Testing. Find more information about CRRC's Random Testing program in Chapter 3.6 and Appendix 4 of the CRRC Product Rating Program Manual (CRRC 2020).
- **Removing products without aged ratings.** The CRRC Directory lists both initial and aged product ratings. There are processes in place to inactivate products that do not receive the aged rating. After initial testing, the specimens are sent to CRRC-approved, accredited test farms to undergo a three-year natural weathering process. Manufacturers pay test farms to undergo the three-year exposure. In a small number of cases, manufacturers that are seeking a CRRC rating may abandon products before the three-year exposure period is complete and request that their specimens be removed from the test farms. Test farms are required to notify the CRRC within 30 days if specimens have been pulled before the three-year exposure period is completed, and the initial ratings are

subsequently removed from the CRRC Directory. For specimens that complete the three-year exposure period and undergo aged testing, the Accredited Independent Test Lab (AITL) that completes the aged testing is required to report the aged ratings to the CRRC within 90 days from the product being removed from the test farm. If the aged ratings are not reported to the CRRC by the AITL within this 90-day period, the product enters a 30-day "under review" period and the manufacturer is notified. If the CRRC still does not receive the aged results after this 30-day period, the product is removed from the CRRC Directory. This process provides assurance that products that are abandoned before aged testing is conducted are promptly removed from CRRC Directory. Find more information about the aged testing requirements in the CRRC-1 Product Rating Program Manual (CRRC 2020).

Assumptions and Calculation Methods

Filtering "Other Roofing Manufacturers"

The CRRC Directory includes a field titled "Product Market," which describes how that product is sold. The options for this field are: "all markets", "end-users", and "other roofing manufacturers." The CRRC staff recommended excluding products classified as "other roofing manufacturers" in an analysis that aims to represent products that are available for contractors to install in projects in California because these products are typically brought to market by another manufacturer with a different brand and model name. Most of these products (927 of 968) are factory-applied paints for metal roofs. Table 168 summarizes products that are designated as the "other roofing manufacturer" product market and were not included in the analyses presented in this appendix.

Table 168: Summary of Products with a Primary Market of "Other Roofing Manufacturers"

Product Type	Number of products (both low and steep slope)	Number of products (low-sloped)	Number of products (steep-sloped)	Total
Asphalt Shingle			1	1
Asphaltic Membrane: Modified Bitumen	1	3		4
Coating: Acrylic	18			18
Coating: Polyurethane	7			7
Coating: SEBS	1			1
Coating: Silicone	5			5
Coating: Urethane				
Metal: Pre-painted Shake Facsimile			4	4
Metal: Pre-painted Shingle or Slate Facsimile			4	4
Metal: Pre-painted Standing Seam or Through-Fastened	751	4	164	919
Single-Ply: PVC		2		2
Single-Ply: TPO		3		3
TOTAL	**783**	**12**	**173**	**968**

Low-sloped and Steep-sloped Determination

The Statewide CASE Team used the "slope" field in the CRRC Directory to differentiate between products that were included in the low- and steep-sloped analyses. The Directory has three options for the "slope" field: "both low and steep", "low", and "steep." Products that are classified in the CRRC Directory as "both low and steep" were included in both analyses presented below. Table 169 presents the number of products in the CRRC Directory by slope designation. This table does not include products classified as serving the "other roofing manufacturer" product market.

Table 169: Slope Designation of Rated Products

Slope Designation	Number of Products in CRRC Rated Products Directory [a]
Total Steep-sloped	1,711
Total Low-sloped	1,309
Total Products in CRRC Directory	**2,085**

a. Does not include products classified as serving the "other roofing manufacturer" product market.

Calculating Aged Values

To analyze the rated product database, the Statewide CASE Team used aged product ratings when available. This included products that have received a CRRC Rapid Rating, which are interim, laboratory aged values based on a standard laboratory aging practice (ASTM D7897-18) that can be used while the product undergoes the three-year weathering (CRRC n.d.). Where aged solar reflectance was not yet available for a particular product, a calculation was performed using a formula depicted in Section 5.5.3 of the Nonresidential Alternative Compliance Manual (ACM), shown in Figure 7.

The solar reflectance values for roughly 200 products came from this calculation while the remaining products used the rated solar reflectance information. The calculated value tends to yield a lower aged solar reflectance value than the rated result, so it is likely that once these products receive their rated values that the solar reflectances will be higher.

3-year Aged Solar Reflectance = [0.2 + β(ρinitial – 0.2)]

ρinitial = Initial Solar Reflectance

β = Soiling Resistance by product type:

- Field-Applied Coating β = 0.65
- Other β = 0.70

Example: If the initial solar reflectance value is 0.8 for a field-applied coating

3-yr Aged Solar Reflectance = [0.2 + 0.65 (0.8 – 0.2)]
= 0.2 + 0.39
= 0.59

Figure 7: How to Calculate Aged Solar Reflectance per the Nonresidential ACM

Product listing and unique model offerings

Each product rating on the CRRC Directory represents a distinct product with tested solar reflectance and thermal emittance values. However, the CRRC does not require manufacturers to obtain a unique rating for every product model if the surface formulation is the same. Instead, multiple models with the same surface formulation (which correlates to solar reflectance and thermal emittance performance) can be grouped into a “Compound Rating.” The product shown in Figure 8 is an example of a Compound Rating. In this example, the various brand and model names displayed correspond to differences in metrics such as warranty and weight that do not impact the radiative performance (i.e., solar reflectance and thermal emittance) of the product. The results of the product availability analysis presented in in this section will show this as only one product, even though multiple models may be available.

MANUFACTURER	BRAND AND MODEL	PRODUCT TYPE	COLOR	SOLAR REFLECTANCE		THERMAL EMITTANCE		SRI	
				INITIAL	3 YEAR	INITIAL	3 YEAR	INITIAL	3 YEAR
CertainTeed LLC	**Landmark®** Silver Birch | **Landmark® PRO** Silver Birch | **NorthGate™** Silver Birch | **Landmark Solaris®** Silver Birch | **Landmark PRO Solaris®** Silver Birch	Asphalt Shingle	Off-White	0.26	0.27	0.90	0.89	27	28

Figure 8: Example of a product listing with multiple models

Steep-Sloped Roofs Product Availability

Steep-Sloped Market Impacts

The prescriptive cool roof requirements can be met in one of two ways. Designers can comply by meeting both the aged solar reflectance and thermal emittance values or by meeting the Solar Reflectance Index (SRI) values. The SRI is calculated by weighing the solar reflectance and thermal emittance. The higher the solar reflectance and thermal emittance, the higher the SRI will be. The proposed revisions to the prescriptive cool roof requirements for steep-sloped roofs in Climate Zones 2 and 4 through 16 are as follows (there is no proposed change in Climate Zones 1 and 3):

- Raise aged solar reflectance requirement from 0.20 to 0.25
- Raise thermal emittance requirement from 0.75 to 0.80
- Raise SRI from 16 to 23

Figure 9 shows how the number of available steep-sloped products are distributed across a range of solar reflectance ratings and requirements. There are 65 steep-sloped product types with rated aged solar reflectances or calculated solar reflectances under 0.25 that would comply with the proposed requirements because they meet the proposed SRI requirements. These products would not meet the aged solar reflectance threshold, but they meet the SRI requirement due to high aged thermal emittances values.

Product-specific analyses for asphalt shingles, metal, and tile products are provided in the following sections.

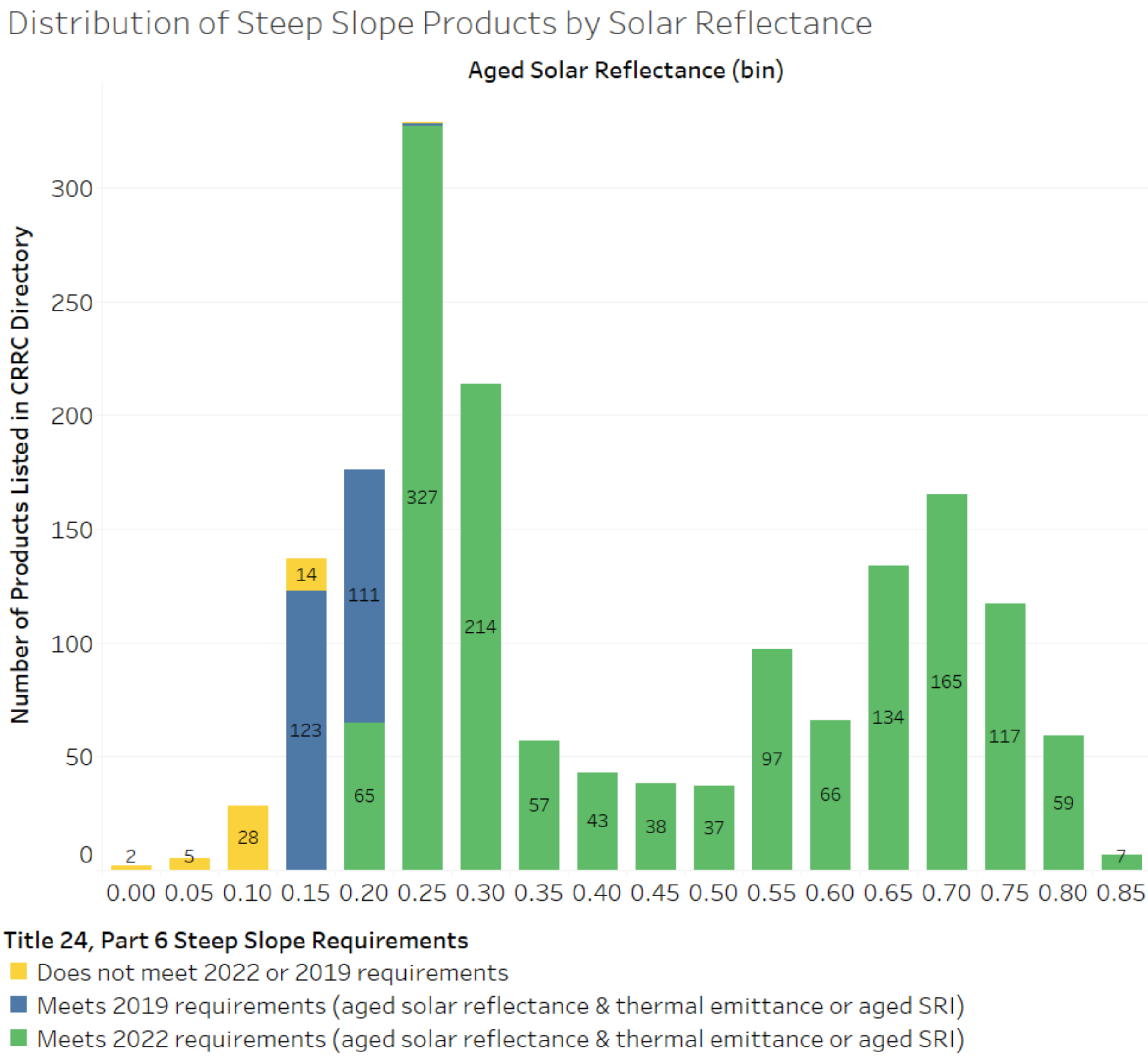

Figure 9: Impact of proposed requirements on steep-sloped product availability.

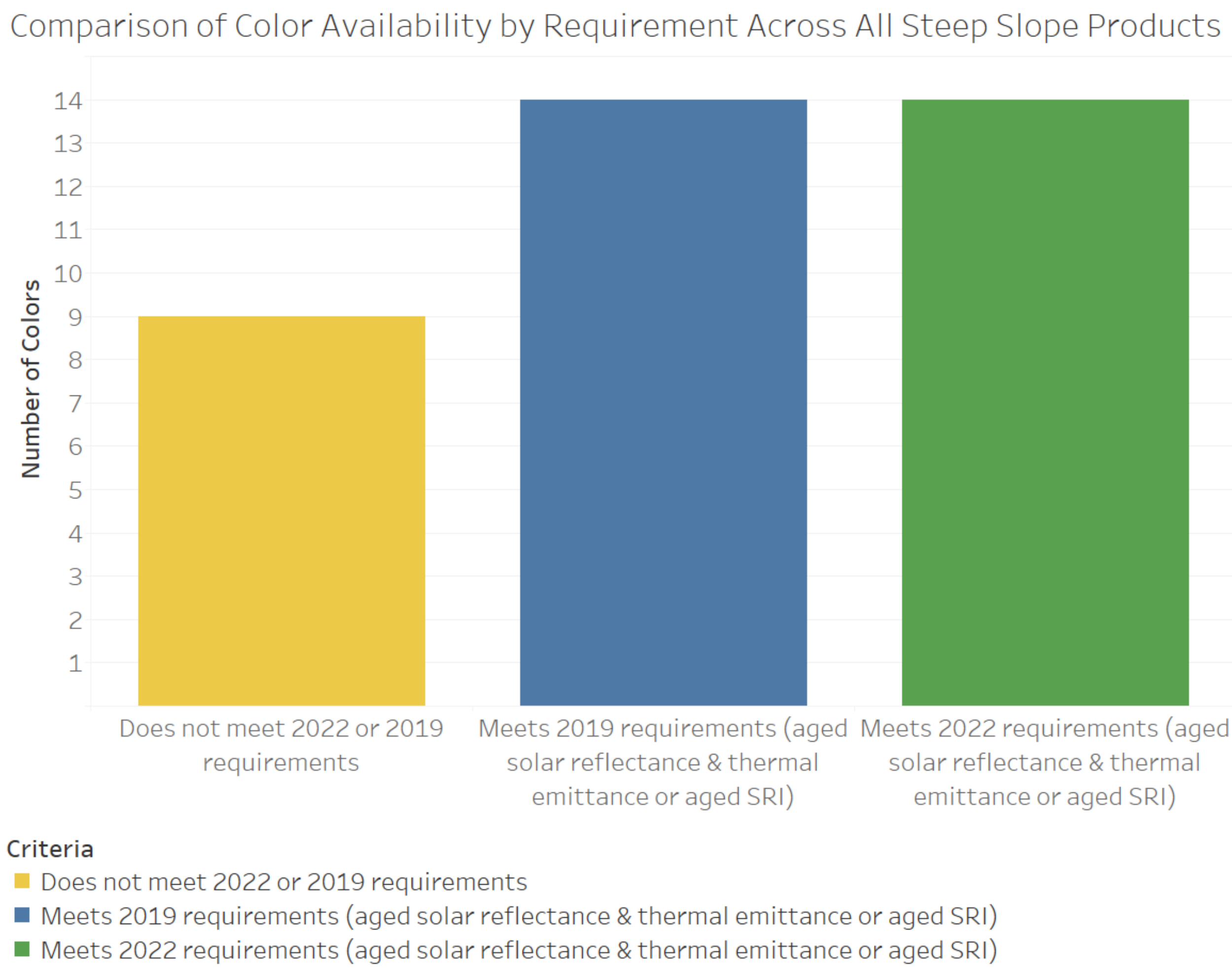

Figure 10: Impact of proposal on steep-sloped product color availability.

All Steep-sloped Products

Table 170 presents the number of steep-sloped products listed in the CRRC Directory by product type according to their ability to meet the current and proposed prescriptive cool roof requirements.

Table 170: Number of Unique Products: Steep-sloped

Product Type	All Listed Products	Does not meet Current or Proposed Require-ments	Meet Current Require-ments [a]	Meets Proposed require-ments	Percent Meeting Current Requirements that Also Meets Proposed Requirement
Asphalt Shingle	184	1	183	74	44%
Asphaltic Membrane	54	0	54	54	100%
Coating[b]	507	3	504	504	100%
Fluid-Applied Membrane	15	0	15	15	100%
Metal	417	1	416	405	97%
Polymer/ Composite	46	0	46	45	98%
Single-Ply	150	6	144	142	99%
Stone/Rock	2	0	2	2	100%
Tile	333	39	294	182	62%
Wood	3	0	3	3	100%
Total	**1,711**	**50**	**1,661**	**1,426**	**86%**

a. If a product meets the 2022 requirements, it is also counted as meeting the 2019 requirements.

b. Coatings do not alone comprise the membrane of a roofing system but are added to built-up roofs, asphaltic membranes, or single-ply membranes.

Table 171 shows the impact of the proposal on the number of manufacturers that produce compliant products; over 90 percent have products that meet the 2022 requirement.

Table 171: Number of Manufacturers Offering Products: Steep-sloped

Product Type	All Listed Products	Does Not Meet Current or Proposed Requirements	Meets Current Requirements [a]	Meets Proposed Requirements
Asphalt Shingle	14	1	13	7
Asphaltic Membrane	13	0	13	13
Coating[b]	102	2	100	100
Fluid-Applied Membrane	6	0	6	6
Metal	31	1	30	23
Polymer/Composite	6	0	6	5
Single-Ply	30	5	25	24
Stone/Rock	1	0	1	1
Tile	17	3	14	9
Wood	1	0	1	1
Total	**221**	**12**	**209**	**189**

a. If a product meets the 2022 requirements, it is also counted as meeting the 2019 requirements.

b. Coatings do not alone comprise the membrane of a roofing system but are added to built-up roofs, asphaltic membranes, or single-ply membranes.

Asphalt Products

As shown in Table 171, 183 asphalt shingle products meet the current requirements and 74 asphalt shingle products would meet the proposed requirements; the same number of colors are available within both groups. 189 manufacturers have steep-sloped products listed in the CRRC Directory that meet the proposed requirements; seven of these companies manufacture asphalt shingles. Major manufacturers – Owens Corning, Malarkey, GAF, CertainTeed, IKO Industries – make asphalt shingles that can meet the current and proposed cool roof standards and offer these products in California.

Figure 11 shows the number of asphalt shingle manufactures that have products at each aged solar reflectance value. This figure also shows the cumulative number of products that have an aged solar reflectance equal to or above the value shown on the x-axis.

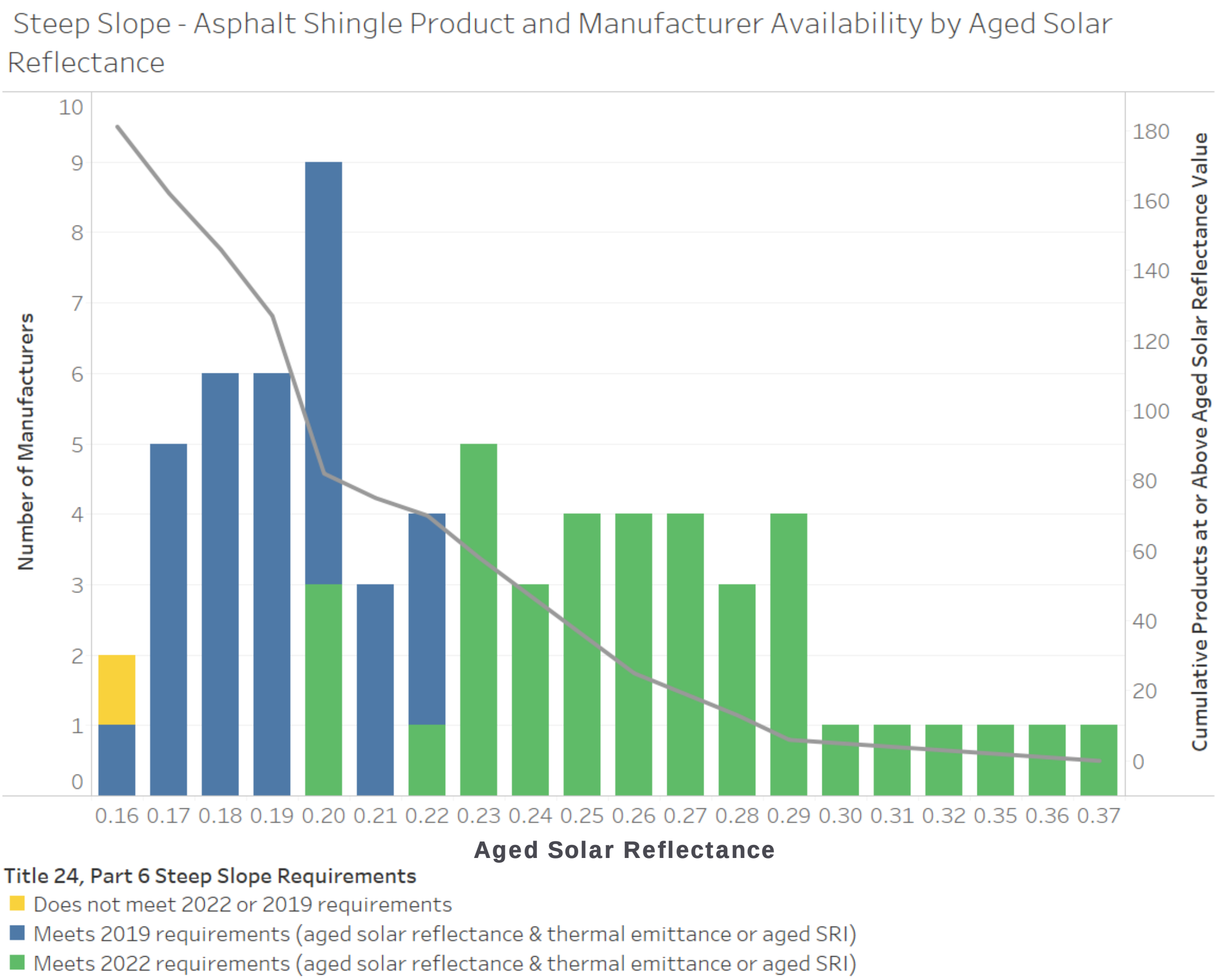

Figure 11: Impact of proposal on product availability and manufacturers: steep-sloped asphalt shingle.

Notes: The bars refer to the number of manufacturers that have products listed in the CRRC Directory at the associated aged solar reflectance level. The left vertical axis corresponds to the number of manufacturers with listed products. The grey line represents the total number of products in the CRRC Directory with an aged solar reflectance that is equal to or greater than the aged solar reflectance on the x-axis. The cumulative number of products corresponds to the right vertical axis. For instance, at aged solar reflectance of 0.25, 4 manufacturers make products at that level and roughly 45 products have aged solar reflectance at or above that level.

Numerous colors of shingles meet the proposed requirements, including red, orange, silver, brown, grey and white. There is no impact from the steep-sloped proposal on the possible number of discrete color choices for asphalt shingles, as shown below.

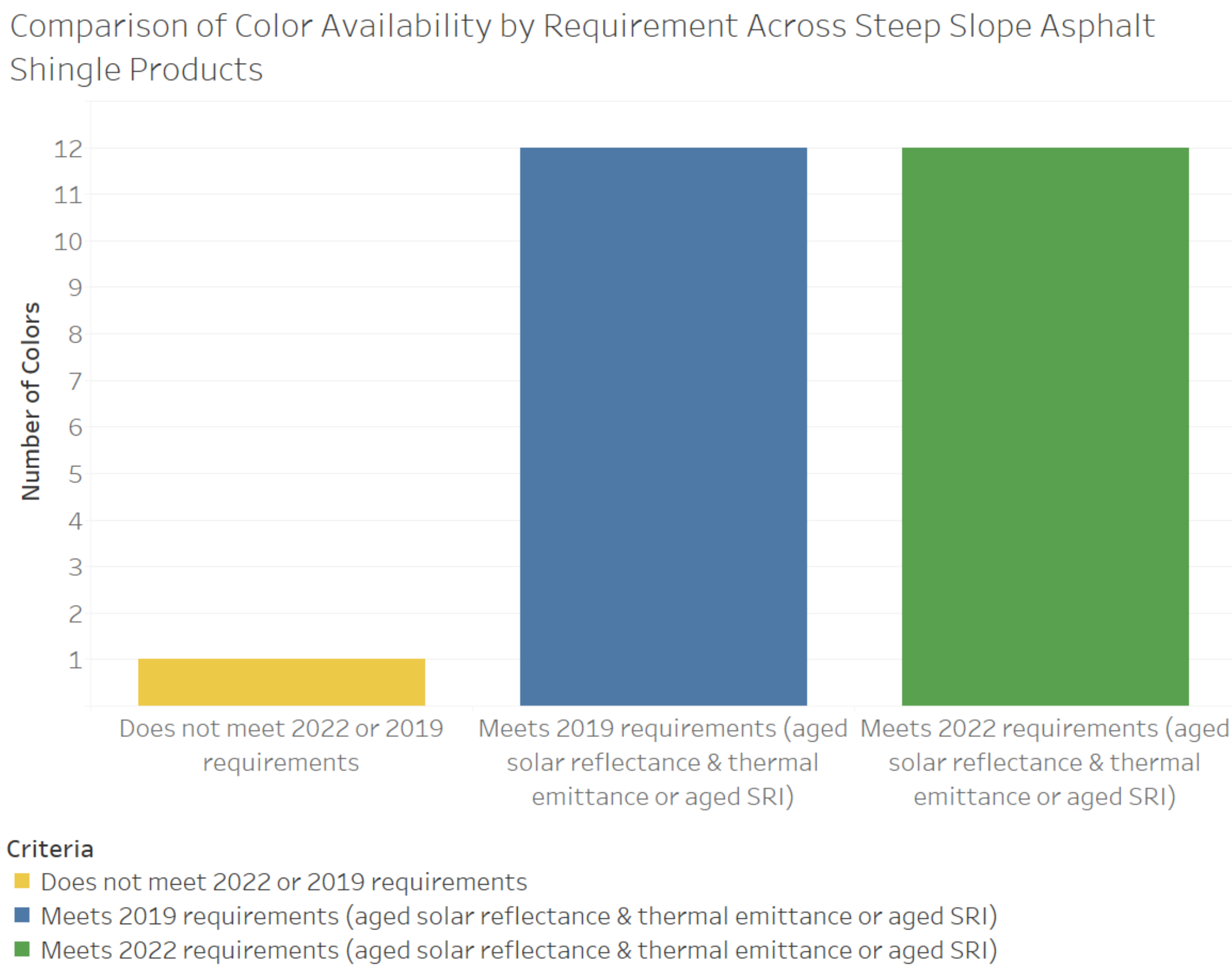

Figure 12: Impact of proposal on color availability: steep-sloped asphalt shingle.

Metal Products

Figure 13 and Figure 14 show the impacts of the steep-sloped proposal on metal products availability and color options.

As Table 170 and Table 171 show, 23 manufacturers make the 405 products that meet the proposed standard. Major manufacturers with product available in California, such as ACM, ASC Profiles and Metal Sales Manufacturing, all make numerous products that meet the proposed standard. Of the of the 416 metal products that meet the current cool roofs standards, 405 (97 percent) also meet the proposed standard.

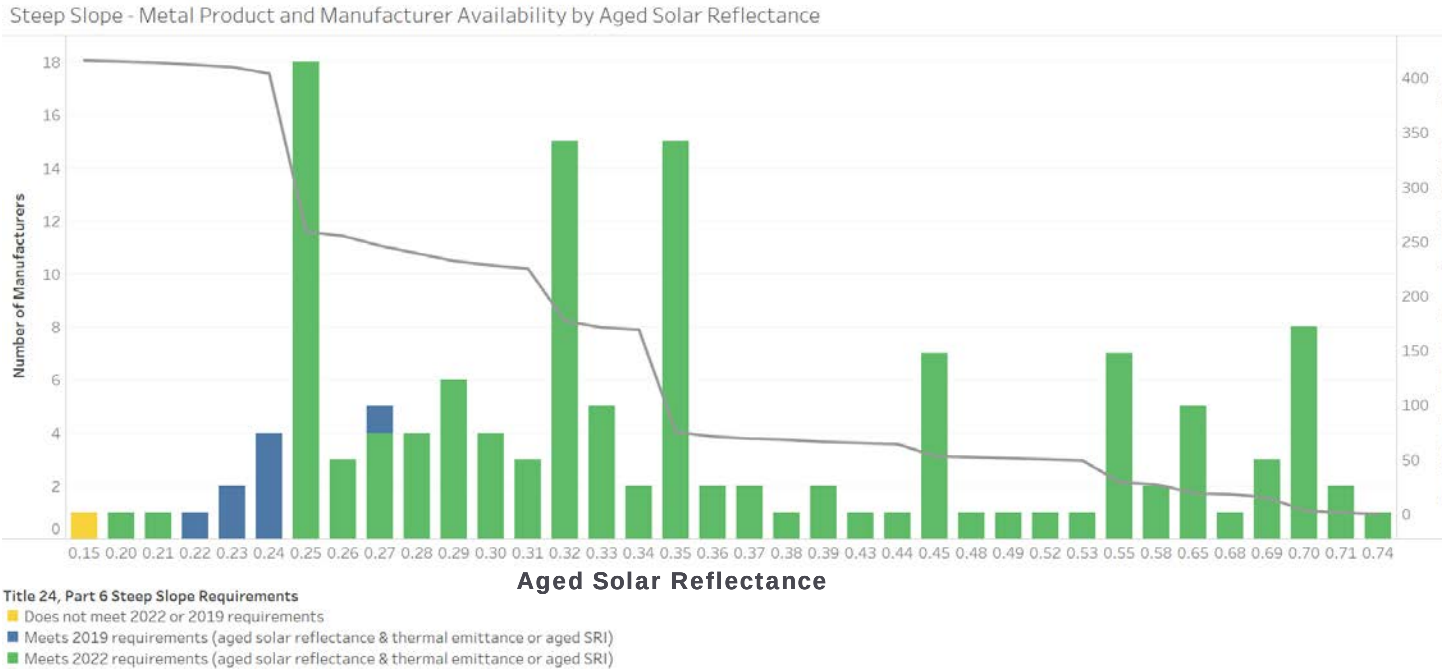

Figure 13: Impact of proposal on availability and manufacturers: steep-sloped metal.

Notes: The bars refer to the number of manufacturers that have products listed in the CRRC Directory at the associated aged solar reflectance level. The left vertical axis corresponds to the number of manufacturers with listed products. The grey line represents the total number of products in the CRRC Directory with an aged solar reflectance that is equal to or greater than the aged solar reflectance on the x-axis. The cumulative number of products corresponds to the right vertical axis. For instance, at aged solar reflectance of 0.25, 18 manufacturers make products at that level and roughly 250 products have aged solar reflectance at or above that level.

The same number of colors (13) are available for metal products at the proposed standard as at the current standard.

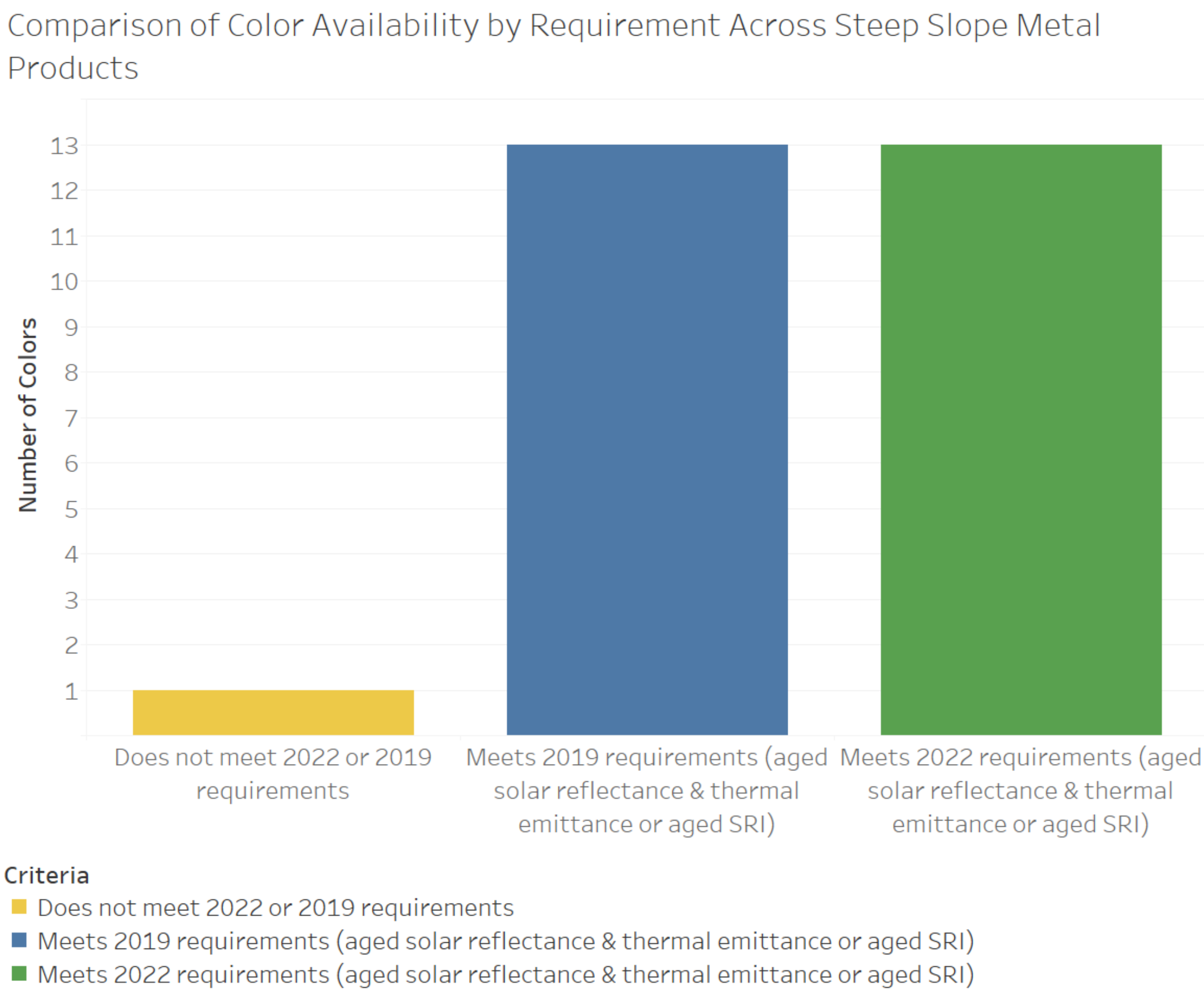

Figure 14: Impact of proposal on color availability: steep-sloped metal.

Tile Products

Figure 15 and Figure 16 show the impacts of the proposal on tile product availability and color options. As Table 170 and Table 171 show, there are 9 manufacturers that make the 182 products that meet the proposed cool roof requirements. Major manufacturers such as Boral and Eagle roofing have numerous compliant products available from across California. Of the 294 tile products that meet the current cool roof standards,182 (62 percent) also meet the proposed standard.

Tile products that meet the current requirements can be found in 14 colors, and tile products that meet the proposed requirement can be met with 12 colors. This slight decrease in color options is seen with darker colors such as green and brown.

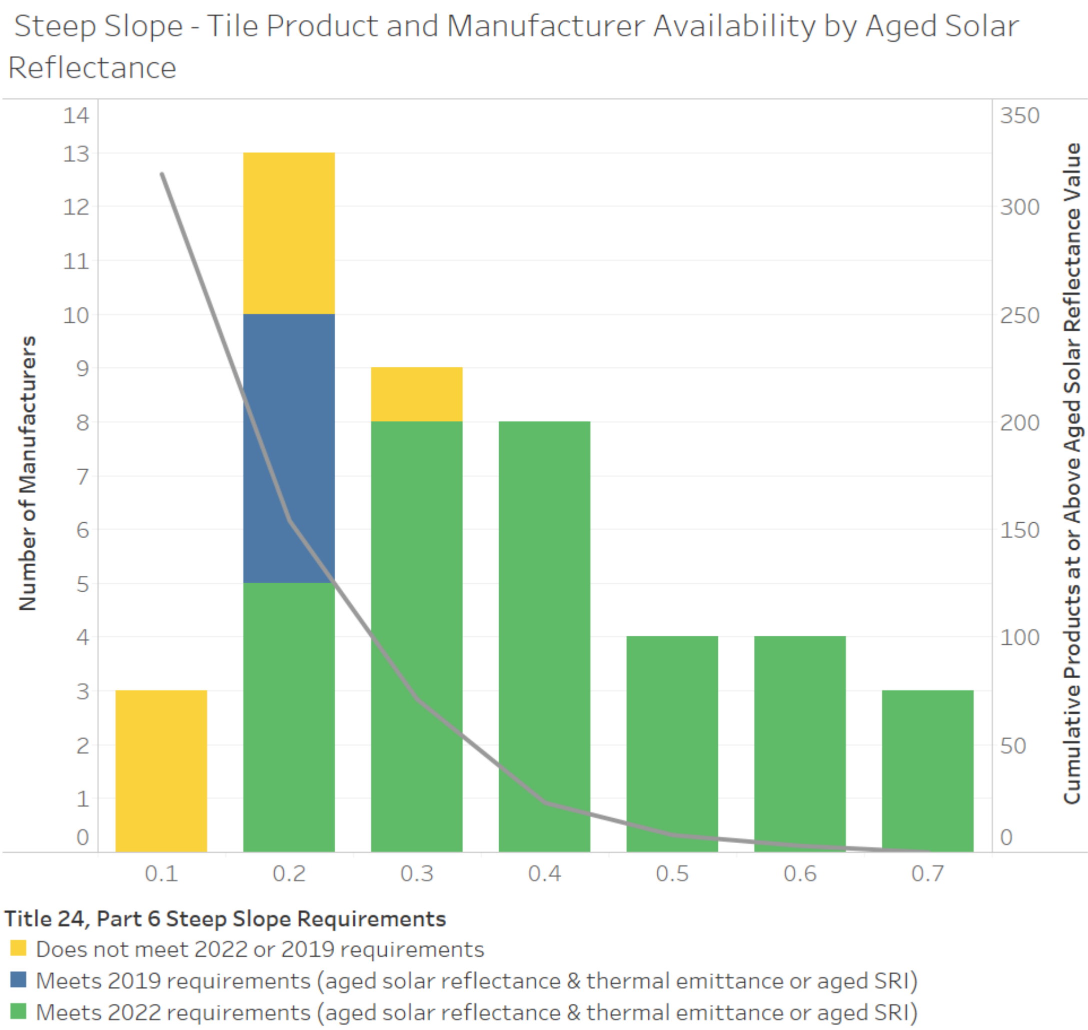

Figure 15: Impact of proposal on availability and manufacturers: steep-sloped tile.

Notes: To read this table, the bars refer to the number of manufacturers that make products at the given aged solar reflectance level. This total appears on the left axis. The grey line represents the number of products at or above the given aged solar reflectance. This total is on the right axis. For instance, at aged solar reflectance of 0.40, 8 manufacturers make products at that level and roughly 175 products have aged solar reflectance at or above that level. Values are rounded to the nearest tenth.

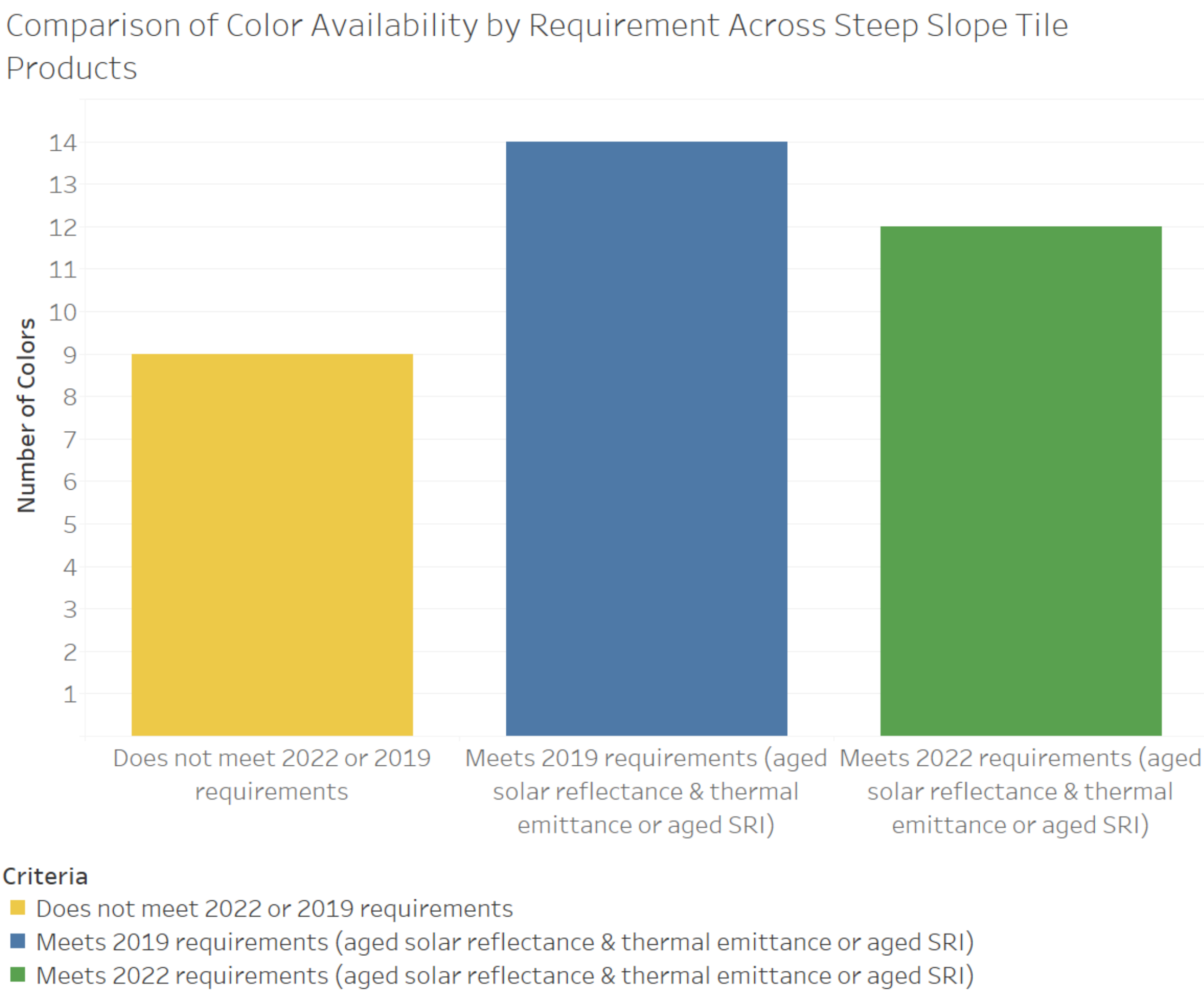

Figure 16: Impact of proposal on color availability: steep-sloped tile.

Low-Sloped Products

Low-Sloped Market Impacts

As with the steep-sloped requirements, the low-sloped cool roof requirements can be met in one of two ways. Designers can comply by meeting both the aged solar reflectance and thermal emittance values or by meeting the Solar Reflectance Index (SRI) values. The proposed revisions to the prescriptive cool roof requirements for low-sloped roofs in Climate Zones 4, 6 through 11, and 13 through 15 are as follows:

- Raising aged solar reflectance requirement from 0.63 to 0.70
- Keeping thermal emittance level at 0.75
- Raising SRI from 75 to 85

There would be no change to the requirements in climate zones 1, 2, 3, 5, 12, or 16.

Figure 17 shows how the number of available low-sloped products are distributed across a range of solar reflectance ratings and requirements. There are 6 low-sloped product types with aged solar reflectance under 0.70 that would comply with the proposed requirements because they meet the proposed SRI requirements. These products would not meet the aged solar reflectance threshold, but they meet the SRI requirement due to high aged thermal emittances values.

Figure 18 shows how the number of color options changes between the current and proposed standard while Table 174 shows a more detailed breakdown by product. The primary products used in the low-sloped market are described in the following sections: asphaltic membranes, field-applied roof coatings, and single-ply roof membranes.

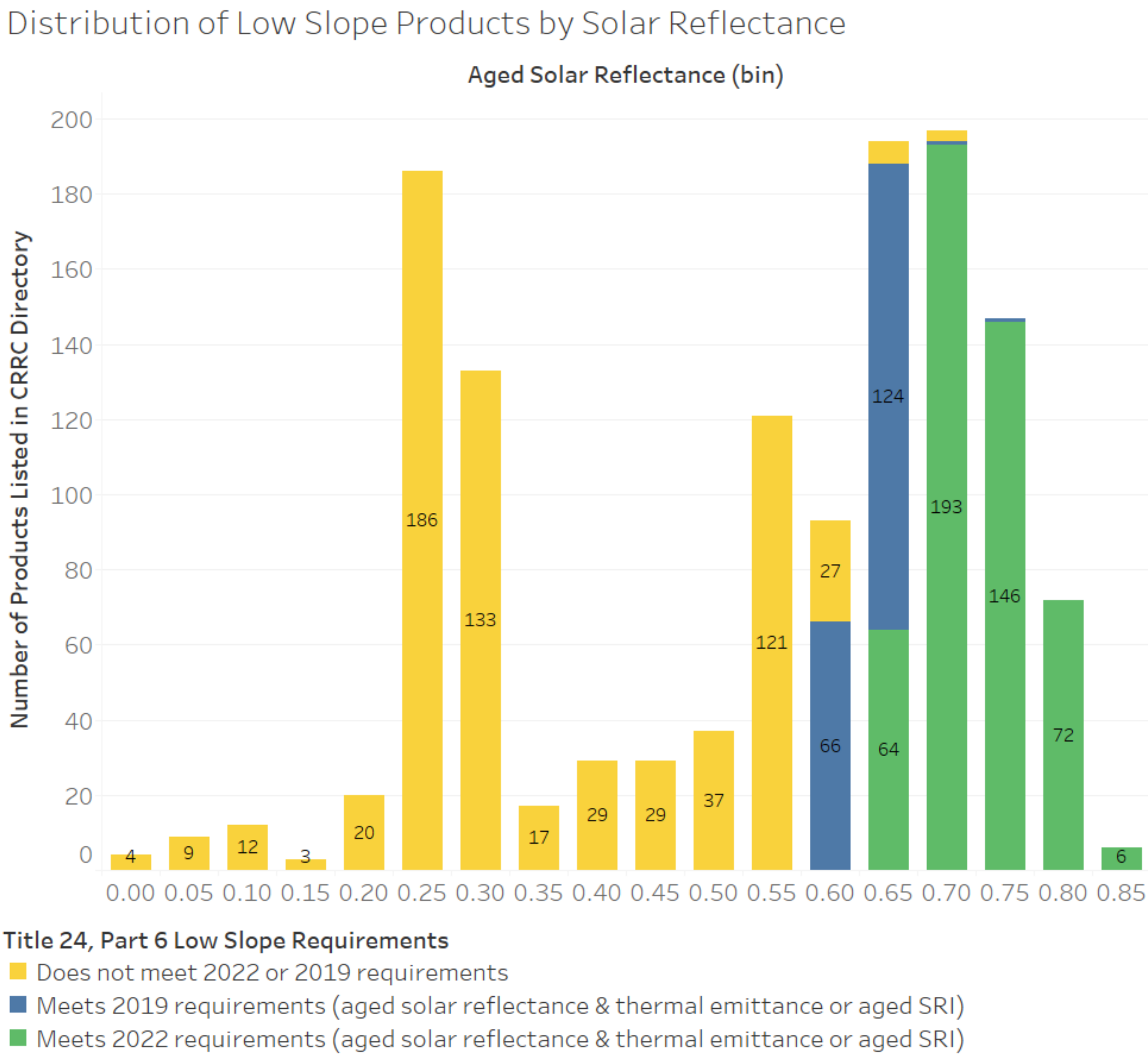

Figure 17: Impact of proposed requirements on all low-sloped products listed in CRRC Directory.

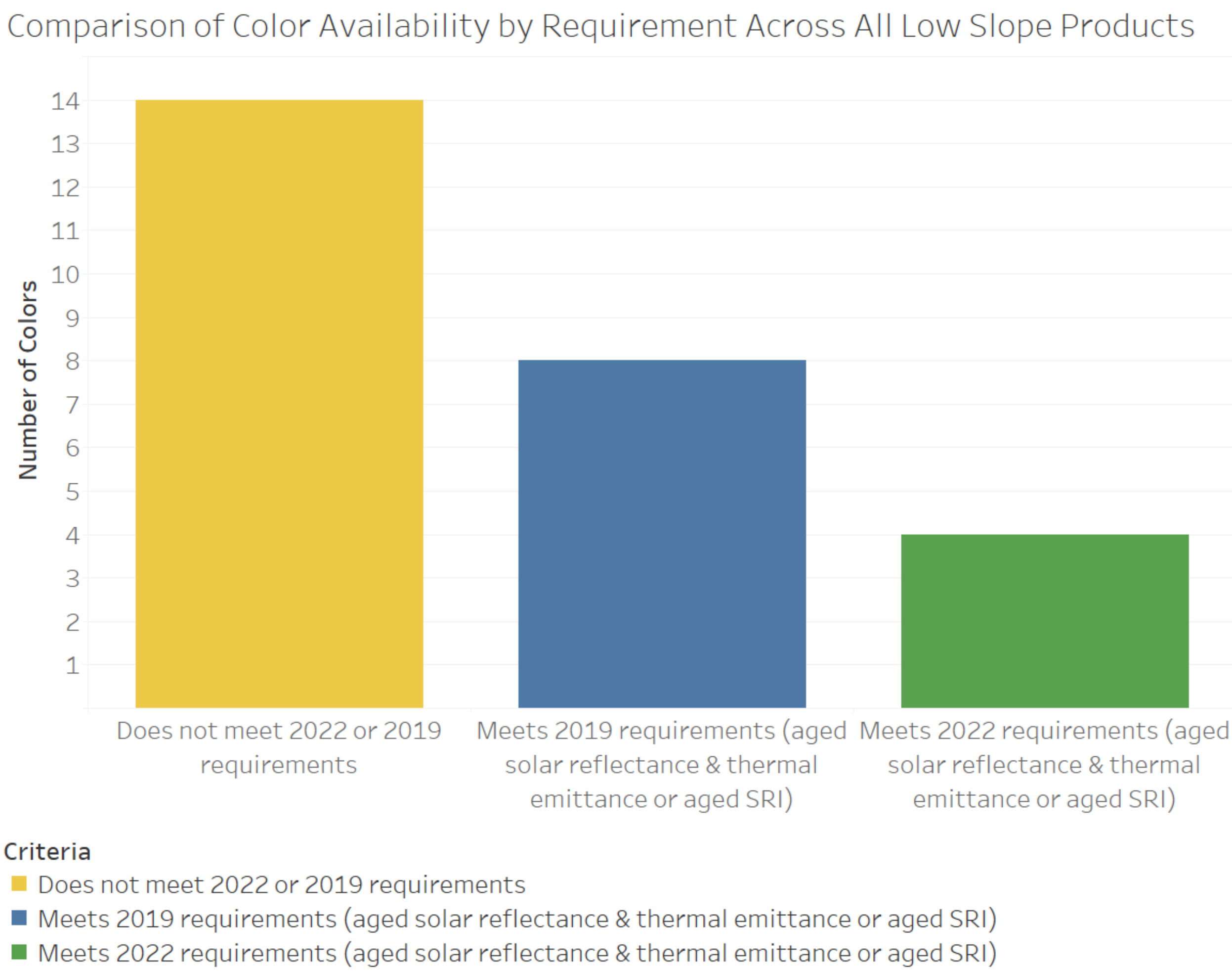

Figure 18: Impact of proposal on low-sloped color availability.

All Low-sloped Products

Table 172 presents the number of low-sloped products listed in the CRRC Directory by product type along with the number of products that meet the 2019 prescriptive cool roof requirements and the proposed 2022 requirements. There are 1,309 unique low-sloped products. Roughly 50 percent of these products are coatings, 14 percent are single-ply, and 10 percent are asphaltic membrane. Table 173 shows the impact of the proposal on the number of manufacturers that make compliant products.

Table 172: Number of Unique Products: Low-sloped

Product Type	All Listed Products	Does not meet require-ments	Meet Current Require-ments [a]	Meets Proposed require-ments	Percent Meeting Current Requirements that Also Meets Proposed Requirement
Asphalt Shingle	4	4	0	0	N/A
Asphaltic Membrane	116	82	34	10	29%
Coating[b]	650	161	489	377	77%
Fluid-Applied Membrane	19	6	13	12	92%
Metal	322	299	23	14	61%
Polymer/Composite	3	3	0	0	n/a
Single-Ply	186	74	112	68	61%
Stone/Rock	6	5	1	0	0%
Tile	2	2	0	0	n/a
Foam	1	0	1	0	0%
Total	**1,309**	**636**	**673**	**481**	**71%**

a. If a product meets the 2022 requirements, it is also counted as meeting the 2019 requirements.

b. Coatings do not alone comprise the membrane of a roofing system but are added to built-up roofs, asphaltic membranes, or single-ply membranes.

Table 173: Number of Manufacturers Offering Products: Low-sloped

Product Type	All Listed Products	Do Not Meet Current Requirements	Meet Current Requirements [a]	Meet Proposed Requirements
Asphalt Shingle	2	2	0	0
Asphaltic Membrane	38	16	22	8
Coating	202	52	150	97
Fluid-Applied Membrane	11	2	9	8
Metal	33	19	14	8
Polymer/Composite	2	2	0	0
Single-Ply	63	18	45	26
Stone/Rock	3	2	1	0
Tile	2	2	0	0
Foam	1	0	1	0
Total	**357**	**115**	**242**	**147**

a. If a product meets the 2022 requirements, it is also counted as meeting the 2019 requirements.

Asphaltic Membrane – Modified Bitumen

For low-sloped asphalt roofing products, modified bitumen cap sheets and built-up roofs are available. For a built-up roof to meet the current cool roof requirements, it must have a reflective coating or modified bitumen cap sheet. According to the National Roofing Contractors Association 2015-2016 market survey, modified bitumen membranes made-up a total of 10 percent of the 2016 low-sloped new construction market and 14 percent of re-roofing in the Pacific region. Eight manufacturers make products that meet the proposed standard. This includes major manufacturers such as Polyglass, Johns Manville, and US Ply.

There are 34 low-sloped asphalt membranes that meet the current low-sloped standard, and 10 that meet the proposed standard. The Statewide CASE Team has confirmed that at least five of the products that meet the proposed standards can be purchased from distributors or direct from manufacturers in California. White and metallic asphaltic products meet the proposed standard.

To better understand the technology of modified bitumen cap sheets, the Statewide CASE Team met with a former laboratory lead researcher from a company that produces granules used in these products. It was noted that the reflectivity of the ceramic-coated granules in the cap sheet is a key in factor determining the aged solar reflectance of the asphaltic membrane. Additionally, to comply with the current and proposed cool roof requirements, a field or factory applied coating needs to be added to the membrane. Online manufacturer data sheets also show that factory coatings are sometimes applied to modified bitumen membranes, potentially improving reflectivity.

If a designer wants to use the prescriptive path with a modified bitumen cap sheet that does not meet the proposed aged solar reflectance requirement, the roof/ceiling insulation trade-off option may be employed for both new construction and alterations

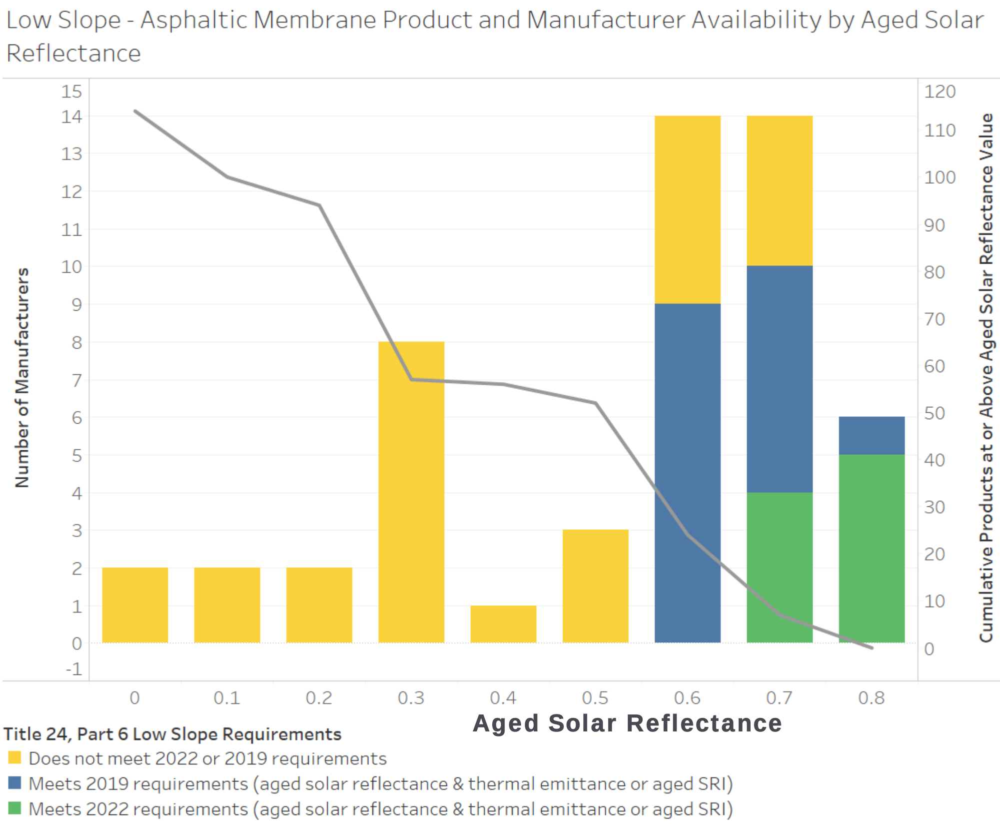

Figure 19: Impact of proposal on asphaltic membrane availability and manufacturers.

Notes: To read this table, the bars refer to the number of manufacturers that make products with aged solar reflectances between the tick mark and the next one. This total appears on the left axis. The grey line represents the number of products at or above the given aged solar reflectance. This total is on the right axis. For instance, at aged solar reflectance between 0.40 and 0.50, 1 manufacturer makes products at these levels and roughly 50 products have aged solar reflectance at or above that level. Values are rounded to the nearest tenth.

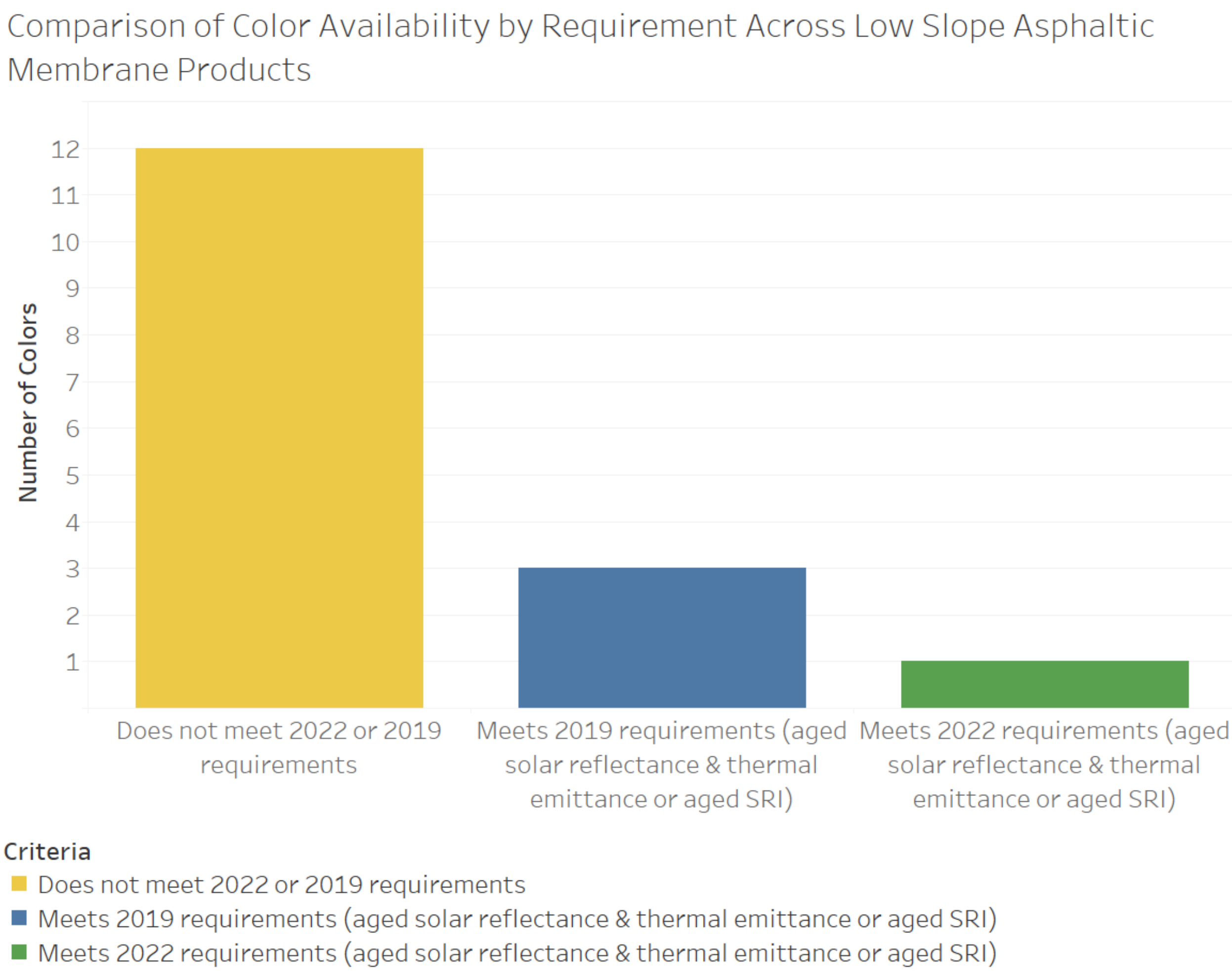

Figure 20: Impact of proposal on asphaltic membrane color availability.

Coatings

Figure 21 and Figure 22 show the impact of this proposal on the availability of coatings. As shown in Table 172, 377 of the 489 (77 percent) coatings that meet the current cool roof requirements also meet the proposed requirements. These 377 compliant products are produced by 97 manufacturers including major manufacturers such as APOC, Henry, and Tropical Roofing.

The number of distinct colors that can be used to meet the proposed standard decreases from 7 to 4. In addition to white, green, grey, and tan coatings also meet the low-sloped proposal.

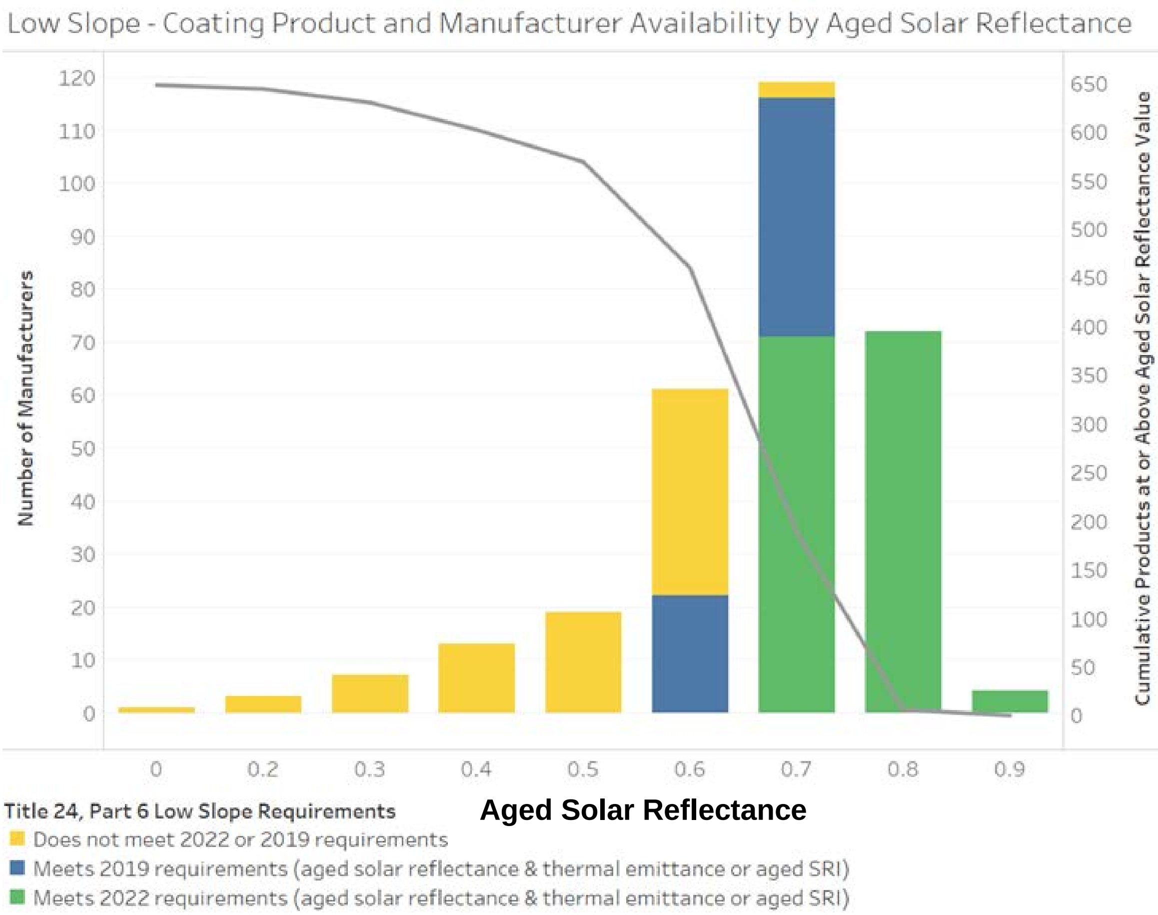

Figure 21: Impact of low-sloped proposal on coating availability and manufacturers.

Notes: To read this table, the bars refer to the number of manufacturers that make products with aged solar reflectances between the tick mark and the next one. This total appears on the left axis. The grey line represents the number of products at or above the given aged solar reflectance. This total is on the right axis. For instance, at aged solar reflectance between 0.40 and 0.50, roughly 13 manufacturers make products at these levels and roughly 600 products have aged solar reflectance at or above that level. Values are rounded to the nearest tenth.

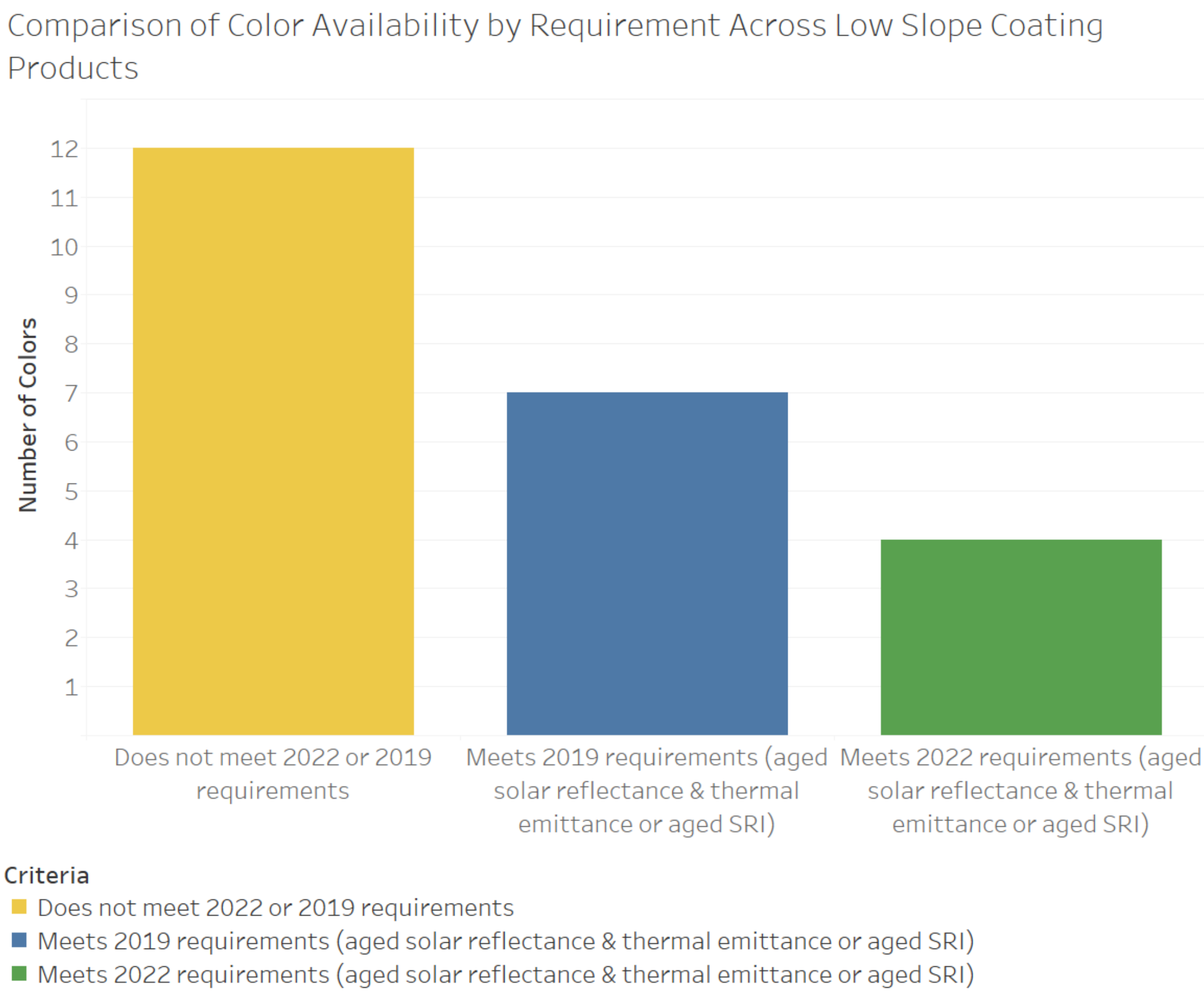

Figure 22: Impact of proposal on coating color availability.

Single Ply

Figure 23 and Figure 24 show the impact of the proposal on the availability of single-ply products and color options. As shown in Table 172, 68 of the 112 single-ply products (61 percent) that meet the current cool roof requirements also meet the proposed requirements. These 68 compliant products are produced by 26 manufacturers, including Johns Manville, GAF, Carlisle, Versico, Firestone, among others.

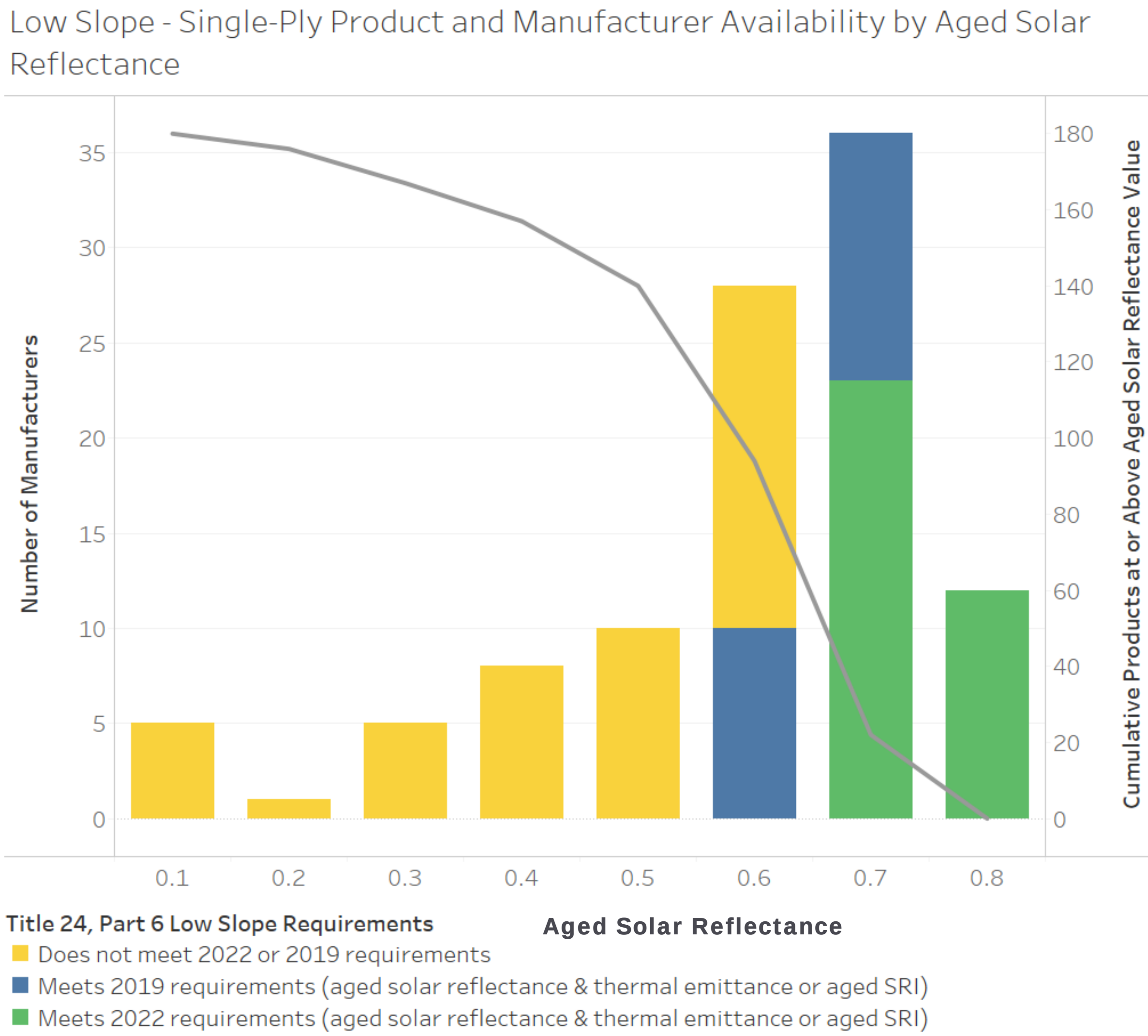

Figure 23: Impact of proposal on single-ply availability and manufacturers.

Notes: To read this table, the bars refer to the number of manufacturers that make products with aged solar reflectances between the tick mark and the next one. This total appears on the left axis. The grey line represents the number of products at or above the given aged solar reflectance. This total is on the right axis. For instance, at aged solar reflectance between 0.40 and 0.50, roughly 7 manufacturers make products at these levels and roughly 16 products have aged solar reflectance at or above that level. Values are rounded to the nearest tenth.

All single-ply products currently in the CRRC Directory that would meet the proposed standard are white. However, if a building designer wanted to use a tan or gray single-ply product, they could still comply with the prescriptive requirements by meeting the associated insulation value for either new construction or alterations.

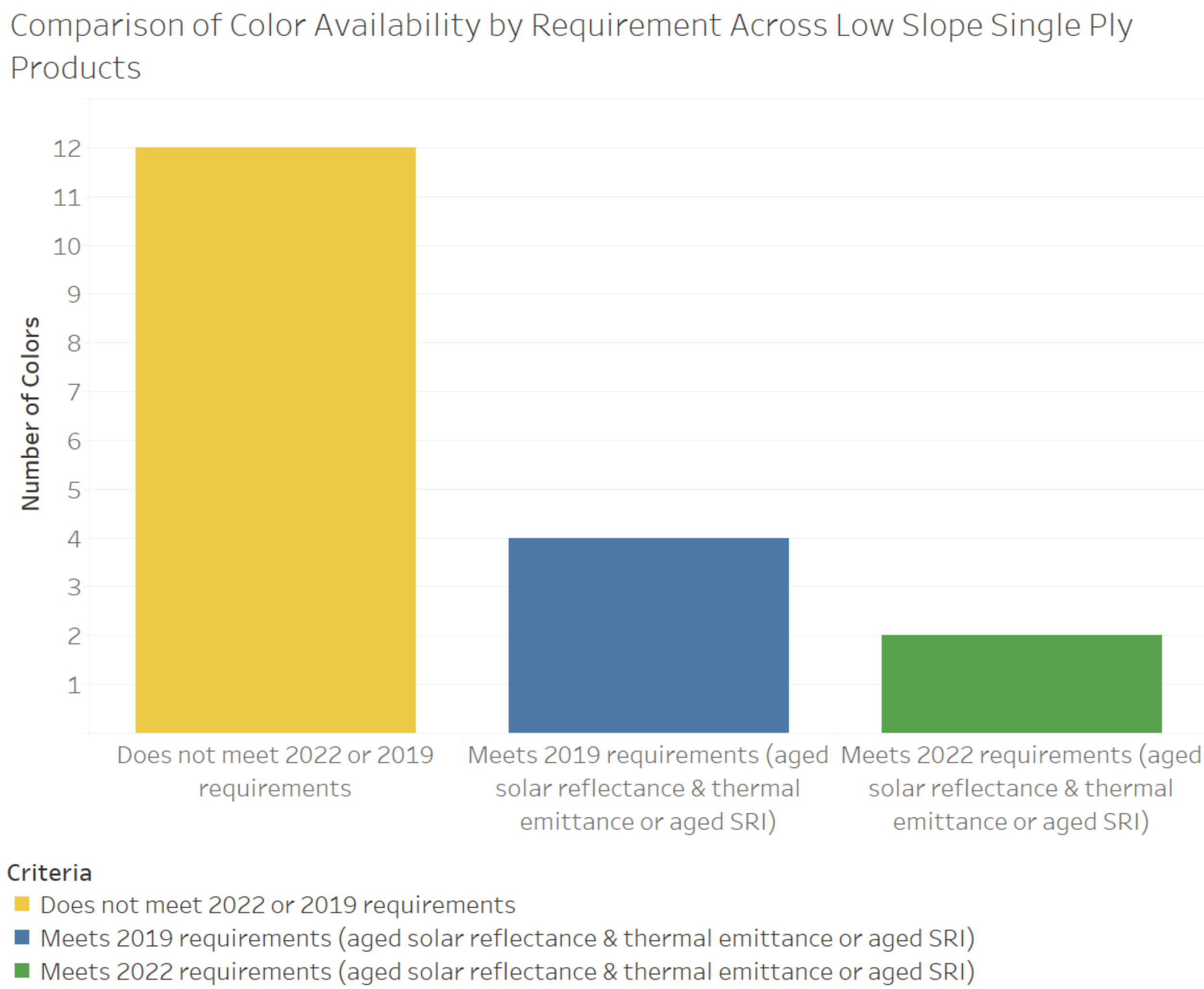

Figure 24: Impact of proposal on single-ply color availability.

Color Choices for Cool Roofs

The Statewide CASE Team agrees that color choice is important for some building owners and that this proposal reduces the number of rated products with non-white colors that would meet prescriptive cool roof requirements. The Statewide CASE Team has learned that color choice is less of a concern with low-sloped roofs compared to steep-sloped, but some building owners may have concerns about glare from low-slope roofs. As noted in the introduction, buildings can still comply with prescriptive roofing product requirements by choosing the insulation trade-off pathway for both new construction and alteration, and have access to a range of colors, in both low-sloped and steep-sloped categories.

Table 174: Low-sloped Product Colors

#	Colors[a]	Total Number of Products in CRRC Directory	Number of Products that Do Not Meet Current or Proposed Requirements	Number of Products: Meet Current Requirements	Number of Products: Meet Proposed Requirements
1	Black	42	35	7	3
2	Blue	95	84	11	5
3	Bright White	774	80	694	560
4	Brown	173	152	21	10
5	Green	170	138	32	8
6	Grey	259	181	78	40
7	Metallic	126	90	36	25
8	Multicolor	21	18	3	1
9	Off-White	132	86	46	20
10	Orange	13	12	1	0
11	Purple	2	2	0	0
12	Red	147	129	18	10
13	Tan	166	105	61	40
14	Yellow	2	1	1	0
	Total	**2,122**	**1,113**	**1,009**	**722**

a. Some products that do not cleanly fall into one color group have multiple colors listed in the CRRC directory. The total number of products in this table is higher than the total number of products listed in this table than in Table 6 above

Table 175: Steep-Sloped Product Colors

#	Colors[a]	Total Number of Products in CRRC Directory	Number of Products that Do Not Meet Current or Proposed Requirements	Number of Products: Meet Current Requirements	Number of Products: Meet Proposed Requirements
1	Black	110	17	93	82
2	Blue	128	0	128	128
3	Bright White	624	0	624	620
4	Brown	365	25	340	305
5	Green	233	3	230	225
6	Grey	413	15	398	365
7	Metallic	149	0	149	149
8	Multicolor	224	14	210	155
9	Off-White	178	0	178	168
10	Orange	117	1	116	87
11	Purple	7	1	6	4
12	Red	246	4	242	228
13	Tan	318	12	306	268
14	Yellow	42	0	42	39
	Total	**3154**	**92**	**3062**	**2823**

a. Some products that do not cleanly fall into one color group have multiple colors listed. This is why the total number of products is higher in this table than in Table 4 above.

Appendix I: Cool Roof Moisture Accumulation Background Information

Literature and Technical Review

A modeling analysis by Kehrer shows that white roofs with a solar reflectance of 0.70 can have condensation accumulation of roughly twice that of a roof with a solar reflectance of 0.15. The difference between a low or high moisture supply in the building can cause up to ten times more condensation. A low indoor moisture supply or low air intrusion rate leads to a low risk of intermediate condensation levels for both white and dark roofs (Kehrer 2013). During a phone call with the Statewide CASE Team, Kehrer, in pointing to his research, noted that although a cool roof alone does not cause moisture accumulation concerns, the current cool roof standards are too high, and raising the reflectivity rate would lead to higher risks of moisture problems (Kehrer 2020).

Further modeling analysis by Desjarlais et al. (2017) has focused on wood deck roofs that are common in California. Roofs with reflectance levels of 0.65 and 0.10 were modeled. These results show that with high rates of indoor moisture and air infiltration, the more reflective roofs are more prone to failure than darker roofs. Failure was defined as greater than 30 percent moisture saturation of the roof deck. Nonetheless, “data clearly shows that air intrusion is the biggest culprit when it comes to moisture accumulation in these roofing systems, followed by moisture supply, and then color” (Desjarlais, Pallin and Pierce 2017). This study also determined R-values of above deck insulation needed in white roofs to mitigate moisture accumulation concerns by making sure the wood deck stays above the dew point. Similarly, in a different report, Desjarlais et al. ran an analysis with four rates of indoor moisture load (low, medium, high, and excessive) for both white and dark roofs with wood decks. With the excessive of moisture load, white roofs in San Francisco and Sacramento were simulated to fail while white roofs in Los Angeles and San Diego all passed under all-indoor moisture rate assumptions. Failures were considered simulations in which the maximum water content of the wood materials in the second and third years exceeded 30 percent saturation. In simulations with three lower indoor moisture concentration assumptions, there were no simulated failures for California roofs. The excess rates of moisture that accompanied the simulated failures in San Francisco are based on a moisture load for a two-bedroom residential building according to ASHRAE 160-Criteria for Moisture-Control Design Analysis in Buildings (Pallin, Kehrer and Desjarlais 2013). In the Statewide CASE Team’s view, this excess moisture value is not a well-aligned representation of indoor moisture rates for the typical nonresidential building.

However, Akbari and Ahrab (2013) conducted analysis on flat wooden roofs, assuming typical indoor office conditions. This study showed that there is limited risk for moisture accumulation for both white and standard flat roofs with conventional vapor retarders. While dark roofs experience less moisture content than white roofs, total moisture content remained below concerning levels in national climate zones relevant to California (Akbari and Ahrab 2013). Bludau et al. determined that self-drying roofs, roofs that can dry to the interior, with steel decking and foam insulation can safely be used with white roofs in simulations for both Phoenix and Chicago (Bludau, Zirkelbach and Kunzel 2009). Similarly, analysis of steel roofs by Saber et al., using European and ASHRAE recommendations for indoor conditions, shows that white roofs in Toronto, Seattle, Wilmington, Montreal, and Phoenix face low risk of moisture accumulation concerns (Saber, et al. 2011).

Ennis and Kehrer presented research on two field studies and one modeling analysis. Similar to the results mentioned in the prior paragraph, modeling results, as expected, showed that white roofs with a reflectivity of 70 percent will have more moisture accumulation relative to dark roofs. One of the field studies examined commercial buildings in national Climate Zone 5 during winter months to investigate the roofs when they were most vulnerable to moisture accumulation. Ten single-ply steel-deck roofs with a single layer of insulation and no vapor retarders were chosen. Of the ten roofs, only three had any moisture present, and none at detrimental levels. An additional field analysis consisted of reroofing the non-cool roof of a commercial building with half of the roof staying dark and the other half switching to a white TPO roof. The side of the roof with the dark membrane dried slightly quicker but no damage to insulation or fasteners was observed anywhere on the roof (Kehrer and Ennis 2011). Another field study performed by manufacturer Sika Sarnafil and the retailer Target showed similar findings. Twenty-six Target stores with white PVC membranes throughout ASHRAE Climate Zones 4, 5, and 6 were analyzed with two cuts being made on each steel-decked roof. No vapor retarders were a part of these assemblies. Of these 26 roofs, 11 had a single layer of polyisocyanurate insulation, 11 had a base layer of polyisocyanurate with an additional layer and/or a cover board, and 4 had recover boards between the old and new membranes. Only one of these 52 cuts had moisture accumulation or signs of moisture accumulation (e.g., staining) in the roof insulation, and this was due to a leakage from a nearby heating, ventilation, and air conditioning (HVAC) unit (DiPetro 2014).

While modeling research and the basic laws of hygrometry indicate that lighter color roofs, by decreasing surface temperature, will have greater risks of moisture accumulation, field experience based on the studies above and stakeholder feedback appears to show different realities. A representative of the single-ply roofing industry noted that, in the numerous roofing projects involving white single-ply membranes with which he has worked, moisture accumulation has not presented serious problems.

Fewer than 12 of the 35 respondents to the first cool roof survey conducted in January 2020 noted that moisture accumulation was a maintenance concern.

Additionally, a survey of roofing contractors conducted by Southern California Edison appears to show limited concern for moisture accumulation in cool roofs. This survey spoke with randomly selected roofing contractors, contractors who previously broached moisture concerns, and nonresidential program recipients who have installed cool roofs. Of the 47 respondents, 30 did not experience any moisture issues with cool roof installations while 6 noted that cool roofs could be the main cause of moisture damage. Of those six, one specialized in moisture accumulation repair and two only experienced moisture issues once or twice in their careers (Southern California Edison 2016).

Analyzing market trends in cooler climate zones is another practical pathway to determine the severity of moisture accumulation concerns with white roofs. The NRCA 2015-2016 survey projected that for 2016, over 50 percent of the low-sloped new construction market would be composed of PVC and TPO roofs for the New England region, which lies primarily in cooler national Climate Zones 5 and 6. The ASHRAE 90.1 cool roof code does not prescribe any reflectance level for these climate zones, so the impetus to installing these single-ply membranes, that are typically highly reflective, is not code compulsion. If lighter roof membranes were leading to systematic moisture accumulation problems, the market should already be shying away from this technology, and this does not appear to be the market reality.

Dregger notes that roof decay due to cool roof installation occurs in combination with other roofing problems, such as air infiltration and moisture accumulation (Dregger 2012). If such problems occur, one of the potential methods to mitigate moisture accumulation, as noted by Dregger and Ober, is the addition of above deck insulation, which is required in the roof alterations proposal of this Final CASE Report. “The good news is that for most projects a relatively modest amount of R-value on top can make a big difference below” (Taylor 2017). Taylor also notes that the addition of above deck insulation is a pathway to mitigate moisture concerns and that the degree of air infiltration into the roof changes how much is needed

Another potential avenue to address moisture concerns would be to reduce the amount of warm interior air introduced into the roofing assembly by installing a vapor barrier. However, it is noted incomplete or discontinuous vapor retarders can actually trap moisture in the roof deck. This can be the case if there is below deck insulation with pipes or ducts nearby. However, vapor-permeable air barriers can mitigate this potential (Dregger 2012). Similar to Dregger, Taylor notes that vapor retarders can trap any moisture that does get into the roof deck and the retarder should be vapor permeable if installed (Taylor 2017). Additionally, the Statewide CASE Team has been informed that if a vapor retarder is installed, water that enters through a roof leak can migrate along the barrier and emerge away from the source of water intrusion, which may necessitate a replacement of the entire system (Markman 2020).

The Statewide CASE Team is not aware of literature or guidelines from roofing manufacturers that direct designers to take corrective actions to mitigate moisture buildup when installing white roofs. The Statewide CASE Team has learned that the installation of two layers of above deck insulation with staggered joints run is the ideal way to prevent moisture from impacting the roof deck (Ober 2020).

In order to combat moisture accumulation concerns, the Statewide CASE Team is proposing the installation of at least R-10 insulation above deck when installing a cool roof during a roof alteration. From outreach to contractors and researchers, the Statewide CASE Team has learned that the vast majority of moisture issues occur from a roof alteration. Additionally, these individuals have noted that R-10 is both a feasible level of insulation to install above the deck and enough insulation to mitigate potential moisture accumulation.

The cost effectiveness of this insulation improvement and cool roof change is shown in Appendix J:.

Appendix J: Combined Energy Savings and Cost Effectiveness of Cool Roof and Roof/Ceiling Insulation Recommendations

Though the Statewide CASE Team is not proposing low-sloped cool roof changes, analysis was conducted to see the interactive effects of a change with insulation improvements. Several stakeholders requested that the Statewide CASE Team evaluate the combined impact of the proposed changes to the roof / ceiling insulation requirements and the cool roof requirements for low-sloped buildings. This appendix presents the requested information.

The Statewide CASE Team calculated the energy savings and cost effectiveness using the same methodology presented in the body of this report. That is, energy impacts were simulated using version 9.01 of EnergyPlus with CBECC-Com rulesets applied. The Standard Design represents minimal compliance with 2019 code requirements and the Proposed Design represents minimal compliance with the proposed requirements for the 2022 code cycle. Table 176 present the specific assumptions used when simulating energy impacts. For this analysis, the Statewide CASE Team modified both the cool roof and roof insulation assumptions at the same time to simulate the impact of both revisions occurring simultaneously. For altered buildings, the Statewide CASE Team evaluated the combined impacts of cool roofs and the recommended requirements for roof recovers.

The Medium Office prototype was used to evaluate the combined impacts of the cool roof and roof insulation requirements because this building type is one that is impacted by all measures of this proposal and represents a substantial amount of square footage.

Table 177 presents the assumed incremental cost of the proposed code changes over the 30-year period of analysis. These cost estimates are consistent with cost presented in Sections 2.4, 3.4, and 5.4. The OfficeMedium prototype has a roof area of 17,878 ft^2.

The energy cost savings over the 30-year period of analysis (benefit) was calculated by multiplying the annual TDVKBtu savings by the TDV energy cost multiplier, consistent with the methodology used to calculate the energy cost savings of each proposed change independently.

Table 178 and Table 179 present the combined energy savings and cost effectiveness of the low-sloped cool roofs and roof insulation recommendations for new construction and alterations, respectively. While the Opaque Envelope benefit-to-cost ratio for all climate zones for the medium office prototype are less than 1.0, the interactive benefit-to-cost results with the cool roof proposal is over 1.0 for multiple climate zones. For all climate zones, apart from Climate Zone 1 where the cool roof measure sees negative savings, the combined TDV savings are greater than for either proposal as

Table 178 shows.

For the interactive alteration results, the benefit-to-cost ratio is above 1.0 in every climate zone despite the cool roof measure being below 1.0 in three climate zones as shown in Table 179. In all climate zones, except for Climate Zone 1 where the cool roof measures sees negative savings, the interactive TDV savings are greater than for either individual proposal.

Table 176: Assumptions for Standard Design and Proposed Design to Simulate Combined Impacts of Proposed Cool Roof and Roof / Ceiling Insulation Requirements for New Construction and Alterations

Type of Construction	Submeasure	Climate Zones	Parameter	Standard Design	Proposed Design
New Construction	Low-sloped Cool Roof	All	Solar Reflectance	0.63	0.70
New Construction	Low-sloped Cool Roof	All	Thermal Emittance	0.75	0.75
New Construction	Roof / Ceiling Insulation	1 – 5, 9 – 16	U-Factor (without air film)	0.035	0.031
New Construction	Roof / Ceiling Insulation	6 – 8		0.051	0.042
Alterations	Low-sloped Cool Roof	All	Solar Reflectance	0.63	0.70
Alterations	Low-sloped Cool Roof	All	Thermal Emittance	0.75	0.75
Alterations	Roof / Ceiling Insulation	1, 3-5, 9	U-Factor (with air film)	U-0.125	U-0.043
Alterations	Roof / Ceiling Insulation	2, 10-16	U-Factor (with air film)	U-0.071	U-0.043
Alterations	Roof / Ceiling Insulation	6 – 8	U-Factor (with air film)	U-0.125	U-0.059

Table 177: Incremental Costs used to Calculate the Combined Impacts of Proposed Cool Roof and Roof / Ceiling Insulation Requirements for New Construction and Alterations

Type of Construction	Submeasure	Climate Zones	Total Incremental Cost Over 30-year Period of Analysis
Construction	Low-sloped Cool Roof	All	$1,159
New Construction	Roof / Ceiling Insulation	All	$5,363
Alterations	Low-sloped Cool Roof	All	$1,159
Alterations	Roof / Ceiling Insulation	1, 3-5, 9	$21,714
Alterations	Roof / Ceiling Insulation	2, 10-16	$12,744
Alterations	Roof / Ceiling Insulation	6 – 8	$13,278

Table 178: Energy Savings and Cost Effectiveness of Cool Roof and Roof Insulation Proposals Independently and Combined – Office Medium Prototype for New Construction[a]

Climate Zone	Low-sloped Cool Roof Independent TDV Energy Savings (TDVkBtu/ft^2)	Roof Insulation for New Construction Independent TDV Energy Savings (TDVkBtu/ft^2)	Combined Low-sloped Cool Roof and Roof Insulation for New Construction TDV Energy Savings per ft2 (TDVkBtu/ft^2)	Low-sloped Cool Roof Independent Benefit-to-Cost Ratio	Roof Insulation Independent Benefit-to-Cost Ratio	Combined Low-sloped Cool Roof and Roof Insulation for New Construction Benefit-to-Cost Ratio
1[b]	(0.08)	0.57	0.495	(0.55)	0.88	0.63
2[b]	0.16	0.46	0.615	1.16	0.71	0.78
3[b]	0.06	0.3	0.368	0.45	0.47	0.47
4	0.16	0.32	0.516	1.13	0.49	0.65
5[b]	0.05	0.32	0.36	0.33	0.48	0.46
6	0.25	0.4	0.611	1.80	0.61	0.77
7	0.22	0.27	0.478	1.55	0.41	0.6
8	0.44	0.52	0.833	3.13	0.81	1.05
9	0.31	0.35	0.636	2.21	0.53	0.8
10	0.28	0.32	0.558	2.01	0.49	0.71
11	0.26	0.49	0.719	1.82	0.75	0.91
12	0.21	0.43	0.627	1.52	0.66	0.79
13	0.35	0.51	0.817	2.47	0.78	1.03
14	0.34	0.55	0.841	2.40	0.85	1.06
15	0.43	0.44	0.793	3.05	0.67	1.00
16[b]	0.06	0.57	0.625	0.41	0.88	0.79

a. Low-sloped cool roof requirements are not proposed for Title 24, Part 6

b. Cool roof changes are not proposed in CALGreen for this climate zone

Table 179: Energy Savings and Cost Effectiveness of Cool Roof and Roof Replacement Proposals Independently and Combined – Office Medium Prototype[a]

Climate Zone	Low-sloped Cool Roof Independent TDV Energy Savings (TDVkBtu/ft^2)	Roof Replacement Independent TDV Energy Savings (TDVkBtu/ft^2)	Combined Low-sloped Cool Roof and Roof Replacement TDV Energy Savings per ft2 (TDVkBtu//ft^2)	Low-sloped Cool Roof Independent Benefit-to-Cost Ratio	Roof Replacement Independent Benefit-to-Cost Ratio	Combined Low-sloped Cool Roof and Roof Replacement Benefit-to-Cost Ratio
1 [a]	(0.28)	6.50	6.40	(2.0)	2.4	2.3
2 [a]	0.26	2.49	2.70	1.8	1.6	1.5
3 [a]	0.11	4.49	4.57	0.8	1.7	1.6
4	0.56	5.54	5.76	4.0	2.1	2.0
5 [a]	0.16	4.69	4.74	1.1	1.7	1.7
6	0.61	2.65	2.95	4.3	1.6	1.7
7	0.36	2.06	2.31	2.6	1.2	1.3
8	1.06	4.01	4.53	7.6	2.4	2.6
9	0.89	5.02	5.38	6.4	1.9	1.9
10	0.52	1.98	2.32	3.7	1.2	1.3
11	0.40	2.82	3.12	2.9	1.8	1.8
12	0.35	2.71	2.97	2.5	1.7	1.7
13	0.51	2.55	2.98	3.6	1.6	1.7
14	0.45	2.81	3.11	3.2	1.8	1.8
15	0.88	2.65	3.17	6.3	1.7	1.8
16 [a]	0.04	3.23	3.27	0.2	2.0	1.8

a. Low-sloped cool roof requirements are not proposed for Title 24, Part 6

b. Cool roof changes are not proposed in CALGreen for this climate zone

Appendix K: Energy Cost Savings in Nominal Dollars and Complete Cost-Effectiveness Results

The Energy Commission requested energy cost savings over the 30-year period of analysis in both 2023 present value dollars (2023 PV$) and nominal dollars. The cost effectiveness analysis uses energy cost values in 2023 PV$, and results of energy cost savings are presented in Sections 2.4, 3.4, 0, and 5.4. This appendix presents energy cost savings for each submeasure in nominal dollars. Though not proposed for Title 24, Part 6, results the low-sloped cool roof changes are presented below. Benefit-to-cost ratios above 1.0 represent cost-effective measures as defined by the Energy Commission.

Cool Roofs

Table 180: Nominal savings per square foot - Low-sloped (Nominal $ per square foot)- New Construction

Prototype Climate Zone	4	6	7	8	9	10	11	12	13	14	15
Hospital	0.10	0.01	0.13	0.04	0.04	0.03	0.21	(0.02)	(0.06)	0.02	0.00
OfficeLarge	0.01	0.01	0.00	(0.00)	0.01	0.02	0.00	0.00	0.01	0.01	0.01
OfficeMedium	0.03	0.05	0.04	0.09	0.06	0.05	0.05	0.04	0.07	0.07	0.09
OfficeMediumLab	(0.00)	(0.04)	(0.06)	(0.02)	(0.01)	(0.03)	(0.03)	(0.04)	(0.02)	(0.02)	0.10
OfficeSmall	0.25	0.38	0.36	0.46	0.33	0.32	0.25	0.24	0.29	0.25	0.38
RestaurantFastFood	0.04	0.16	0.13	0.30	0.15	0.52	0.10	2.19	3.65	3.31	0.30
SchoolPrimary	0.13	0.27	0.22	0.32	0.21	0.21	0.14	0.14	0.18	0.13	0.28
SchoolSecondary	(0.02)	(0.04)	(0.06)	0.04	0.04	0.02	0.10	(0.02)	0.10	0.00	0.06

Table 181: Nominal savings per square foot - Low-sloped (Nominal $ per square foot)- Alterations

Prototype Climate Zone	4	6	7	8	9	10	11	12	13	14	15
OfficeLarge	0.01	0.04	0.01	0.04	0.02	0.00	0.01	0.00	0.01	0.01	0.02
OfficeMedium	0.11	0.13	0.07	0.23	0.19	0.10	0.08	0.06	0.10	0.08	0.19
OfficeMediumLab	(0.07)	(0.09)	(0.11)	(0.04)	(0.02)	(0.08)	0.11	(0.06)	(0.02)	(0.00)	(0.03)
OfficeSmall	0.70	0.67	0.66	1.11	1.01	0.55	0.53	0.41	0.70	0.41	0.82
RestaurantFastFood	(1.15)	0.07	0.21	0.55	0.36	0.31	0.23	0.14	0.27	0.15	0.57
SchoolPrimary	0.47	0.69	0.43	0.95	0.77	0.55	0.42	0.29	0.44	0.29	0.60
SchoolSecondary	(0.03)	(0.04)	(0.10)	0.16	0.12	0.07	0.01	(0.01)	0.06	(0.00)	0.16
Warehouse[b]	(0.55)	(0.39)	(0.41)	(0.38)	(0.49)	(0.20)	(0.26)	(0.32)	(0.27)	(0.37)	(0.14)

Table 182: Nominal savings per square foot - Steep-sloped (Nominal $ per square foot)- New Construction

Prototype **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Office Small	0.21	0.26	0.18	0.38	0.38	0.48	0.32	0.32	0.25	0.24	0.28	0.24	0.46	0.09
Restaurant	(0.05)	0.04	(0.14)	0.14	(0.13)	0.27	0.14	0.15	0.11	0.06	0.14	0.07	0.30	(0.12)
Retail Stand Alone	(0.54)	(0.36)	0.13	0.09	0.09	0.38	0.49	(0.38)	1.08	0.03	(0.08)	(0.49)	0.75	(0.01)
Retail Strip Mall	0.84	0.61	0.05	0.16	0.22	0.45	0.14	0.38	0.05	(0.08)	0.23	0.16	0.43	(0.15)

Table 183: Nominal savings per square foot - Steep-sloped (Nominal $ per square foot)- Alterations

Prototype **Climate Zone**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Office Small	0.57	1.00	0.80	1.11	1.10	1.38	1.30	0.88	0.66	0.70	0.74	0.66	0.99	0.37
Restaurant	(0.11)	0.11	(0.30)	0.20	0.77	0.53	0.46	0.29	0.19	0.11	0.25	0.14	2.76	(0.19)
Retail Stand Alone	(1.20)	(0.11)	(0.16)	0.38	0.06	0.85	(0.22)	(0.10)	0.30	(0.65)	0.49	(0.03)	0.65	(0.50)
Retail Strip Mall	(0.61)	1.02	0.65	0.87	1.00	1.26	0.59	0.25	0.46	0.26	1.04	0.52	0.89	0.20

Table 184: Cool Roof Low-Sloped- New Construction; Benefit-to-Cost Ratio by Climate Zone and Prototype Building [a]

Prototype **Climate Zone**	**4**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Hospital	5.8	1.2	7.7	3.2	3.1	2.1	14.0	(0.9)	(3.7)	1.6	0.5
OfficeLarge	1.6	1.9	0.8	0.1	1.6	2.5	0.8	0.9	1.4	1.4	1.3
OfficeMedium	1.2	1.9	1.6	3.3	2.3	2.1	1.9	1.6	2.6	2.5	3.2
OfficeMediumLab	0.7	(0.5)	(1.2)	0.5	0.5	(0.1)	(0.1)	(0.4)	0.3	0.3	4.2
OfficeSmall	2.7	3.8	3.6	4.6	3.4	3.3	2.7	2.6	3.1	2.8	3.8
RestaurantFastFood	1.2	2.4	2.1	3.8	2.2	6.0	1.7	22.6	38.2	34.8	3.4
SchoolPrimary	1.8	3.4	2.8	4.0	2.6	2.7	2.0	2.0	2.5	1.9	3.3
SchoolSecondary	0.1	(0.1)	(0.4)	1.5	1.2	0.8	2.2	0.2	2.5	0.6	1.5

a. Low-sloped changes are proposed for Title 24, Part 11.

Table 185: Cool Roof Low-Sloped- Alterations; Benefit-to-Cost Ratio by Climate Zone and Prototype Building [a]

Prototype / Climate Zone	4	6	7	8	9	10	11	12	13	14	15
OfficeLarge	2.17	4.74	1.80	5.12	3.12	0.65	1.61	0.73	1.47	2.20	2.25
OfficeMedium	4.01	4.32	2.56	7.58	6.35	3.67	2.88	2.49	3.64	3.21	6.25
OfficeMediumLab	(0.47)	(1.29)	(1.79)	0.94	1.60	(0.75)	4.79	(0.34)	1.04	1.19	0.58
OfficeSmall	7.22	6.61	6.49	10.73	9.98	5.42	5.43	4.40	6.73	4.41	7.81
RestaurantFastFood	(9.13)	2.17	3.44	6.78	5.46	4.10	3.32	2.73	3.76	2.76	6.10
SchoolPrimary	6.75	8.38	5.42	11.31	9.57	6.68	5.40	4.16	5.67	4.16	6.85
SchoolSecondary	1.21	0.70	(0.35)	4.37	3.68	2.13	1.01	0.85	2.02	1.10	3.63

a. Low-sloped changes are proposed for Title 24, Part 11.

Table 186: Cool Roof Steep-Sloped- New Construction; Benefit to Cost Ratio by Climate Zone and Prototype Building

Prototype / Climate Zone	2	4	5	6	7	8	9	10	11	12	13	14	15	16
OfficeSmall	4.82	5.39	3.95	7.67	7.53	9.53	6.52	6.57	5.46	5.33	5.91	5.27	9.06	3.06
RestaurantFastFood	1.13	2.37	(0.71)	4.41	(1.32)	6.96	4.14	4.40	3.49	2.87	4.12	3.00	6.82	(0.07)
RetailStandAlone	(11.24)	(7.52)	4.12	2.68	2.65	9.47	11.97	(8.14)	25.81	1.69	(1.04)	(10.24)	17.55	1.69
RetailStripMall	19.87	14.30	1.66	3.86	5.28	10.48	3.41	8.97	1.81	(1.07)	5.76	4.23	9.81	(1.83)

Table 187: Cool Roof Steep-Sloped- Alterations; Benefit to Cost Ratio by Climate Zone and Prototype Building

Prototype / Climate Zone	2	4	5	6	7	8	9	10	11	12	13	14	15	16
OfficeSmall	12.78	21.06	17.55	22.15	21.93	27.57	26.16	17.86	14.21	14.99	15.55	14.31	19.55	10.12
RestaurantFastFood	1.71	6.39	(0.61)	6.86	18.42	13.62	12.61	8.21	6.27	5.22	7.34	5.68	57.28	0.70
RetailStandAlone	(25.07)	0.52	(0.06)	10.56	2.88	21.46	(2.84)	(0.85)	8.85	(12.76)	13.11	1.48	15.67	(7.74)
RetailStripMall	(12.30)	25.62	17.65	20.85	23.71	29.87	15.04	6.86	12.07	7.49	25.02	13.49	20.70	8.46

Roof Alterations

Table 188: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – (Nominal $ Per Square Foot) – Replacements

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	5.1	4.9	3.8	4.2	3.9	5.3	4.7	6.6	3.9	4.1	5.2	5.0	5.0	5.4	4.3	6.8
Hospital	0.9	0.8	0.7	0.8	0.5	1.5	1.2	1.6	0.7	0.8	0.7	0.8	0.7	0.8	0.8	1.0
HotelSmall	1.2	0.9	0.7	0.7	0.7	0.7	0.6	1.0	0.6	0.6	1.0	0.9	0.9	1.0	0.7	1.4
OfficeLarge	0.3	0.3	0.4	0.3	0.2	0.0	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.4
OfficeMedium	1.2	1.0	0.7	0.9	0.8	0.9	0.8	1.3	0.7	0.8	1.1	1.1	1.0	1.1	0.9	1.5
OfficeMediumLab	1.4	1.3	1.0	1.2	1.2	1.3	1.3	1.7	1.1	1.1	1.2	1.2	1.1	1.4	0.8	1.8
OfficeSmall	2.8	2.4	1.4	1.6	1.3	1.2	0.8	2.3	1.3	1.5	3.0	2.4	2.8	2.7	2.8	3.8
RestaurantFastFood	4.6	4.7	3.4	4.4	3.3	3.2	2.9	4.5	3.9	3.2	4.0	4.0	3.7	3.9	5.0	4.7
RetailLarge	5.1	3.2	2.1	2.5	2.4	2.4	1.8	3.1	1.5	2.4	3.2	2.9	3.0	1.9	1.6	6.0
RetailStandAlone	1.8	2.0	1.0	0.2	1.2	1.3	1.0	1.6	0.7	0.5	2.7	2.3	1.5	2.3	0.4	2.8
RetailStripMall	3.8	3.8	2.3	1.0	2.5	2.5	2.1	3.0	1.4	1.2	4.8	4.1	2.9	4.1	0.8	5.6
SchoolPrimary	4.1	2.6	1.9	2.8	2.0	1.1	0.9	2.9	0.9	2.2	2.2	3.4	3.6	2.9	2.7	5.0
SchoolSecondary	4.2	3.4	2.0	2.1	2.4	2.5	1.7	4.2	1.8	2.4	3.8	3.3	3.5	3.5	2.5	4.8
Warehouse	3.1	2.8	2.0	2.2	2.2	2.7	2.3	3.8	2.2	2.1	2.7	2.7	2.6	3.0	2.0	4.4

Table 189: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – (Nominal $ Per Square Foot) – Recovers

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	5.0	4.6	3.6	3.9	3.6	7.8	7.0	9.3	3.2	3.4	5.1	4.7	4.7	5.3	4.4	4.7
Hospital	0.8	0.9	0.6	0.7	0.6	1.9	1.5	2.6	1.4	0.5	0.7	0.7	0.8	0.8	0.4	1.1
HotelSmall	1.2	1.0	0.7	0.7	0.7	1.3	1.0	1.7	0.6	0.7	1.0	0.9	0.9	1.0	0.7	1.4
OfficeLarge	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.2	0.3	0.2	0.2	0.3	0.1	0.3
OfficeMedium	1.1	1.0	0.6	0.7	0.7	1.3	1.1	1.9	0.7	0.8	1.0	1.0	1.0	0.9	0.9	1.3
OfficeMediumLab	1.3	1.2	0.9	1.0	1.0	1.6	1.5	2.1	1.0	1.0	1.2	1.1	1.0	1.3	0.7	1.6
OfficeSmall	2.9	2.3	1.3	1.6	1.3	2.1	1.3	4.1	1.3	1.7	2.9	2.5	2.7	2.7	2.5	3.6
RestaurantFastFood	4.1	3.6	3.1	4.1	2.9	4.7	3.6	5.5	2.7	1.8	3.6	3.5	3.3	3.4	0.4	4.0
RetailLarge	5.0	3.1	2.3	2.2	2.5	3.6	3.2	5.2	1.6	2.4	3.4	2.7	3.4	3.0	2.2	5.7
RetailStandAlone	4.4	3.8	1.9	2.0	2.6	3.3	3.4	4.7	1.3	1.4	4.3	3.2	3.3	4.2	1.1	5.5
RetailStripMall	4.2	2.9	1.4	1.4	1.8	2.2	2.3	7.7	0.8	2.2	3.0	2.4	2.0	2.7	3.0	4.9
SchoolPrimary	4.2	3.8	2.1	2.3	2.6	5.3	3.9	7.6	2.2	2.7	3.8	3.8	3.5	3.7	3.1	4.7
SchoolSecondary	3.1	2.9	2.1	2.3	2.2	4.7	4.0	6.6	2.2	2.2	2.9	2.8	2.6	3.2	2.0	4.5
Warehouse	3.2	2.0	1.7	1.6	1.6	2.2	2.0	2.3	1.1	1.1	2.0	1.9	1.5	1.8	0.6	3.3

High Performance Windows

Table 190: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – (Nominal $ Per Square Foot) – Fixed Windows

Prototype / **Climate Zone**	**2**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Grocery	($0.05)	($0.11)	($0.05)	($0.05)	($0.02)	($0.00)	($0.01)	$0.02	$0.02	$0.05	$0.00	$0.07
Hospital	$0.28	$0.40	$0.34	$0.21	$0.26	$0.22	$0.31	$0.56	$0.16	$0.40	$0.38	$0.27
OfficeLarge	$0.23	$0.12	$0.10	$0.25	$0.26	$0.37	$0.39	$0.30	$0.26	$0.32	$0.40	$0.31
OfficeMedium	$0.20	$0.09	$0.35	$0.31	$0.42	$0.44	$0.40	$0.43	$0.32	$0.45	$0.51	$0.60
OfficeMediumLab	$0.03	($0.17)	($0.05)	($0.06)	$0.06	$0.07	$0.03	$0.13	$0.05	$0.07	$0.13	$0.24
OfficeSmall	$0.44	$0.38	$0.63	$0.53	$0.57	$0.61	$0.64	$0.63	$0.51	$0.60	$0.58	$0.84
RestaurantFast Food	$0.17	$0.01	$0.54	$0.47	$0.65	$0.59	$0.60	$0.50	$2.41	$0.47	$0.28	$0.76
RetailLarge	($0.00)	$0.06	$0.05	$0.02	($0.05)	$0.06	($0.14)	($0.01)	$0.04	$0.10	($0.04)	$0.13
RetailMixedUse	($0.08)	($0.21)	$0.16	($0.19)	($0.00)	$0.03	$0.04	$0.13	($0.11)	$0.13	$0.08	$0.33
RetailStandAlone	$0.20	$0.01	$0.09	$0.05	$0.31	$0.02	$0.10	($0.00)	$0.20	$0.61	$0.19	$0.33
RetailStripMall	$0.02	($0.30)	$0.14	$0.03	($0.27)	($0.06)	($0.01)	($0.04)	$0.08	($0.05)	$0.12	$0.09
SchoolPrimary	$0.40	$0.33	$0.64	$0.57	$0.71	$0.72	$0.69	$0.68	$0.51	$0.70	$0.61	$1.03
SchoolSecondary	$0.04	($0.02)	$0.04	$0.01	$0.12	$0.11	$0.12	$0.23	$0.07	$0.21	$0.13	$0.18
Warehouse	$0.00	($0.00)	($0.01)	$0.00	($0.00)	$0.01	($0.00)	$0.00	($0.00)	($0.00)	$0.01	$0.00

Table 191: High Performance Windows - Fixed, Benefit-to-Cost Ratio by Climate Zone and Building Prototype

Prototype / **Climate Zone**	**2**	**5**	**6**	**7**	**8**	**9**	**11**	**12**	**13**	**14**	**15**
Grocery	(0.12)	(0.82)	(0.22)	(0.24)	0.12	0.41	0.63	0.56	0.86	0.53	1.10
Hospital	2.66	3.70	3.14	2.12	2.55	2.19	5.43	1.61	3.73	3.64	2.76
OfficeLarge	0.84	0.45	0.44	0.89	1.01	1.33	1.10	0.95	1.20	1.47	1.19
OfficeMedium	0.72	0.39	1.07	0.95	1.29	1.39	1.36	1.04	1.41	1.64	1.84
OfficeMediumLab	0.27	(0.28)	0.11	0.06	0.44	0.46	0.60	0.38	0.49	0.66	1.04
OfficeSmall	1.65	1.44	2.21	1.87	2.02	2.16	2.29	1.87	2.17	2.16	2.93
RestaurantFastFood	1.31	0.82	2.34	2.06	2.71	2.55	2.25	9.17	2.12	1.60	2.95
RetailLarge	0.12	1.12	0.97	0.34	(0.75)	1.01	(0.05)	0.83	1.72	(0.44)	2.21
RetailMixedUse	(0.29)	(1.20)	1.11	(1.21)	0.04	0.32	1.13	(0.57)	1.02	0.82	2.28
RetailStandAlone	2.50	0.41	1.10	0.71	3.57	0.37	0.20	2.44	6.90	2.37	3.64
RetailStripMall	0.43	(1.70)	1.09	0.31	(1.68)	(0.25)	0.04	0.79	(0.12)	1.20	0.71
SchoolPrimary	0.98	0.87	1.34	1.20	1.49	1.51	1.50	1.15	1.52	1.40	2.08
SchoolSecondary	0.25	0.09	0.27	0.13	0.55	0.51	0.92	0.33	0.90	0.63	0.78
Warehouse	0.07	(0.05)	(0.57)	0.30	(0.18)	1.33	0.47	(0.08)	(0.21)	0.88	0.52

Table 192: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – (Nominal $ Per Square Foot) – Curtain Wall / Storefront Windows

Prototype / **Climate Zone**	**1**	**7**	**16**
Grocery	$0.10	$0.03	$0.12
HotelSmall	$0.18	$0.01	$0.15
OfficeMedium	$0.34	$0.05	$0.42
OfficeSmall	$0.22	$0.01	$0.28
RestaurantFast Food	$0.50	($0.04)	$0.30
RetailLarge	$0.07	$0.09	$0.06
RetailMixedUse	$0.09	$0.15	$0.14
RetailStand Alone	($0.03)	$0.43	$0.17
RetailStripMall	$0.14	$0.14	$0.18

Table 193: High Performance Windows – Curtain wall/Storefront, Benefit-to-Cost Ratio by Climate Zone and Building Prototype

Prototype / **Climate Zone**	**1**	**7**	**16**
Grocery	1.64	0.54	2.05
HotelSmall	1.90	(0.02)	1.57
OfficeMedium	1.22	0.11	1.50
OfficeSmall	0.85	0.00	1.11
Restaurant FastFood	2.08	(0.43)	0.75
RetailLarge	1.68	2.54	1.26
RetailMixedUse	0.56	1.77	0.99
RetailStandAlone	(0.50)	8.17	2.69
RetailStripMall	0.95	1.58	1.36

Opaque Envelope

Table 194: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – (Nominal $ Per Square Foot) – Opaque Envelope

Prototype / **Climate Zone**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Grocery	$1.29	$1.02	$0.97	$0.94	$0.75	$0.83	$0.77	$1.09	$0.80	$0.84	$1.20	$1.10	$1.16	$1.31	$0.96	$1.23
Hospital	$0.23	$0.20	$0.08	$0.19	($0.14)	$0.04	$0.14	$0.24	$1.57	$0.27	$0.17	$0.27	$0.35	$0.39	$0.32	$0.29
OfficeLarge	$0.23	$0.22	$0.20	$0.15	$0.24	$0.37	$0.17	$0.18	$0.15	$0.21	$0.19	$0.18	$0.36	$0.37	$0.13	$0.20
OfficeMedium	$0.51	$0.40	$0.37	$0.30	$0.26	$0.26	$0.21	$0.31	$0.29	$0.28	$0.44	$0.38	$0.43	$0.45	$0.37	$0.55
OfficeMediumLab	$0.70	$0.54	$0.61	$0.52	$0.45	$0.44	$0.38	$0.45	$0.38	$0.36	$0.46	$0.49	$0.36	$0.47	$0.38	$0.62
OfficeSmall	$0.88	$0.91	$0.74	$0.70	$0.51	$0.82	$0.63	$1.02	$0.70	$0.84	$1.19	$0.96	$1.12	$1.08	$1.35	$1.29
RestaurantFast Food	$1.77	$1.66	$1.82	$2.58	$1.32	$1.57	$1.18	$1.42	$1.38	$1.48	$1.72	$1.63	$1.59	$1.62	$3.25	$1.53
RetailLarge	$0.90	$0.23	$0.68	($0.17)	$0.39	($0.65)	($0.06)	$0.18	($0.07)	$0.22	$0.38	$0.90	$0.36	$0.14	$0.03	$0.97
RetailMixedUse	$0.51	$0.29	$0.66	($0.00)	($0.13)	$0.09	($0.02)	$0.19	$0.06	$0.05	$0.53	$0.34	$0.68	$0.30	$0.52	$0.58
RetailStandAlone	$1.18	$1.07	$0.60	$0.63	$0.45	$0.55	$0.23	$1.35	$0.63	$0.10	$0.82	($0.17)	$1.65	$1.04	$2.47	$1.36
RetailStripMall	$1.24	$1.65	$0.96	$0.44	$0.58	$0.03	$0.23	$0.46	$0.53	($0.25)	$0.73	$1.02	$0.76	$0.77	$1.20	$1.47
SchoolPrimary	$0.93	$0.91	$0.65	$0.51	$0.36	$0.43	$0.30	$0.55	$0.44	$0.55	$0.78	$0.73	$0.72	$0.74	$0.66	$1.05
SchoolSecondary	$0.70	$0.51	$0.49	$0.41	$0.45	$0.40	$0.34	$0.51	$0.35	$0.38	$0.62	$0.49	$0.57	$0.56	$0.38	$0.84
Warehouse	$1.00	$0.53	$0.56	$0.37	$0.39	$0.29	$0.28	$0.29	$0.22	$0.23	$0.52	$0.49	$0.40	$0.43	$0.13	$0.90

Table 195: Benefit-to-Cost Ratio by Climate Zone and Building Prototype, Opaque Envelope – Roof

Prototype **Climate Zone**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Grocery	2.28	1.94	1.82	1.83	1.41	1.62	1.51	2.19	1.57	1.66	2.31	2.12	2.28	2.59	1.96	2.12
Hospital	1.40	1.43	0.19	1.41	(1.38)	0.33	0.92	2.01	15.82	2.29	1.20	2.04	2.78	2.89	3.02	2.16
OfficeLarge	2.62	2.85	2.39	1.94	3.28	5.24	2.25	2.55	1.96	2.97	2.53	2.36	5.27	5.20	1.98	2.14
OfficeMedium	2.02	1.72	1.52	1.30	1.05	1.13	0.91	1.45	1.37	1.28	2.06	1.69	2.06	2.11	1.92	2.28
OfficeMediumLab	2.78	2.26	2.49	2.21	1.81	1.83	1.56	1.99	1.73	1.59	2.06	2.11	1.66	2.13	2.13	2.48
OfficeSmall	1.18	1.46	1.16	1.17	0.78	1.47	1.12	1.82	1.23	1.46	2.00	1.57	1.91	1.79	2.46	1.93
RestaurantFastFood	2.38	2.49	2.59	4.26	1.90	2.48	1.83	2.26	2.21	2.36	2.66	2.51	2.52	2.50	5.71	2.22
RetailLarge	1.46	0.16	1.22	(0.65)	0.62	(1.75)	(0.36)	0.18	(0.33)	0.32	0.55	1.78	0.55	0.01	(0.02)	1.61
RetailMixedUse	4.17	2.70	7.41	(0.76)	(2.50)	0.86	(0.44)	2.33	0.41	0.13	5.71	3.46	8.04	2.99	6.75	5.12
RetailStandAlone	1.67	1.79	0.75	1.00	0.57	0.90	0.25	2.60	1.11	(0.04)	1.26	(0.81)	3.14	1.79	5.13	2.07
RetailStripMall	1.62	2.89	1.45	0.58	0.85	(0.12)	0.30	0.72	0.87	(0.72)	0.98	1.60	1.14	1.14	2.31	2.06
SchoolPrimary	1.40	1.68	1.09	0.89	0.50	0.77	0.51	1.02	0.83	1.04	1.38	1.29	1.33	1.31	1.36	1.69
SchoolSecondary	1.81	1.37	1.26	1.10	1.20	1.06	0.88	1.45	0.99	1.06	1.80	1.31	1.72	1.60	1.21	2.27
Warehouse	1.56	0.83	0.88	0.57	0.61	0.46	0.45	0.45	0.35	0.34	0.81	0.76	0.62	0.68	0.19	1.41

Appendix L: Answers to Frequently Asked Questions

Below is a comprehensive overview of key comments and questions the Statewide CASE Team received on the Draft CASE Report, and the associated responses to these concerns.

Cool Roofs

1. A concern raised by numerous commenters is that the energy modeling alone is not enough to show that cool roofs save energy. Commenters recommended that the HVAC data from state-owned buildings that have recently installed cool roofs or buildings that have used utility incentives to install cool roofs be analyzed.
    a. Response: The Statewide CASE Team acknowledges that no energy model produces perfect results; however, modeling is the best tool available to evaluate the energy impacts of building design features. It is outside the scope of this measure to evaluate the specific attributes of EnergyPlus compared to other modeling software. Furthermore, Section 2.3.4 shows numerous prior field studies and simulations that have been conducted over two decades have shown the energy savings benefits of cool roofs. Lastly, the Statewide CASE Team is unable to show the impacts of cool roof on a state-owned building or utility provided incentives, as the roof reflectance changes are accompanied by changes to other systems in the building and identifying the specific cool roof impacts is not feasible.
2. An additional concern raised by multiple stakeholders is that the Statewide CASE Team needs to confirm that products are available in California markets that meet the proposed reflectance levels.
    a. Response: The Statewide CASE Team has called dozens of distributors across the state and confirmed that products that meet both the proposed low-sloped and steep-sloped standards are available. Additionally, a survey conducted by the Statewide CASE Team has confirmed that numerous products with reflectances at or above the proposed reflectance level are used, and thus available, in California markets.
3. One stakeholder noted that the low-slope proposal would severely limit color choice to only white membranes.
    a. Response: The Statewide CASE Team acknowledges that, currently, only white single-ply or mod-bit membranes could meet the proposed low-slope aged solar reflectance requirements. Section 2.2.2.4 discusses this issue more in-depth. While white membranes are only available to meet the

prescriptive cool roof requirements, non-white membranes can be used to meet the insulation trade-off or also in the performance path. Additionally, numerous non-white coatings have aged reflectances above 0.70.

4. One stakeholder noted that the whole building approach is preferred rather than requiring one specific code change.
    a. Response: The Statewide CASE Team acknowledges that what may work for one building may not work for another. The whole building approach is an option for designers who follow the performance path. If the prescriptive path is followed, designers are given more flexibility with the roof reflectance/insulation trade-off table.
5. One commenter noted that the current aged solar reflectance test procedure outlined in ANSI/CRRC S100 is flawed and does not show real world impacts.
    a. Response: Assessing the accuracy of test procedure is considered outside the scope of this code change proposal. The Statewide CASE Team is not aware of any studies showing the current test procedures produce flawed results.
6. One commenter sought clarification from which the market share assumptions came.
    a. Response: The low-slope market assumptions came from a 2015-2016 National Roofing Contractor Association survey (NRCA 2015). For the steep-slope market share, the research behind assuming an evenly split market share between metal, tile and asphalt has been clarified in Section 2.2.1.1.
7. Multiple commenters noted that the Statewide CASE Team would be imposing undue cost upon manufacturers, such as the relocation of manufacturing plant materials, and needs to consider this.
    a. Response: California has established specific and ambitious energy and climate goals that are guiding the Energy Commission's efforts to update Title 24, Part 6.[34] The Statewide CASE Team is supporting the Energy Commission in its pursuit of these goals, in part through cost-effective

[34] Energy Commission staff have cited the following as establishing goals for new building codes: 2008 California Public Utilities Commission and Energy Commission Energy Action Plan that establishes a goal that newly constructed nonresidential buildings be zero net energy by 2030; Senate Bill 100, which requires renewable energy and zero-carbon resources to supply 100 percent of electric retail sales to end-use customers by 2045; Executive OrderB-55-18, which requires the state to achieve carbon neutrality by 2045; and Assembly Bill 3232, which requires the Energy Commission to assess how to reduce greenhouse gas emissions from the residential and commercial buildings by 40 percent below 1990 levels by 2030.

changes to Title 24, Part 6 that lead to energy savings and emissions reductions. Criteria to assess the cost-effectiveness of these proposals direct the Statewide CASE Team to look into the cost impacts on the building owner, and the analysis presented in Section 2.4 demonstrate this. The products that meet the current prescriptive requirements can still be used in California in conjunction with the insulation tradeoff or through the performance approach, so current manufacturer processes need not necessarily be greatly changed.

8. One commenter noted the Statewide CASE Team should add a thermal emittance requirement to the existing thermal mass exception
    a. Response: The Statewide CASE Team will not be proposing a change to the existing exception for thermal mass. The existing exception is more stringent than those in ASHRAE 90.1 2019 and IECC 2018.
9. Multiple commenters noted the Statewide CASE Team should account for HVAC sizing in determining cost-effectiveness.
    a. Response: The Statewide CASE Team notes that impacts of any individual submeasure are too small to have a calculable difference in the sizing of HVAC impact.

Appendix M: Recommended Simplifications for Hotel / Motel Envelope Requirements

Background on Envelope Requirements for Hotel/Motel

As of the 2019 Title 24, Part 6 requirements, hotel/motel buildings are subject to two different sets of envelope requirements: the nonresidential space types must comply with requirements in Table 140.3-B that apply to nonresidential buildings, and guestroom spaces must comply with requirements in Table 140.3-C. The existing requirements pose compliance challenges and make the code overly complex. In practice, a designer is unlikely to design a building with different roof and wall insulation, roof reflectance, and window performance depending on whether the adjacent space is a guestroom or a common area. This proposal would simplify requirements for hotel/motel. The entire hotel/motel roof would need to adhere to one requirement as opposed to different requirements depending on the space type located under the roof.

Table 140.3-C currently includes envelope requirements that apply to guestroom spaces within hotel/motel and high-rise residential. With the multifamily restructuring recommendations that the Statewide CASE Team is proposing for this code cycle, the envelope requirements that apply to high-rise residential would be moved to the new multifamily section. The requirements in Table 140.3-C would then only apply to guestroom spaces within hotel/motel buildings.

Recommended Requirements for Hotel/Motel Envelope

To simplify the code requirements and address compliance challenges, the Statewide CASE Team is recommending that envelope requirements for guestroom spaces in hotel/motel buildings be the same as the nonresidential spaces. Table 196 presents existing requirements in Table 140.3-B, and Table 140.3-C. The table also presents the recommended requirements that would apply to the entire hotel/motel building. The recommended envelope requirements for hotel/motel are consistent with the proposed envelope requirements for nonresidential buildings presented in this report. The tables provided below show the proposed stringency increases.

The window performance requirements in the 2019 code are the same for nonresidential spaces and guestroom spaces. The recommended code changes presented in Section 4 of this report apply to all windows in nonresidential buildings.

Table 196: Recommended Envelope Requirements for Hotel / Motel

		Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roof	Table 140.3-B	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Roof	Table 140.3-C	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Roof	**Recommendation**	Metal Building	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**
Roof	Table 140.3-B	Wood Framed and Other	0.034	0.034	0.034	0.034	0.034	0.049	0.049	0.049	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Roof	Table 140.3-C	Wood Framed and Other	0.028	0.028	0.034	0.028	0.034	0.034	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Roof	**Recommendation**	Wood Framed and Other	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.042**	**0.042**	**0.042**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**	**0.030**
Walls	Table 140.3-B	Metal-framed	0.069	0.062	0.082	0.062	0.062	0.069	0.069	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Walls	Table 140.3-C	Metal-framed	0.069	0.069	0.069	0.069	0.069	0.069	0.105	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
Walls	**Recommendation**	Metal-framed	**0.060**	**0.055**	**0.071**	**0.055**	**0.055**	**0.060**	**0.060**	**0.055**	**0.055**	**0.055**	**0.055**	**0.055**	**0.055**	**0.055**	**0.055**	**0.055**
Roofing Products	Table 140.3-B	Low-Sloped Aged Solar Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Roofing Products	Table 140.3-C	Low-Sloped Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	0.55	NR	0.55	0.55	0.55	NR
Roofing Products	**Recommendation**	Low-Sloped Aged Solar Reflectance	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**	**0.63**
Roofing Products	Table 140.3-B	Low-Sloped Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Roofing Products	Table 140.3-C	Low-Sloped Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	0.75	NR	0.75	0.75	0.75	NR
	Recommendation	Low-Sloped Thermal Emittance	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**
	Table 140.3-B	Steep-Sloped Aged Solar Reflectance	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
	Table 140.3-C	Steep-Sloped Aged Solar Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	NR
	Recommendation	Steep-Sloped Aged Solar Reflectance	**0.20**	**0.25**	**0.20**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**

		Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Table 140.3-B	Steep-Sloped Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	Table 140.3-C	Steep-Sloped Thermal Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	NR
	Recommendation	Steep-Sloped Thermal Emittance	0.75	**0.80**	**0.75**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**	**0.80**
Roof Replacements	Current Requirement for NR (Table 141.0-C)	Continuous Insulation	R-8	R-14	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-14	R-14	R-14	R-14	R-14	R-14	R-14
	Current Requirement for Guestrooms (Table 141.0-C)	Continuous Insulation	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14	R-14
	Recommendation	Continuous insulation	**R-23**	**R-23**	**R-23**	**R-23**	**R-23**	**R-17**	**R-17**	**R-17**	**R-23**	**R-23**	**R-23**	**R-23**	**R-23**	**R-23**	**R-23**	**R-23**

Note: The recommended envelope requirements would apply to the entire hotel/motel building. The recommendation is to align with the proposed requirements as presented in this report. When the recommendation is highlighted green, the requirements for nonresidential spaces and guestroom spaces are the same in the 2019 code and there are no proposed revisions for the 2022 code cycle. When the recommended requirements are highlighted yellow, the recommended requirement for guestroom space is more stringent than the 2019 code requirements. When the recommended requirements are highlighted in blue, the proposed requirements for guestroom spaces are less stringent than current requirements.

Energy Savings and Cost-Effectiveness of Proposed Envelope Requirements for Hotel/Motel

Energy Savings

Energy Savings Methodology for Hotel / Motel

The Statewide CASE Team calculated the energy savings and cost effectiveness using the same methodology presented in the body of this report. That is, energy impacts were simulated using version 9.01 of EnergyPlus with CBECC-Com rulesets applied. The Standard Design represents minimal compliance with 2019 code requirements and the Proposed Design represents minimal compliance with the proposed requirements for the 2022 code cycle. The hotel/motel prototype is described in Table 197.

Table 197: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)	Description
HotelSmall	4	43,206	4 story Hotel with 77 guest rooms. WWR-11%

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

To develop savings estimates for the proposed code changes, the Statewide CASE Team generated a Standard Design using the CBECC-Com Hotel prototype model and created a Proposed Design by modifying the relevant inputs in the Standard Design model to reflect the submeasure. The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 198 and Table 199 present which parameters were modified and what values were used in the Standard Design and Proposed Design for new construction and alterations, respectively. There are two baseline value, one value for the guestroom space and one for the common space or nonresidential space. There is one Proposed Design that would apply to the entire hotel/motel.

The steep-sloped cool roof and roof recover proposed requirements were not modeled for the HotelSmall prototype and it was assumed that hotel/motels would not be affected by the curtain wall/storefront window requirements so those were also not modeled.

Table 198: Modifications Made to Standard Design to Simulate all Proposed Code Changes for Hotels – New Construction

Climate Zone	Low-Sloped Cool-Roof Aged Solar Reflectance			Roof Replacement Roof U-factor			Opaque Envelope Metal-Framed Wall U-factor			Windows U-factor / SHGC		
	Standard Design Guestroom Space	Standard Design Nonresidential Space	Proposed Design	Standard Design Guestroom Space	Standard Design Nonresidential Space	Proposed Design	Standard Design Guestroom Space	Standard Design Nonresidential Space	Proposed Design	Standard Design Guestroom Space	Standard Design Nonresidential Space	Proposed Design
1	0.08	0.63	0.63	0.071	0.125	0.043	0.069	0.069	0.06	0.36 / 0.25	0.36 / 0.25	0.36 / 0.25
2	0.08	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
3	0.08	0.63	0.63	0.071	0.125	0.043	0.069	0.082	0.071	0.36 / 0.25	0.36 / 0.25	0.36 / 0.25
4	0.08	0.63	0.63	0.071	0.125	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.36 / 0.25
5	0.08	0.63	0.63	0.071	0.125	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
6	0.08	0.63	0.63	0.071	0.125	0.059	0.069	0.069	0.06	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
7	0.08	0.63	0.63	0.071	0.125	0.059	0.105	0.069	0.06	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
8	0.08	0.63	0.63	0.071	0.125	0.059	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
9	0.55	0.63	0.63	0.071	0.125	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
10	0.55	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.36 / 0.25
11	0.55	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
12	0.08	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
13	0.55	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
14	0.55	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
15	0.55	0.63	0.63	0.071	0.071	0.043	0.048	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.34 / 0.22
16	0.08	0.63	0.63	0.071	0.071	0.043	0.069	0.062	0.055	0.36 / 0.25	0.36 / 0.25	0.36 / 0.25

Table 199: Modifications Made to Standard Design to Simulate all Proposed Code Changes for Hotels – Alterations

Climate Zone	Low-Sloped Cool-Roof Aged Solar Reflectance			Opaque Envelope Wood Framed and Other Roof U-factor		
	Standard Design Guestroom Space	Standard Design Nonresidential Space	Proposed Design	Standard Design Guestroom Space	Standard Design Nonresidential Space	Proposed Design
1	0.08	0.63	0.63	0.028	0.034	0.03
2	0.08	0.63	0.63	0.028	0.034	0.03
3	0.08	0.63	0.63	0.034	0.034	0.03
4	0.08	0.63	0.63	0.028	0.034	0.03
5	0.08	0.63	0.63	0.034	0.034	0.03
6	0.08	0.63	0.63	0.034	0.049	0.042
7	0.08	0.63	0.63	0.039	0.049	0.042
8	0.08	0.63	0.63	0.028	0.049	0.042
9	0.08	0.63	0.63	0.028	0.034	0.03
10	0.55	0.63	0.63	0.028	0.034	0.03
11	0.55	0.63	0.63	0.028	0.034	0.03
12	0.08	0.63	0.63	0.028	0.034	0.03
13	0.55	0.63	0.63	0.028	0.034	0.03
14	0.55	0.63	0.63	0.028	0.034	0.03
15	0.55	0.63	0.63	0.028	0.034	0.03
16	0.08	0.63	0.63	0.028	0.034	0.03

CBECC-Com calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). 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) (Energy + Environmental Economics 2020). CBECC-Com also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$).

Per Unit Energy Impacts Results

Energy savings and peak demand reductions per unit for new construction and alterations per building prototype square foot unit are presented in Table 200 and

Table 201. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. The energy models were run across all climate zones. All simulated results used the weather files the Energy Commission provided, which are based on historic weather.

Energy savings per square foot of total building square footage are presented in the tables below. Electricity savings are shown in Wh/ft^2. Natural gas savings are shown in millitherm/ft^2. Total TDV energy savings are shown in TDVKBtu/ft^2. When the proposed code change would increase energy use, the energy savings are negative and savings are shown as negative, depicted in red font and in parentheses ( ).

Table 200: Energy Savings Per ft^2 For Hotels – New Construction – All Measures

Climate Zone	Electricity Savings (Wh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings (millitherms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
1	(1.16)	0.00	2.14	0.69
2	25.00	0.00	0.42	1.31
3	6.41	0.00	1.39	0.79
4	23.63	0.00	1.04	1.26
5	10.71	0.00	(0.07)	0.29
6	42.19	0.00	(0.61)	1.05
7	44.54	0.00	0.47	1.31
8	56.03	0.00	(0.71)	1.65
9	29.79	0.00	0.63	1.39
10	20.10	0.00	1.50	1.23
11	39.30	0.00	2.23	2.23
12	47.02	0.00	0.89	2.01
13	45.00	0.00	1.50	2.13
14	36.05	0.00	1.58	1.90
15	55.65	0.00	(0.14)	1.67
16	24.56	0.00	4.34	2.05

Table 201: Energy Savings Per Square Foot – Hotels – Alterations

Climate Zone	Electricity Savings (Wh/ft^2)	Peak Electricity Demand Reductions (W/ft^2)	Natural Gas Savings (millitherms/ft^2)	TDV Energy Savings (TDV kBtu/ft^2)
1	5.91	0.00	3.59	1.44
2	68.76	0.00	1.12	2.44
3	30.43	0.00	2.82	1.81
4	86.02	0.00	3.15	3.55
5	41.09	0.00	2.99	1.81
6	77.88	0.00	0.29	1.96
7	69.39	0.00	0.29	1.62
8	121.64	0.00	0.77	3.54
9	121.79	0.00	2.27	4.03
10	36.42	0.00	2.96	1.90
11	37.28	0.00	4.79	2.71
12	97.48	0.00	1.78	3.29
13	47.07	0.00	3.69	2.60
14	37.51	0.00	4.86	2.79
15	67.24	0.00	1.45	2.45
16	63.44	0.00	3.43	2.52

Cost and Cost Effectiveness

Incremental First and Maintenance Cost

The incremental costs include the incremental material and labor costs associated with the proposed change over the 30-year period of analysis. This cost information was gathered through calls to distributors, 2020 RS Means, and other data collection methods as described in Sections 2.4, 3.4, 0, and 5.4.

To estimate incremental costs of the proposed changes for hotel/motel, the Statewide CASE Team determined the incremental cost of the following on a per square foot of affected space basis:

- Incremental cost of current requirements that apply to guestroom spaces relative to the proposed requirements.
- Incremental cost of the current requirements that apply to nonresidential spaces within the hotel/motel relative to the proposed requirement.

The Statewide CASE Team then used the building geometry in the prototypical hotel/motel building, which are shown in Table 202, to develop a floorspace weighted average incremental cost per square foot of impacted envelope element. The total cost for the entire prototypical building were calculated as were the cost per square foot of total building area. See the assumed incremental costs for new construction and alterations in Table 203 and Table 204 respectively.

Table 202: Floorspace Within Small Hotel Prototype Identified as Guestroom Space and Nonresidential Space by Submeasure

Measure	Floorspace Impacted by the Proposed Envelope Measure Guestroom Space (ft^2)	Floorspace Impacted by the Proposed Envelope Measure Nonresidential Space(ft^2)	Total Floorspace (ft^2)
Cool Roof	8,507	2,295	10,802
Wall Insulation	9,950	8,292	18,242
Roof Insulation	8,507	2,295	10,802
Windows	1,421	563	1,984
Total Building Area			42,544

Table 203: Total Incremental Cost Over 30-year Period of Analysis – Hotel Envelope Requirement Simplification – New Construction

Measure	Climate Zone	Incremental First Cost per Square Foot of Impacted Building Floorspace Baseline Nonresidential Space to Proposed (2023$/ft^2 of nonresidential space)	Incremental First Cost per Square Foot of Impacted Building Floorspace Baseline Guestroom Space to Proposed (2023$/ft^2 of guestroom space)	Weighted Average Incremental First Cost (2023$/ft^2 of impacted building space)	Incremental Maintenance Cost per Square Foot of Impacted Building Floorspace Baseline Nonresidential Space to Proposed (Nominal$/ft^2 of nonresidential space)	Incremental Maintenance Cost per Square Foot of Impacted Building Floorspace Baseline Guestroom Space to Proposed (Nominal $/ft^2 of guestroom space)	Weighted Average Incremental Maintenance Cost (Nominal$/ft^2 of impacted building space)	Total Incremental Cost per Square Foot of Entire Building (2023$/ft^2)
Cool roof	1	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	2	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	3	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	4	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	5	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	6	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	7	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	8	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	9	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	10	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	11	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	12	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	13	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	14	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	15	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	16	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17

Wall Insulation	1	$0.10	$0.10	$0.10	$0.00	$0.00	$0.00	$0.04
	2	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	3	$0.10	($0.02)	$0.04	$0.00	$0.00	$0.00	$0.02
	4	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	5	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	6	$0.10	$0.10	$0.10	$0.00	$0.00	$0.00	$0.04
	7	$0.10	$0.33	$0.22	$0.00	$0.00	$0.00	$0.10
	8	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	9	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	10	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	11	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	12	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	13	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	14	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
	15	$0.10	($0.12)	($0.02)	$0.00	$0.00	$0.00	($0.01)
	16	$0.10	$0.17	$0.14	$0.00	$0.00	$0.00	$0.06
Roof Insulation	1	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	2	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	3	$0.30	$0.30	$0.30	$0.00	$0.00	$0.00	$0.08
	4	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	5	$0.30	$0.30	$0.30	$0.00	$0.00	$0.00	$0.08
	6	$0.30	($0.42)	($0.27)	$0.00	$0.00	$0.00	($0.07)
	7	$0.30	($0.14)	($0.04)	$0.00	$0.00	$0.00	($0.01)
	8	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	9	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	10	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	11	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	12	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	13	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	14	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	15	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)
	16	$0.30	($0.18)	($0.08)	$0.00	$0.00	$0.00	($0.02)

Windows	1	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	2	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	3	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	4	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	5	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	6	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	7	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	8	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	9	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	10	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	11	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	12	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	13	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	14	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	15	$1.75	$1.75	$1.75	$0.00	$0.00	$0.00	$0.08
	16	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
All Measures	1							$0.20
	2							$0.30
	3							$0.27
	4							$0.21
	5							$0.39
	6							$0.23
	7							$0.34
	8							$0.30
	9							$0.30
	10							$0.14
	11							$0.22
	12							$0.30
	13							$0.22
	14							$0.22
	15							$0.15
	16							$0.21

Table 204: Total Incremental Cost Over 30-year Period of Analysis – Hotel Envelope Requirement Simplification – New Construction

Measure	Climate Zone	Incremental First Cost per Square Foot of Impacted Building Floorspace Baseline Nonresidential Space to Proposed (2023$/ft² of nonresidential space)	Incremental First Cost per Square Foot of Impacted Building Floorspace Baseline Guestroom Space to Proposed (2023$/ft² of guestroom space)	Weighted Average Incremental First Cost (2023$/ft² of impacted building space)	Incremental Maintenance Cost per Square Foot of Impacted Building Floorspace Baseline Nonresidential Space to Proposed (Nominal$/ft² of nonresidential space)	Incremental Maintenance Cost per Square Foot of Impacted Building Floorspace Baseline Guestroom Space to Proposed (Nominal $/ft² of guestroom space)	Weighted Average Incremental Maintenance Cost (Nominal$/ft² of impacted building space)	Total Incremental Cost per Square Foot of Entire Building (2023$/ft²)
Cool roof Alterations	1	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	2	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	3	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	4	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	5	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	6	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	7	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	8	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	9	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	10	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	11	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	12	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17
	13	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	14	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	15	$0.00	$0.30	$0.24	$0.00	$0.30	$0.24	$0.10
	16	$0.00	$0.53	$0.42	$0.00	$0.53	$0.42	$0.17

Roof Replacements	1	$1.21	$0.71	$0.82	$0.00	$0.00	$0.00	$0.20
	2	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	3	$1.21	$0.71	$0.82	$0.00	$0.00	$0.00	$0.20
	4	$1.21	$0.71	$0.82	$0.00	$0.00	$0.00	$0.20
	5	$1.21	$0.71	$0.82	$0.00	$0.00	$0.00	$0.20
	6	$0.74	$0.47	$0.53	$0.00	$0.00	$0.00	$0.13
	7	$0.74	$0.47	$0.53	$0.00	$0.00	$0.00	$0.13
	8	$0.74	$0.47	$0.53	$0.00	$0.00	$0.00	$0.13
	9	$1.21	$0.71	$0.82	$0.00	$0.00	$0.00	$0.20
	10	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	11	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	12	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	13	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	14	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	15	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
	16	$0.71	$0.71	$0.71	$0.00	$0.00	$0.00	$0.18
All Measures	1							$0.38
	2							$0.35
	3							$0.38
	4							$0.38
	5							$0.38
	6							$0.30
	7							$0.30
	8							$0.30
	9							$0.38
	10							$0.27
	11							$0.27
	12							$0.35
	13							$0.27
	14							$0.27
	15							$0.27
	16							$0.35

Cost Effectiveness

See Table 205 and Table 206 for the results of the cost effectiveness analysis. Eliminating the existing requirement that guestroom space comply with different envelop requirements than the nonresidential space will simplify the code and improve the code compliance process. As shown below, applying the proposed envelope requirements that would be applicable for all nonresidential buildings for the 2022 code cycle to hotel/motel buildings is cost effective in many climate zones.

Table 205: 30-Year Cost-effectiveness Summary Per Square Foot – Hotel/Motel New Construction

Climate Zone	2023 PV $ Energy Cost Savings + Other PV Savings per ft^2	Costs Total Incremental PV Costs	Benefit-to-Cost Ratio
1	$0.11	$0.20	0.54
2	$0.20	$0.30	0.68
3	$0.12	$0.27	0.46
4	$0.19	$0.21	0.91
5	$0.04	$0.39	0.11
6	$0.16	$0.23	0.70
7	$0.20	$0.34	0.59
8	$0.25	$0.30	0.86
9	$0.21	$0.30	0.73
10	$0.19	$0.14	1.37
11	$0.34	$0.22	1.57
12	$0.31	$0.30	1.05
13	$0.33	$0.22	1.50
14	$0.29	$0.22	1.33
15	$0.26	$0.15	1.70
16	$0.32	$0.21	1.48

Table 206: 30-Year Cost-effectiveness Summary Per Square Foot – Hotel/Motel Alterations

Climate Zone	2023 PV $ Energy Cost Savings + Other PV Savings per ft2	Costs Total Incremental PV Costs	Benefit-to-Cost Ratio
1	$0.22	$0.38	0.58
2	$0.38	$0.35	1.06
3	$0.28	$0.38	0.73
4	$0.55	$0.38	1.43
5	$0.28	$0.38	0.73
6	$0.30	$0.31	0.98
7	$0.25	$0.31	0.81
8	$0.54	$0.31	1.77
9	$0.62	$0.38	1.63
10	$0.29	$0.28	1.05
11	$0.42	$0.28	1.50
12	$0.51	$0.35	1.43
13	$0.40	$0.28	1.44
14	$0.43	$0.28	1.54
15	$0.38	$0.28	1.35
16	$0.39	$0.35	1.09

Statewide Energy Savings

The statewide energy and energy cost savings estimates for new construction and alterations are presented in Table 207 and Table 208, respectively.

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code changes. The Statewide CASE Team calculated the first-year statewide savings for additions and alterations by multiplying the per-unit savings by assumptions about the percentage of existing buildings that would be impacted by the proposed code changes.

The new construction first-year energy impacts represent the first-year annual savings from all buildings that will be completed in 2023 that would be impacted by the proposed code change. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 207: 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 (kW)	First-Year Natural Gas Savings (thousand therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.05	(0.00)	0.01	0.11	$0.01
2	0.31	0.01	0.37	0.13	$0.06
3	1.43	0.01	1.01	1.99	$0.17
4	0.74	0.02	1.04	0.77	$0.14
5	0.14	0.00	0.14	(0.01)	$0.01
6	0.85	0.04	1.39	(0.52)	$0.14
7	0.91	0.04	1.71	0.42	$0.18
8	1.18	0.07	2.76	(0.83)	$0.30
9	1.80	0.05	3.81	1.13	$0.39
10	1.03	0.02	1.45	1.54	$0.19
11	0.20	0.01	0.38	0.46	$0.07
12	1.19	0.06	2.24	1.06	$0.37
13	0.39	0.02	0.45	0.58	$0.13
14	0.22	0.01	0.47	0.35	$0.07
15	0.17	0.01	0.31	(0.02)	$0.04
16	0.07	0.00	0.15	0.30	$0.02
TOTAL	**10.69**	**0.35**	**17.71**	**7.47**	**$2.29**

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

Table 208: Statewide Energy and Energy Cost Impacts – Additions and Alterations

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 (kW)	First-Year Natural Gas Savings (million therms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.06	0.38	0.16	0.23	$0.01
2	0.38	0.03	1.07	0.42	$0.14
3	1.72	0.05	4.85	4.84	$0.48
4	0.89	0.08	3.54	2.80	$0.48
5	0.18	0.01	0.46	0.53	$0.05
6	1.11	0.09	2.88	0.33	$0.34
7	1.20	0.08	2.54	0.34	$0.30
8	1.53	0.19	5.40	1.18	$0.83
9	2.38	0.29	10.06	5.40	$1.48
10	1.37	0.05	1.93	4.05	$0.40
11	0.25	0.01	0.52	1.18	$0.10
12	1.43	0.14	6.04	2.53	$0.72
13	0.47	0.02	1.11	1.74	$0.19
14	0.30	0.01	0.69	1.43	$0.13
15	0.21	0.01	0.54	0.30	$0.08
16	0.09	0.01	0.23	0.30	$0.03
TOTAL	**13.55**	**1.43**	**42.01**	**27.61**	**$5.77**

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

Proposed Revisions to Code Language

The proposed revisions to the standards language can be found in Sections 2.6.2, 3.6.2, 4.6.2, and 1.1.1.

Appendix N: Fenestration U-Factor Maximum

Prior to publishing the Draft CASE Report, the Statewide CASE Team was approached with a proposal to regulate maximum window U-factor along the performance path of compliance. Currently there are maximum thermal performance values for wall insulation, but none for fenestration. This would have updated Section 120.7 of the code with maximum thermal transmittance values (U-factor) for fenestration in order to prevent drastically lower performing fenestration, as compared to the prescriptive requirements, from being installed due to the allowed trade-off with higher performing HVAC and lighting in the performance compliance path. The Statewide CASE Team is not pursuing these updates at this time and recommends that the California Energy Commission consider the stakeholder feedback outlined in this appendix for the next code change cycle.

The Draft CASE Report included a summary of this potential change and specifically asked for stakeholder feedback. Seven stakeholders commented on this specific aspect of the Draft CASE Report. Five stakeholders expressed support and provided specific recommendations, while one stakeholder directly opposed adding a backstop.

Proposed code language presented in Draft CASE Report:

SECTION 120.7 – MANDATORY INSULATION AND FENESTRATION REQUIREMENTS

(d) **Fenestration U-factor**. Vertical fenestration that separates conditioned spaces from unconditioned spaces or ambient air shall meet the applicable requirements of Items 1 and 2 below:

Fixed windows, curtain wall, or storefront - The weighted average U-factor of the combined fenestration assemblies shall not exceed X.

Operable windows - The weighted average U-factor of the combined fenestration assemblies shall not exceed Y.

Exception to Section 120.7(d): Fire-protection-rated fenestration assemblies, blast-resistant fenestration assemblies, renovation projects.

Table 209: Summary of Stakeholder Comments on Fenestration Backstop

Proposal	Number of Stakeholders in Support
10% over prescriptive values, varying by window product category	2
Overall U-factor maximum of 0.50	2
Overall U-factor maximum of 0.45	1

The Façade Tectonics Institute (FTI) provided the following extensive feedback, in correspondence with the Energy Commission and Statewide CASE Team:

> The Façade Tectonics Institute is supportive of the need to promote the implementation of higher performing façades and to make it less easy to trade off poor façade performance with higher internal system performance. The use of a single metric around which the building is optimized – energy use intensity- can lead to buildings with sub-optimal occupant comfort, resilience and passive survivability which does not help the state manage the impact of climate change nor move quickly towards net zero energy performance. The current heat wave which is causing brown and black outs across the state illustrates the importance of a high-performance envelope to maintain a functional indoor environment for a reasonable amount of time. A high-performance HVAC system is of no help if there is no power. The Institute agrees that some architectural design flexibility is needed to manage innovation and challenging applications and believe that this can be achieved by identifying exceptions and through setting the area weighted limits somewhat higher than the prescriptive values.
>
> FTI recommends that:
>
> 1. The maximum area weighted U-factors be separated according to the way in which T24 already separates fenestration (i.e., fixed windows, curtain wall and storefront, operable windows), rather than combining fixed windows with curtain wall and storefront.
>
> 2. The maximum area weighted U-factors be set at values 10% higher than the respective prescriptive requirement, to give design teams some flexibility.
>
> > a. Assuming the prescriptive U-factor requirements for fixed windows, operable windows and curtain wall/storefront are at 0.34, 0.46 and 0.41 respectively, this would mean maximum limits of 0.37, 0.51, 0.45 respectively, all of which are easily achievable with standard systems. We don't recommend putting specific numbers for maximum U-factor, just the +10% over the prescriptive baseline so that when the prescriptive numbers are reduced, so does this requirement.
>
> 3. Operable fenestration typically has higher U-factors than fixed fenestration. In order to support the use of natural ventilation, the area weighted U-factor for operable fenestration may be traded off with better area weighted average of the fixed fenestration types in the building, so long as the total area weighted U-factor of the fixed and operable fenestration does not exceed the sum of the maximum allowable U-factor (operable)*Area of operable fenestration plus maximum allowable U-factor (fixed fenestration)*Area fixed fenestration divided by the total fenestration area. (We can provide an equation for this, but hopefully you get what we are proposing).
>
> 4. The exceptions are as follows:
>
> > a. Fire resistant glazing (as already stated in the proposal)
> >
> > b. Blast resistant glazing (as already stated in the proposal)

c. Historic Preservation or historic restoration. We believe that an exception for just “renovation” is much too broad and that design teams should be made to increase the performance of the façade in all renovations unless they are true historic preservations or restorations. After all, renovations generally only happen once in a generation, and if we want to address existing building energy performance which is where most of the energy savings and resiliency impacts will be, we need to have higher expectations of post renovation performance.

d. Structural glass facades on the ground floor of single/two-story buildings or standalone structures where loads and/or movements (e.g. seismic) as demonstrated by engineering calculations preclude the use of insulating glass.

The one stakeholder that directly opposed the inclusion of a backstop for the 2022 code change cycle did express interest for inclusion in a future code change cycle after more thorough research, analysis, and more time for stakeholder feedback.

Appendix O: Roof Alterations and Insulation Costs

The methodology for determining material and labor costs for the roof alterations submeasure is described in Section 3.4.3, along with a summary of the costs. The Statewide CASE Team determined the cost for every California climate zone and then the costs were weighted based on the existing building forecast provided by the Energy Commission – see Table 210 for the forecast.

Table 210: Forecast of Existing Buildings for Each Climate Zone in 2023

Climate Zone	Nonresidential Existing Buildings (million ft^2)	Weighting Percent
1	30.89	0.4%
2	183.49	2.4%
3	851.99	10.9%
4	436.97	5.6%
5	86.81	1.1%
6	630.78	8.1%
7	470.95	6.0%
8	900.40	11.6%
9	1,458.22	18.7%
10	902.57	11.6%
11	177.20	2.3%
12	912.77	11.7%
13	350.66	4.5%
14	206.24	2.6%
15	124.12	1.6%
16	64.88	0.8%
Total	7,788.95	100%

To determine the labor cost for each R-value, the labor costs were plotted for each climate zone and fitted with a logarithmic curve. The cost per R-value was then weighted by the construction forecast. The plot of the labor O&P costs can be found in Figure 25.

The material and labor costs for each climate zone can be found in Table 210. Bare material, bare labor, bare total, and total O&P (overhead and profit) are taken directly from the RSMeans values for 2020. Material O&P and labor O&P were determined by multiplying the respective bare value by the ratio of O&P total/bare total.

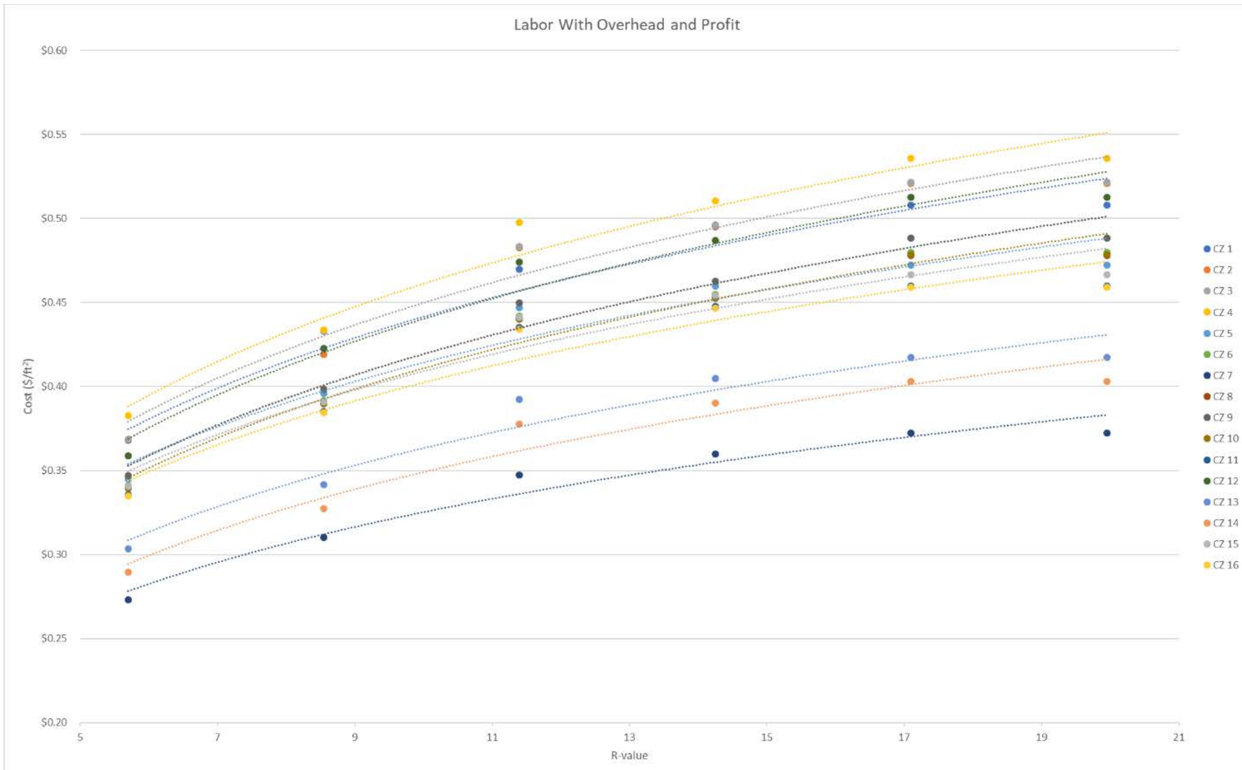

Figure 25: The labor cost for each climate zone for each insulation value in RSMeans.

The values for each climate zone were fit with a logarithmic curve to estimate the cost per R-1.

Table 211: Material and Labor Costs for Each Climate Zone – Roof Alterations

Climate Zone	Inches	Bare Material	Bare Labor	Bare Total	Total O&P	Material O&P	Labor O&P	Material $ / R-1	O&P / Bare	Bare Material $ / R-1
1	1	$0.50	$0.29	$0.79	$1.08	$0.68	$0.37	$0.12	1.37	$0.09
	1.5	$0.67	$0.33	$1.00	$1.32	$0.88	$0.42	$0.10	1.32	$0.08
	2	$1.03	$0.37	$1.40	$1.78	$1.31	$0.47	$0.11	1.27	$0.09
	2.5	$1.12	$0.39	$1.51	$1.91	$1.42	$0.50	$0.10	1.26	$0.08
	3	$1.26	$0.40	$1.66	$2.10	$1.59	$0.51	$0.09	1.27	$0.07
	3.5	$1.86	$0.40	$2.26	$2.77	$2.28	$0.51	$0.11	1.23	$0.09
	Average							$0.11	1.27	$0.08
2	1	$0.50	$0.29	$0.79	$1.07	$0.68	$0.37	$0.12	1.35	$0.09
	1.5	$0.66	$0.33	$0.99	$1.31	$0.87	$0.42	$0.10	1.32	$0.08
	2	$1.01	$0.38	$1.39	$1.76	$1.28	$0.48	$0.11	1.27	$0.09
	2.5	$1.10	$0.39	$1.49	$1.89	$1.40	$0.50	$0.10	1.27	$0.08
	3	$1.25	$0.41	$1.66	$2.10	$1.58	$0.52	$0.09	1.27	$0.07
	3.5	$1.84	$0.41	$2.25	$2.76	$2.26	$0.52	$0.11	1.23	$0.09
	Average							$0.10	1.27	$0.08
3	1	$0.48	$0.29	$0.77	$1.05	$0.65	$0.37	$0.11	1.36	$0.08
	1.5	$0.64	$0.34	$0.98	$1.28	$0.84	$0.43	$0.10	1.31	$0.07
	2	$0.97	$0.38	$1.35	$1.73	$1.24	$0.48	$0.11	1.28	$0.09
	2.5	$1.06	$0.39	$1.45	$1.85	$1.35	$0.50	$0.09	1.28	$0.07
	3	$1.20	$0.41	$1.61	$2.04	$1.52	$0.52	$0.09	1.27	$0.07
	3.5	$1.77	$0.41	$2.18	$2.68	$2.18	$0.52	$0.11	1.23	$0.09
	Average							$0.10	1.27	$0.08
4	1	$0.47	$0.30	$0.77	$1.05	$0.64	$0.38	$0.11	1.36	$0.08
	1.5	$0.63	$0.34	$0.97	$1.28	$0.83	$0.43	$0.10	1.32	$0.07
	2	$0.96	$0.39	$1.35	$1.72	$1.22	$0.50	$0.11	1.27	$0.08
	2.5	$1.04	$0.40	$1.44	$1.85	$1.34	$0.51	$0.09	1.28	$0.07
	3	$1.18	$0.42	$1.60	$2.03	$1.50	$0.54	$0.09	1.27	$0.07
	3.5	$1.74	$0.42	$2.16	$2.66	$2.14	$0.54	$0.11	1.23	$0.09
	Average							$0.10	1.28	$0.08

Climate Zone	Inches	Bare Material	Bare Labor	Bare Total	Total O&P	Material O&P	Labor O&P	Material $ / R-1	O&P / Bare	Bare Material $ / R-1
5	1	$0.43	$0.27	$0.70	$0.96	$0.59	$0.34	$0.10	1.37	$0.08
	1.5	$0.57	$0.31	$0.88	$1.16	$0.75	$0.40	$0.09	1.32	$0.07
	2	$0.88	$0.35	$1.23	$1.57	$1.12	$0.45	$0.10	1.28	$0.08
	2.5	$0.96	$0.36	$1.32	$1.68	$1.22	$0.46	$0.09	1.27	$0.07
	3	$1.08	$0.37	$1.45	$1.86	$1.39	$0.47	$0.08	1.28	$0.06
	3.5	$1.60	$0.37	$1.97	$2.43	$1.97	$0.47	$0.10	1.23	$0.08
	Average							$0.09	1.28	$0.07
6	1	$0.49	$0.27	$0.76	$1.03	$0.66	$0.34	$0.12	1.36	$0.09
	1.5	$0.65	$0.31	$0.96	$1.26	$0.85	$0.39	$0.10	1.31	$0.08
	2	$1.00	$0.35	$1.35	$1.71	$1.27	$0.44	$0.11	1.27	$0.09
	2.5	$1.09	$0.36	$1.45	$1.83	$1.38	$0.45	$0.10	1.26	$0.08
	3	$1.23	$0.38	$1.61	$2.02	$1.54	$0.48	$0.09	1.25	$0.07
	3.5	$1.82	$0.38	$2.20	$2.68	$2.22	$0.48	$0.11	1.22	$0.09
	Average							$0.10	1.26	$0.08
7	1	$0.49	$0.22	$0.71	$0.93	$0.64	$0.27	$0.11	1.31	$0.09
	1.5	$0.65	$0.25	$0.90	$1.16	$0.84	$0.31	$0.10	1.29	$0.08
	2	$1.00	$0.28	$1.28	$1.59	$1.24	$0.35	$0.11	1.24	$0.09
	2.5	$1.09	$0.29	$1.38	$1.71	$1.35	$0.36	$0.09	1.24	$0.08
	3	$1.23	$0.30	$1.53	$1.89	$1.52	$0.37	$0.09	1.24	$0.07
	3.5	$1.82	$0.30	$2.12	$2.54	$2.18	$0.37	$0.11	1.20	$0.09
	Average							$0.10	1.24	$0.08
8	1	$0.49	$0.27	$0.76	$1.02	$0.66	$0.34	$0.12	1.34	$0.09
	1.5	$0.65	$0.31	$0.96	$1.25	$0.85	$0.39	$0.10	1.30	$0.08
	2	$1.00	$0.35	$1.35	$1.69	$1.25	$0.44	$0.11	1.25	$0.09
	2.5	$1.08	$0.36	$1.44	$1.82	$1.37	$0.45	$0.10	1.26	$0.08
	3	$1.22	$0.38	$1.60	$2.01	$1.53	$0.48	$0.09	1.26	$0.07
	3.5	$1.81	$0.38	$2.19	$2.66	$2.20	$0.48	$0.11	1.21	$0.09
	Average							$0.10	1.26	$0.08

Climate Zone	Inches	Bare Material	Bare Labor	Bare Total	Total O&P	Material O&P	Labor O&P	Material $ / R-1	O&P / Bare	Bare Material $ / R-1
9	1	$0.41	$0.27	$0.68	$0.94	$0.57	$0.35	$0.10	1.38	$0.07
	1.5	$0.55	$0.31	$0.86	$1.15	$0.74	$0.40	$0.09	1.34	$0.06
	2	$0.84	$0.35	$1.19	$1.54	$1.09	$0.45	$0.10	1.29	$0.07
	2.5	$0.92	$0.36	$1.28	$1.64	$1.18	$0.46	$0.08	1.28	$0.06
	3	$1.04	$0.38	$1.42	$1.81	$1.33	$0.49	$0.08	1.27	$0.06
	3.5	$1.53	$0.38	$1.91	$2.36	$1.89	$0.49	$0.09	1.24	$0.08
	Average							$0.09	1.28	$0.07
10	1	$0.49	$0.27	$0.76	$1.03	$0.66	$0.34	$0.12	1.36	$0.09
	1.5	$0.66	$0.31	$0.97	$1.26	$0.86	$0.39	$0.10	1.30	$0.08
	2	$1.00	$0.35	$1.35	$1.70	$1.26	$0.44	$0.11	1.26	$0.09
	2.5	$1.09	$0.36	$1.45	$1.83	$1.38	$0.45	$0.10	1.26	$0.08
	3	$1.23	$0.38	$1.61	$2.02	$1.54	$0.48	$0.09	1.25	$0.07
	3.5	$1.82	$0.38	$2.20	$2.68	$2.22	$0.48	$0.11	1.22	$0.09
	Average							$0.10	1.26	$0.08
11	1	$0.57	$0.27	$0.84	$1.12	$0.76	$0.34	$0.13	1.33	$0.10
	1.5	$0.76	$0.31	$1.07	$1.37	$0.97	$0.39	$0.11	1.28	$0.09
	2	$1.17	$0.35	$1.52	$1.88	$1.45	$0.44	$0.13	1.24	$0.10
	2.5	$1.27	$0.36	$1.63	$2.03	$1.58	$0.45	$0.11	1.25	$0.09
	3	$1.44	$0.37	$1.81	$2.25	$1.79	$0.46	$0.10	1.24	$0.08
	3.5	$2.12	$0.37	$2.49	$3.01	$2.56	$0.46	$0.13	1.21	$0.11
	Average							$0.12	1.24	$0.09
12	1	$0.44	$0.28	$0.72	$1.00	$0.61	$0.36	$0.11	1.39	$0.08
	1.5	$0.59	$0.33	$0.92	$1.22	$0.78	$0.42	$0.09	1.33	$0.07
	2	$0.90	$0.37	$1.27	$1.63	$1.16	$0.47	$0.10	1.28	$0.08
	2.5	$0.98	$0.38	$1.36	$1.75	$1.26	$0.49	$0.09	1.29	$0.07
	3	$1.11	$0.40	$1.51	$1.93	$1.42	$0.51	$0.08	1.28	$0.06
	3.5	$1.64	$0.40	$2.04	$2.51	$2.02	$0.51	$0.10	1.23	$0.08
	Average							$0.09	1.28	$0.07

Climate Zone	Inches	Bare Material	Bare Labor	Bare Total	Total O&P	Material O&P	Labor O&P	Material $ / R-1	O&P / Bare	Bare Material $ / R-1
13	1	$0.43	$0.24	$0.67	$0.91	$0.58	$0.30	$0.10	1.36	$0.08
	1.5	$0.58	$0.27	$0.85	$1.11	$0.76	$0.34	$0.09	1.31	$0.07
	2	$0.88	$0.31	$1.19	$1.51	$1.12	$0.39	$0.10	1.27	$0.08
	2.5	$0.96	$0.32	$1.28	$1.61	$1.21	$0.40	$0.08	1.26	$0.07
	3	$1.08	$0.33	$1.41	$1.79	$1.37	$0.42	$0.08	1.27	$0.06
	3.5	$1.60	$0.33	$1.93	$2.36	$1.96	$0.42	$0.10	1.22	$0.08
	Average							$0.09	1.26	$0.07
14	1	$0.42	$0.23	$0.65	$0.88	$0.57	$0.29	$0.10	1.35	$0.07
	1.5	$0.57	$0.26	$0.83	$1.08	$0.74	$0.33	$0.09	1.30	$0.07
	2	$0.87	$0.30	$1.17	$1.47	$1.09	$0.38	$0.10	1.26	$0.08
	2.5	$0.94	$0.31	$1.25	$1.58	$1.19	$0.39	$0.08	1.26	$0.07
	3	$1.07	$0.32	$1.39	$1.74	$1.34	$0.40	$0.08	1.25	$0.06
	3.5	$1.57	$0.32	$1.89	$2.31	$1.92	$0.40	$0.10	1.22	$0.08
	Average							$0.09	1.26	$0.07
15	1	$0.49	$0.27	$0.76	$1.02	$0.66	$0.34	$0.12	1.34	$0.09
	1.5	$0.65	$0.31	$0.96	$1.25	$0.85	$0.39	$0.10	1.30	$0.08
	2	$1.00	$0.35	$1.35	$1.70	$1.26	$0.44	$0.11	1.26	$0.09
	2.5	$1.09	$0.36	$1.45	$1.82	$1.37	$0.45	$0.10	1.26	$0.08
	3	$1.23	$0.37	$1.60	$2.02	$1.55	$0.47	$0.09	1.26	$0.07
	3.5	$1.81	$0.37	$2.18	$2.67	$2.22	$0.47	$0.11	1.22	$0.09
	Average							$0.10	1.26	$0.08
16	1	$0.58	$0.27	$0.85	$1.12	$0.76	$0.33	$0.13	1.32	$0.10
	1.5	$0.77	$0.31	$1.08	$1.38	$0.98	$0.38	$0.12	1.28	$0.09
	2	$1.19	$0.35	$1.54	$1.90	$1.47	$0.43	$0.13	1.23	$0.10
	2.5	$1.29	$0.36	$1.65	$2.05	$1.60	$0.45	$0.11	1.24	$0.09
	3	$1.46	$0.37	$1.83	$2.27	$1.81	$0.46	$0.11	1.24	$0.09
	3.5	$2.15	$0.37	$2.52	$3.04	$2.59	$0.46	$0.13	1.21	$0.11
	Average							$0.12	1.24	$0.10

Appendix P: Mark-Up Standards Language for All Envelope Measures

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

~~**AZIMUTH** is the degrees of clockwise rotation from absolute north.~~

~~**OVERHANG PROJECTION** is the horizontal distance, measured outward horizontally from the surface of exposed exterior glazing at the head of a window to the outward edge of an overhang.~~

~~**OVERHANG RISE** is the vertical distance between the projected edge of an overhang and the sill of the vertical fenestration below it.~~

CURTAIN WALL/STOREFRONT is an external nonbearing wall intended to separate the exterior nonconditioned and interior conditioned spaces. It also consists of any combination of framing materials, fixed glazing, opaque glazing, operable windows, glazed doors within storefront systems, or other in-fill materials.

GLAZED DOOR is an exterior door having a glazed area of 25 percent or greater of the area of the door. Glazed doors shall meet fenestration product requirements. Glazed doors within storefront systems shall meet the curtain wall/storefront requirements, See: Door.

SITE-BUILT is fenestration designed to be field-glazed or field assembled units using specific factory cut or otherwise factory formed framing and glazing units, that are manufactured with the intention of being assembled at the construction site. These include storefront systems, glazed doors within storefront systems, curtain walls, and atrium roof systems.

SECTION 110.6 – MANDATORY REQUIREMENTS FOR FENESTRATION PRODUCTS AND EXTERIOR DOORS

(a)Certification of Fenestration Products and Exterior Doors other than Field-fabricated. Any fenestration product and exterior door, other than field-fabricated fenestration products and field-fabricated exterior doors, may be installed only if the manufacturer has certified to the Commission, or if an independent certifying organization approved by the Commission has certified that the product complies with all of the applicable requirements of this subsection.

1. Air leakage. Manufactured fenestration products and exterior doors shall have air infiltration rates not exceeding 0.3 cfm/ft² of window area, 0.3 cfm/ft² of door area for residential doors, 0.3 cfm/ft² of door area for nonresidential single doors (swinging and sliding), and 1.0 cfm/ft² for nonresidential double doors (swinging), when tested according to NFRC-400 or ASTM E283 at a pressure differential of 75 pascals (or 1.57 pounds/ft²), incorporated herein by reference.

NOTES TO SECTION 110.6(a)1:Pet doors must meet 0.3 cfm/ft² when tested according to ASTM E283 at 75 pascals (or 1.57 pounds/ft²). AAMA/WDMA/CSA

101/I.S.2/A440-2011 specification is equivalent to ASTM E283 at a pressure differential of 75 pascals (or 1.57 pounds/ft²) and satisfies the air leakage certification requirements of this section.

EXCEPTION to Section 110.6(a)1: Field-fabricated fenestration and field-fabricated exterior doors.

2. **U-factor**. The fenestration product and exterior door's U-factor shall be rated in accordance with NFRC 100, or use the applicable default U-factor set forth in TABLE 110.6-A.

   EXCEPTION 1 to Section 110.6(a)2: If the fenestration product is a skylight, ~~or a vertical site-built fenestration product in a building covered by the nonresidential standards with less than 200 square feet of site-built fenestration,~~ the default U-factor may be calculated as set forth in Reference Nonresidential Appendix NA6.

   EXCEPTION 2 to Section 110.6(a)2: If the fenestration product is an alteration consisting of any area replacement of glass in a skylight product, ~~or in a vertical site-built fenestration product,~~ in a building covered by the nonresidential standards, the default U-factor may be calculated as set forth in Reference Nonresidential Appendix NA6.

3. **Solar Heat Gain Coefficient (SHGC).** The fenestration product's SHGC shall be rated in accordance with NFRC 200, or use the applicable default SHGC set forth in TABLE 110.6-B.

   EXCEPTION 1 to Section 110.6(a)3: If the fenestration product is a skylight ~~or a vertical site-built fenestration product in a building covered by the nonresidential standards with less than 200 square feet of site-built fenestration~~, the default SHGC may be calculated as set forth in Reference Nonresidential Appendix NA6.

   EXCEPTION 2 to Section 110.6(a)3: If the fenestration product is an alteration consisting of any area replacement of glass in a skylight product ~~or in a vertical site-built fenestration product~~, in a building covered by the nonresidential standards, the default SHGC may be calculated as set forth in Reference Nonresidential Appendix NA6.

4. **Visible Transmittance (VT).** The fenestration product's VT shall be rated in accordance with NFRC 200 or ASTM E972, for tubular daylighting devices VT shall be rated using NFRC 203.

   EXCEPTION 1 to Section 110.6(a)4: If the fenestration product is a skylight ~~or a vertical site-built fenestration product~~ , the default VT may be calculated as set forth in Reference Nonresidential Appendix NA6.

   EXCEPTION 2 to Section 110.6(a)4: If the fenestration product is an alteration consisting of any area; replacement of glass in a skylight product ~~or in a vertical site-~~

~~built fenestration product~~ in a building covered by the nonresidential standards, the default VT may be calculated as set forth in Reference Nonresidential Appendix NA6.

SECTION 130.1 – MANDATORY INDOOR LIGHTING CONTROLS

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

EXCEPTION 2 to Section 130.1(d): Areas adjacent to vertical glazing below an overhang, where the overhang covers the entire width of the vertical glazing, no vertical glazing is above the overhang, and the ~~ratio of the overhang projection to the overhang rise~~ projection factor as calculated by Equation 140.3-D is greater than 1.5 for South, East and West orientations or greater than 1.0 for North orientations.

SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

A building complies with this section by being designed with and having constructed to meet all prescriptive requirements in Subsection (a) and the requirements of Subsection (c) and (d) where they apply.

(a) **Envelope Component Requirements.**

1. **Exterior roofs and ceilings.** Exterior roofs and ceilings shall comply with each of the applicable requirements in this subsection:

   A. **Roofing Products.** Shall meet the requirements of Section 110.8 and the applicable requirements of Subsections i through ii:

      i. Nonresidential buildings:

         a. Low-sloped roofs in Climate Zones 1 through 16 shall have:

            1. A minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75; or

            2. A minimum Solar Reflectance Index (SRI) of 75.

            EXCEPTION 1 to Section 140.3(a)1Aia: Wood-framed roofs in Climate Zones 3 and 5 are exempt from the requirements of Section 140.3(a)1Aia if the roof assembly has a U-factor of 0.034 or lower.

            EXCEPTION 2 to Section 140.3(a)1Aia: Roof constructions with a weight of at least 25 lb/ft² over the roof membrane are exempt from the requirements of Section 140.3(a)1Aia.

EXCEPTION 3 to SECTION 140.3(a)1Aia: An aged solar reflectance less than 0.63 is allowed provided the maximum roof/ceiling U-factor in TABLE 140.3 is not exceeded.

b. Steep-sloped roofs:

a. I~~i~~n Climate Zones 1 and 3 shall have either a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

b. In Climate Zones 2 and 4 through shall have either: a minimum aged solar reflectance of 0.25 and a minimum thermal emittance of 0.80, or a minimum SRI 23

~~ii. High-rise residential buildings and hotels and motels:~~

~~c. Low-sloped roofs in Climate Zones 9, 10, 11, 13, 14 and 15 shall have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75 or a minimum SRI of 64.~~

~~**EXCEPTION to Section 140.3(a)1Aiia:** Roof constructions with a weight of at least 25 lb/ft² over the roof membrane.~~

~~d. Steep-sloped roofs in Climate Zones 2 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.~~

TABLE 140.3 Roof/Ceiling Insulation Tradeoff For Aged Solar Reflectance – Nonresidential Buildings

~~**Nonresidential**~~			
Aged Solar Reflectance	**Metal Building All Climate Zones U-factor**	**Wood framed and Other Climate Zone 6 ~~&~~ 7, & 8 U-factor**	**Wood Framed and Other All other Climate Zones U-factor**
0.62-0.56	0.038	0.039 ~~0.045~~	0.029 ~~0.032~~
0.55-0.46	0.035	0.036 ~~0.042~~	0.028 ~~0.030~~
0.45-0.36	0.033	0.033 ~~0.039~~	0.027 ~~0.029~~
0.35-0.25	0.031	0.032 ~~0.037~~	0.026 ~~0.028~~

EXCEPTION to Section 140.3(a)1A: Roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

B. **Roof Insulation.** Roofs shall have an overall assembly U-factor no greater than the applicable value in Table 140.3- B, C or D, and where required by Section 110.8 and 120.7(a)3, insulation shall be placed in direct contact with a continuous roof or drywall ceiling.

2. **Exterior Walls.** Exterior walls shall have an overall assembly U-factor no greater than the applicable value in TABLE 140.3-B, C or D.
3. **Demising Walls.** Demising walls shall meet the requirements of Section 120.7(b)7. Vertical windows in demising walls between conditioned and unconditioned spaces shall have an area-weighted average U-factor no greater than the applicable value in TABLE140.3-B, C or D.
4. **Exterior Floors and Soffits.** Exterior floors and soffits shall have an overall assembly U-factor no greater than the applicable value in TABLE 140.3-B, C or D.
5. **Exterior Windows.** Vertical windows in exterior walls shall:

A. Percent window area shall be limited in accordance with the applicable requirements of i and ii below:

i. a west-facing area no greater than 40 percent of the gross west-facing exterior wall area, or 6 feet times the west-facing display perimeter, whichever is greater; and

ii. a total area no greater than 40 percent of the gross exterior wall area, or 6 feet times the display perimeter, whichever is greater; and

NOTE: Demising walls are not exterior walls, and therefore demising wall area is not part of the gross exterior wall area or display perimeter, and windows in demising walls are not part of the window area.

B. Have an area-weighted average U-factor no greater than the applicable value in TABLE140.3-B, C or D.

EXCEPTION to Section 140.3(a)5B: For vertical windows containing chromogenic type glazing:

i. The lower-rated labeled U-factor shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

ii. Chromogenic glazing shall be considered separately from other glazing; and

iii. Area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

C. Have an area-weighted average Relative Solar Heat Gain Coefficient, RSHGC, excluding the effects of interior shading, no greater than the applicable value in TABLE 140.3-B, C or D.

For purposes of this paragraph, the Relative Solar Heat Gain Coefficient, RSHGC, of a vertical window is:

i. The Solar Heat Gain Coefficient of the window; or

ii. Relative Solar Heat Gain Coefficient is calculated using EQUATION 140.3-A, if the window has an overhang <u>or exterior horizontal slats</u> that extend~~s~~ beyond each side of the window jamb by a distance equal to the overhang's horizontal projection.

EXCEPTION 1 to Section 140.3(a)5C: An area-weighted average Relative Solar Heat Gain Coefficient of 0.56 or less shall be used for windows:

a. That are in the first story of exterior walls that form a display perimeter; and
b. For which codes restrict the use of overhangs to shade the windows.

EXCEPTION 2 to Section 140.3(a)5C: For vertical windows containing chromogenic type glazing:

i. the lower-rated labeled RSHGC shall be used with automatic controls to modulate the amount of heat flow into the space in multiple steps in response to daylight levels or solar intensity; and

ii. chromogenic glazing shall be considered separately from other glazing; and

iii. area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

NOTE: Demising walls are not exterior walls, and therefore windows in demising walls are not subject to SHGC requirements.

D. Have an area-weighted average Visible Transmittance (VT) no less than the applicable value in TABLE 140.3-B and C, or EQUATION 140.3-B, as applicable.

EXCEPTION 1 to Section 140.3(a)5D: When the window's primary and secondary sidelit daylit zones are completely overlapped by one or more skylit daylit zones, then the window need not comply with Section 140.3(a)5D.

EXCEPTION 2 to Section 140.3(a)5D: If the window's VT is not within the scope of NFRC 200, or ASTM E972, then the VT shall be calculated according to Reference Nonresidential Appendix NA6.

EXCEPTION 3 to Section 140.3(a)5D: For vertical windows containing chromogenic type glazing:

iii. The higher rated labeled VT shall be used with automatic controls to modulate the amount of light transmitted into the space in multiple steps in response to daylight levels or solar intensity; and

iv. Chromogenic glazing shall be considered separately from other glazing; and

iii. Area-weighted averaging with other glazing that is not chromogenic shall not be permitted.

NOTE: Demising walls are not exterior walls, and therefore windows in demising walls are not subject to VT requirements.

EQUATION 140.3-A RELATIVE SOLAR HEAT GAIN COEFFICIENT, RSHGC

~~$RSHGC = SHGC_{win} \times [1 + aH/V + b (H/V)2]$~~

$$RSHGC = SHGC \times [1 + a(2.72^{-PF} - 1)(\sin(b \times Az) - c)]$$

WHERE:

RSHGC = Relative Solar Heat Gain Coefficient.

$SHGC_{win}$ = Solar Heat Gain Coefficient of the vertical fenestration ~~window~~.

Az = Azimuth of the vertical fenestration in degrees.

PF = Projection factor as calculated by Equation 140.3-D.

~~H = Horizontal projection of the overhang from the surface of the window in feet, but no greater than *V*.~~

~~V = Vertical distance from the window sill to the bottom of the overhang in feet.~~

~~a = -0.41 for north-facing windows, -1.22 for south-facing windows, and -0.92 for east and west-facing windows.~~

~~b = 0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east and west-facing windows.~~

	a	b	c
Overhang	0.150	0.130	5.67
Exterior Horizontal Slat	0.144	0.133	5.13

EQUATION 140.3-B VERTICAL FENESTRATION MINIMUM VT

$$VT \geq 0.11/ WWR$$

WHERE:

WWR	=	Window Wall Ratio, the ratio of (i) the total window area of the entire building to (ii) the total gross exterior wall area of the entire building. If the WWR is greater than 0.40, then 0.40 shall be used as the value for WWR in EQUATION 140.3-B.
VT	=	Visible Transmittance of framed window.

(Sections omitted)

TABLE 140.3-A MATERIALS DEEMED TO COMPLY WITH SECTION 140.3(a)9A

	MATERIALS AND THICKNESS		MATERIALS AND THICKNESS
1	Plywood – min. 3/8 inches thickness	9	Built up roofing membrane
2	Oriented strand board – min. 3/8 inches thickness	10	Modified bituminous roof membrane
3	Extruded polystyrene insulation board – min. ½ inches thickness	11	Fully adhered single-ply roof membrane
4	Foil-back polyisocyanurate insulation board – min. ½ inches thickness	12	A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inches thickness
5	Closed cell spray foam with a minimum density of 2.0 pcf and a min. 2.0 inches thickness	13	Cast-in-place concrete, or precast concrete
6	Open cell spray foam with a density no less than 0.4 pcf and no greater than 1.5 pcf, and a min. 5½ inches thickness	14	Fully grouted concrete block masonry
7	Exterior or interior gypsum board min. 1/2 inches thickness	15	Sheet steel or sheet aluminum
8	Cement board – min. 1/2 inches thickness	---	--------------------------------

A. Assemblies of materials and components that have an average air leakage not exceeding 0.04 cfm/ft^2, under a pressure differential of 0.3 in. of water (1.57 psf) (0.2 L/m^2 at 75 pa), when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680, or ASTM E283; or

EXCEPTION to Section 140.3(a)9B: The following materials shall be deemed to comply with Section 140.3(a)9B if all joints are sealed and all of the materials are installed as air barriers in accordance with the manufacturer's instructions:

i. Concrete masonry walls that have at least two coatings of paint or at least two coatings of sealer coating.

ii. Concrete masonry walls with integral rigid board insulation.

iii. Structurally Insulated Panels.

iv. Portland cement or Portland sand parge, or stucco, or a gypsum plaster, each with min. 1/2 inches thickness

B. The entire building has an air leakage rate not exceeding 0.40 cfm/ft^2 at a pressure differential of 0.3 in of water (1.57 psf) (2.0 L/ m^2 at 75 pa), when the entire building is tested, after completion of construction, in accordance with ASTM E779 or another test method approved by the Commission.

EXCEPTION to Section 140.3(a)9: Relocatable Public School Buildings.

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; ~~NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS~~)

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Maximum U-factor	**Roofs/ Ceilings**	Metal Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
			Wood Framed and Other	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.049~~ 0.042	~~0.049~~ 0.042	~~0.049~~ 0.042	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030	~~0.034~~ 0.030
		Walls	**Metal Building**	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
			Metal-framed	~~0.069~~ 0.060	~~0.062~~ 0.055	~~0.082~~ 0.071	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.069~~ 0.060	~~0.069~~ 0.060	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055	~~0.062~~ 0.055
			Mass Light[1]	0.196	0.170	0.278	0.227	0.440	0.440	0.440	0.440	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
		Floors/ Soffits	Raised Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
			Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
	Roofing Products	**Low-sloped**	Aged Solar Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		Steep-Sloped	Aged Solar Reflectance	0.20	0.25 ~~0.20~~	0.20	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~	0.25 ~~0.20~~
			Thermal Emittance	0.75	0.80 ~~0.75~~	0.75	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0. 75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~	0.80 ~~0.75~~
	Air Barrier			~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	~~NR~~ REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Exterior Doors, Maximum U-factor		Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
			Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

CONTINUED: TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; ~~NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS~~)

					Climate Zone																
				Area-weighted Performance Weighting	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Fenestration	Vertical			Fixed Window															
				Max U-factor	0.36	~~0.36~~ 0.34	0.36	0.36	~~0.36~~ 0.34	~~0.36~~ 0.34	~~0.36~~ 0.34	~~0.36~~ 0.34	~~0.36~~ 0.34	0.36	~~0.36~~ 0.34	~~0.36~~ 0.34	~~0.36~~ 0.34	~~0.36~~ 0.34	~~0.36~~ 0.34	0.36
				Max RSHGC	0.25	~~0.25~~ 0.22	0.25	0.25	~~0.25~~ 0.22	~~0.25~~ 0.22	~~0.25~~ 0.22	~~0.25~~ 0.22	~~0.25~~ 0.22	0.25	~~0.25~~ 0.22	~~0.25~~ 0.22	~~0.25~~ 0.22	~~0.25~~ 0.22	~~0.25~~ 0.22	0.25
				Min VT	0.42															
					Curtainwall or Storefront															
				Max U-factor	~~0.41~~ 0.38	0.41	0.41	0.41	0.41	0.41	~~0.41~~ 0.38	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	~~0.41~~ 0.38
				Max RSHGC	~~0.26~~ 0.25	0.26	0.26	0.26	0.26	0.26	~~0.26~~ 0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	~~0.26~~ 0.25
				Min VT	0.46															
					Operable Window															
				Max U-factor	0.46															
				Max RSHGC	0.22															
				Min VT	0.32															
					Glazed Doors[2]															
				Max U-factor	0.45															
				Max RSHGC	0.23															
				Min VT	0.17															
			Maximum WWR%	40%																
				All Climate Zones																
		Skyli			Glass, Curb Mounted				Glass, Deck Mounted				Plastic, Curb Mounted				Tubular Daylighting Devices (TDDs)			

			Area-Weighted Performance Rating	Max U-factor	0.58	0.46	0.88	0.88
				Max SHGC	0.25	0.25	NR	NR
			Area-Weighted Performance Rating	Min VT (Min VT_{annual} for TDDs)	0.49	0.49	0.64	0.38
			Maximum SRR%	5%				

CONTINUED: TABLE 140.3-C – PRESCRIPTIVE ENVELOPE CRITERIA FOR ~~HIGH-RISE RESIDENTIAL BUILDINGS~~ AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS

					All Climate Zones			
					Fixed Window	Operable Window	Curtainwall/ Storefront	Glazed Doors[2]
Envelope	Fenestration	Vertical	Area-Weighted Performance Rating	Max U-factor	0.36	0.46	0.41	0.45
				Max RSHGC	0.25	0.22	0.26	0.23
			Area-Weighted Performance Rating	Min VT	0.42	0.32	0.46	0.17
			Maximum WWR%	40%				
		Skylights			Glass, Curb Mounted	Glass, Deck Mounted	Plastic, Curb Mounted	
			Area-Weighted Performance Rating	Max U-factor	0.58	0.46	0.88	
				Max SHGC	0.25	0.25	NR	
			Area-Weighted Performance Rating	Min VT	0.49	0.49	0.64	
			Maximum SRR%	5%				

Notes:

1. As defined in Section 100.0, light mass walls are walls with a heat capacity of at least 7.0 Btu/ft²-oF and less than 15.0 Btu/ft²-oF. Heavy mass walls are walls with a heat capacity of at least 15.0 Btu/ft²-oF.

2. Glazed Doors applies to both site-built and to factory-assembled glazed doors.

TABLE 140.3-D PRESCRIPTIVE ENVELOPE CRITERIA FOR RELOCATABLE PUBLIC SCHOOL BUILDINGS FOR USE IN ALL CLIMATE ZONES

<table>
<tr><td rowspan="2">Roofs/ Ceilings</td><td>Metal Buildings</td><td colspan="3" rowspan="9">Maximum U-factor</td><td>0.041</td></tr>
<tr><td>Non-Metal Buildings</td><td>0.034</td></tr>
<tr><td rowspan="5">Walls</td><td>Wood frame buildings</td><td>0.042</td></tr>
<tr><td>Metal frame buildings</td><td>0.057</td></tr>
<tr><td>Metal buildings</td><td>0.057</td></tr>
<tr><td>Mass/7.0≤ HC</td><td>0.170</td></tr>
<tr><td>All Other Walls</td><td>0.059</td></tr>
<tr><td>Floors and Soffits</td><td>Floors and Soffits</td><td>0.048</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="4">Roofing Products</td><td rowspan="2">Low-Sloped</td><td colspan="3">Aged Solar Reflectance</td><td>0.63</td></tr>
<tr><td colspan="3">Thermal Emittance</td><td>0.75</td></tr>
<tr><td rowspan="2">Steep-Sloped</td><td colspan="3">Aged Solar Reflectance</td><td>~~0.20~~
<ins>0.25</ins></td></tr>
<tr><td colspan="3">Thermal Emittance</td><td>~~0.75~~
<ins>0.80</ins></td></tr>
<tr><td rowspan="11">Fenestration</td><td rowspan="2">Windows</td><td colspan="3">Maximum U-factor</td><td>0.47</td></tr>
<tr><td colspan="3">Maximum SHGC</td><td>0.26</td></tr>
<tr><td rowspan="2">Glazed Doors (Site-Built and Factory Assembled)</td><td colspan="3">Maximum U-factor</td><td>0.45</td></tr>
<tr><td colspan="3">Maximum SHGC</td><td>0.23</td></tr>
<tr><td rowspan="7">Skylights</td><td colspan="2">Glass with Curb</td><td rowspan="3">Maximum U-factor</td><td>0.99</td></tr>
<tr><td colspan="2">Glass without Curb</td><td>0.57</td></tr>
<tr><td colspan="2">Plastic with Curb</td><td>0.87</td></tr>
<tr><td rowspan="2">Glass Type</td><td>0-2% SRR</td><td rowspan="4">Maximum SHGC</td><td>0.46</td></tr>
<tr><td>2.1-5% SRR</td><td>0.36</td></tr>
<tr><td rowspan="2">Plastic Type</td><td>0-2% SRR</td><td>0.69</td></tr>
<tr><td>2.1-5% SRR</td><td>0.57</td></tr>
<tr><td rowspan="2">Exterior Doors</td><td>Non-Swinging doors</td><td colspan="3" rowspan="2">Maximum U-factor</td><td>0.50</td></tr>
<tr><td>Swinging doors</td><td>0.70</td></tr>
</table>

(b) **RESERVED**

(c) **Minimum Daylighting Requirement for Large Enclosed Spaces.** In Climate Zones 2 through 15, conditioned enclosed spaces, and unconditioned enclosed spaces, that are greater than 5,000 ft² and that are directly under a roof with ceiling heights greater than 15 feet, shall meet the following requirements:

1. A combined total of at least 75 percent of the floor area, as determined in building floor plan (drawings) view, shall be within one or more of the following:

   A. Primary Sidelight Daylight Zone in accordance with Section 130.1(d)1B, or

   B. The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

2. All Skylit Daylit Zones and Primary Sidelit Daylit Zones shall be shown on building plans.

3. General lighting in daylit zones shall be controlled in accordance with Section 130.1(d).

4. The total skylight area is at least 3 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights; or the product of the total skylight area and the average skylight visible transmittance is no less than 1.5 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

5. All skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 (notwithstanding its scope) or another test method approved by the Commission.

6. Skylights for conditioned and unconditioned spaces shall have an area-weighted average Visible Transmittance (VT) no less than the applicable value required by Section 140.3(a)6D.

EXCEPTION 1 to Section 140.3(c): Auditoriums, churches, movie theaters, museums, refrigerated warehouses.

EXCEPTION 2 to Section 140.3(c): In buildings with unfinished interiors, future enclosed spaces for which there are plans to have:

A. A floor area of less than or equal to 5,000 square feet; or

B. Ceiling heights of less than or equal to 15 feet. This exception shall not be used for S-1 or S-2 (storage), or for F-1 or F-2 (factory) occupancies.

EXCEPTION 3 to Section 140.3(c): Enclosed spaces having a designed general lighting system with a lighting power density less than 0.5 watts per square foot.

EXCEPTION 4 to Section 140.3(c): Enclosed spaces where it is documented that permanent architectural features of the building, existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.

(d) **Daylighting Design Power Adjustment Factors (PAFs).** To qualify for a Power Adjustment Factor (PAF) as specified in Section 140.6(a)2L, daylighting devices shall meet the following requirements:

1. **Clerestory Fenestration.** To qualify for a PAF, clerestory fenestration shall meet the following requirements:

    A. Shall be installed on east-, west-, or south-facing facades.

    B. Shall have a head height that is at least 10 feet above the finished floor.

    C. Shall have a glazing height that is greater than or equal to 10 percent of the head height.

    D. If operable shading is installed on the clerestory fenestration, then the clerestory fenestration shading shall be controlled separately from shading serving other vertical fenestration.

2. **Interior and Exterior Horizontal Slats.** To qualify for a PAF, horizontal slats shall meet the following requirements:

    A. Shall be installed adjacent to vertical fenestration on east- or west-facing facades with Window Wall Ratios between 20 and 30 percent, and extend to the entire height of the vertical fenestration.

    B. Exterior horizontal slats shall be level or sloped downwards from fenestration. Interior horizontal slats shall be level or sloped upwards from fenestration.

    C. Shall have a projection factor as specified in Table 140.3-D. The projection factor is calculated using EQUATION 140.3-D.

    D. Shall have a minimum Distance Factor of 0.3. The distance factor is calculated using EQUATION 140.3-D.

    EXCEPTION to Section 140.3(d)2D: Where it is documented that existing adjacent structures or natural objects within view of the vertical fenestration block direct sunlight onto the vertical fenestration between 8am and 5pm for less than 500 daytime hours per year.

    E. Shall have a minimum Visible Reflectance of 0.50 when tested as specified in ASTM E903.

    F. Shall be opaque.

    EXCEPTION to Section 140.3(d)2F: Horizontal slats with a Visible Transmittance of 0.03 or less when tested as specified in ASTM E1175.

    G. Shall be permanently mounted and not adjustable.

    H. Shall extend beyond each side of the window jamb by a distance equal to or greater than their horizontal projection.

    EXCEPTION to Section 140.3(d)2H: Where the slats are located entirely within the vertical fenestration's rough opening or a fin is located at the window jambs and extends vertically the entire height of the window jamb and extends horizontally the entire depth of the projection.

I. Shall be shown on the plans with the dimensions for the slat projection and slat spacing as specified in EQUATION 140.3-D.

J. Shall have a conspicuous factory installed label permanently affixed and prominently located on an attachment point of the device to the building envelope, stating the following: “NOTICE: Removal of this device will require re-submittal of compliance documentation to the enforcement agency responsible for compliance with California Title 24, Part 6”.

3. **Interior and Exterior Light Shelves.** To qualify for a PAF, light shelves shall meet the following requirements:

A. Where there is vertical fenestration area below the light shelf, both interior and exterior light shelves shall be installed.

B. Shall be installed adjacent to clerestory fenestration on south-facing facades with Window Wall Ratios greater than 30 percent. The head height of the light shelves shall be no more than one foot below the finished ceiling. The clerestory fenestration shall meet the requirements of Section 140.3(d)1.

C. Shall be level or sloped based on their installation. Exterior light shelves shall be level or sloped downwards from fenestration. Interior light shelves shall be level or sloped upwards from fenestration.

D. Shall have a projection factor of the applicable value as specified in Table 140.3-D. The light shelf projection factor is calculated using EQUATION 140.3-D.

E. Shall have a minimum Distance Factor of 0.3. The distance factor is calculated using EQUATION 140.3-D.

EXCEPTION to Section 140.3(d)3E: Where it is documented that existing adjacent structures or natural objects within view of the vertical fenestration block direct sunlight onto the vertical fenestration between 8am and 5pm for less than 750 daytime hours per year.

F. Shall have a top surface with a minimum Visible Reflectance of 0.50 when tested as specified in ASTM E903.

EXCEPTION to Section 140.3(d)3F: Where an exterior light shelf is installed greater than two feet below the clerestory sill.

G. Shall extend beyond each side of the window jamb by a distance equal to or greater than their horizontal projection.

H. Shall be shown on the plans with the dimensions for the light shelf projection and light shelf spacing as specified in EQUATION 140.3-D.

TABLE 140.3-D Daylighting Devices

Daylighting Device	Orientation of the Vertical Fenestration	Projection Factor
Horizontal Slats	East or West	2.0 to 3.0
Interior Light Shelf	South	1.0 to 2.0
Exterior Light Shelf	South	0.25 to 1.25

EQUATION 140.3-D PROJECTION AND DISTANCE FACTOR CALCULATION

Projection Factor = Projection / Spacing

Distance Factor = D / (H_{AS} x Projection Factor)

WHERE:

Projection = The horizontal distance between the base edge and the projected edge of the overhang, slat, or light shelf.

Spacing = For overhangs, the vertical distance between the projected edge of the overhang and sill of the vertical fenestration below it.

For horizontal slats, the vertical distance between the projected edge of a slat to the base edge of the slat below it.

For interior light shelves, the vertical distance between the projected edge of the light shelf and head of the clerestory fenestration above it.

For exterior light shelves, the vertical distance between the projected edge of the light shelf and sill of the vertical fenestration below it.

D = Distance between the existing structure or nature object and the fenestration

H_{AS} = Height difference between the top of the existing structure or nature object and the bottom of the fenestration

NOTE: The base edge is the edge of ~~a~~ an overhang, slat, or light shelf that is adjacent to the vertical fenestration. The projected edge is the opposite edge from the base edge.

NOTE: Authority: Sections 25213, 25218, 25218.5, 25402 and 25402.1, Public Resources Code. Reference: Sections 25007, 25008, 25218.5, 25310, 25402, 25402.1, 25402.4, 25402.5, 25402.8, and 25943, Public Resources Code.

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

Additions, alterations, and repairs to existing nonresidential, high-rise residential, and hotel/motel buildings, existing outdoor lighting for these occupancies, and internally and externally illuminated signs, shall meet the requirements specified in Sections 100.0 through 110.10, and 120.0 through 130.5 that are applicable to the building project, and either the performance compliance approach (energy budgets) in Section 141.0(a)2 (for additions) or 141.0(b)3 (for alterations), or the prescriptive compliance approach in Section 141.0(a)1 (for additions) or 141.0(b)2 (for alterations), for the Climate Zone in which the building is located. Climate zones are shown in FIGURE 100.1-A.

Covered process requirements for additions, alterations and repairs to existing nonresidential, high-rise residential, and hotel/motel buildings are specified in Section 141.1.

EXCEPTION to Section 141.0: Alterations to healthcare facilities are not required to comply with this Section.

NOTE: For alterations that change the occupancy classification of the building, the requirements specified in Section 141.0(b) apply to the occupancy after the alterations.

(a) **Additions.** Additions shall meet either Item 1 or 2 below.

1. **Prescriptive approach.** The envelope and lighting of the addition; any newly installed space-conditioning system, electrical power distribution system, or water-heating system; any addition to an outdoor lighting system; and any new sign installed in conjunction with an indoor or outdoor addition shall meet the applicable requirements of Sections 110.0 through 120.7, 120.9 through 130.5, and 140.2 through 140.9.

2. **Performance approach.**

   A. The envelope and indoor lighting in the conditioned space of the addition, and any newly installed space-conditioning system, electrical power distribution system, or water-heating system, shall meet the applicable requirements of Sections 110.0 through 120.7, 120.9 through 130.5; and

B. Either:

i. The addition alone shall comply with Section 140.1; or

ii. Existing plus addition plus alteration. The standard design for existing plus addition, plus alteration energy use is the combination of the existing building's unaltered components to remain, existing building altered components that are the more efficient, in TDV energy, of either the existing conditions, or the requirements of Section 141.0(b)2, plus the proposed addition's energy use meeting the requirements of Section 140.1. The proposed design energy use is the combination of the existing building's unaltered components to remain and the altered component's energy features, plus the proposed energy features of the addition.

EXCEPTION 1 to Section 141.0(a): When heating, cooling, or service water heating to an addition are provided by expanding existing systems, the existing systems and equipment need not comply with Sections 110.0 through 120.9, or Sections 140.4 through 140.5.

EXCEPTION 2 to Section 141.0(a): Where an existing system with electric reheat is expanded by adding variable air volume (VAV) boxes to serve an addition, total electric reheat capacity may be expanded so that the total capacity does not exceed 150 percent of the existing installed electric heating capacity in any one permit, and the system need not comply with Section 140.4(g). Additional electric reheat capacity in excess of 150 percent of the existing installed electric heating capacity may be added subject to the requirements of the Section 140.4(g).

EXCEPTION 3 to Section 141.0(a): Duct Sealing. When ducts are extended from an existing duct system to serve the addition, the existing duct system and the extended ducts shall meet the applicable requirements specified in Section 141.0(b)2D.

EXCEPTION 4 to Section 141.0(a): Additions that increase the area of the roof by 2,000 square feet or less are exempt from the requirements of Section 110.10.

(b) **Alterations.** Alterations to components of existing nonresidential, high-rise residential, hotel/motel, or relocatable public school buildings, including alterations made in conjunction with a change in building occupancy to a nonresidential, high-rise residential, or hotel/motel occupancy shall meet item 1, and either Item 2 or 3 below:

1. **Mandatory Requirements**. Altered components in a nonresidential, high-rise residential, or hotel/motel building shall meet the minimum requirements in this Section.

A. **Roof/Ceiling Insulation.** The opaque portions of the roof/ceiling that separate conditioned spaces from unconditioned spaces or ambient air shall meet the requirements of Section **141.0(b)2Biii.**

B. **Wall Insulation. For the altered** opaque portion of walls separating conditioned spaces from unconditioned spaces or ambient air shall meet the applicable requirements of Items 1 through 4 below:

1. **Metal Building.** A minimum of R-13 insulation between framing members, or the weighted average U-factor of the wall assembly shall not exceed U-0.113.
2. **Metal Framed.** A minimum of R-13 insulation between framing members, or the weighted average U-factor of the wall assembly shall not exceed U-0.217.
3. **Wood Framed and Others.** A minimum of R-11 insulation between framing members, or the weighted average U-factor of the wall assembly shall not exceed U-0.110.
4. **Spandrel Panels and Curtain Walls. A minimum of R-**4**, or the weighted average U-factor of the wall assembly shall not exceed U-0.**280.

EXCEPTION to Section 141.0(b)1B: Light and heavy mass walls.

C. **Floor Insulation.** For the altered portion of raised floors that separate conditioned spaces from unconditioned spaces or ambient air shall meet the applicable requirements of Items 1 through 3 below:

1. **Raised Framed Floors.** A minimum of R-11 insulation between framing members, or the weighted average U-factor of the floor assembly shall not exceed the U-factor of U-0.071.
2. **Raised Mass Floors in High-rise Residential and Hotel/Motel Guest Rooms.** A minimum of R-6 insulation, or the weighted average U-factor of the floor assembly shall not exceed the U-factor of U-0.111.
3. **Raised Mass Floors in Other Occupancies.** No minimum U-factor requirement.

2. Prescriptive approach. The altered components of the envelope, or space conditioning, lighting, electrical power distribution and water heating systems, and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110.0 through 110.9, Sections 120.0 through 120.6, and Sections 120.9 through 130.5.

EXCEPTION to Section 141.0(b)2: The requirements of Section 120.2(i) shall not apply to alterations of space-conditioning systems or components.

A. Fenestration alterations other than repair and those subject to Section 141.0(b)2 shall meet the requirements below:

i. Vertical fenestration alterations shall meet the requirements in Table 141.0-A.

ii. Added vertical fenestration shall meet the requirements of TABLE 140.3-B, C, or D.

iii. All altered or newly installed skylights shall meet the requirements of TABLE 140.3-B, C or D.

EXCEPTION 1 to Section 141.0(b)2Ai: In an alteration, where 150 square feet or less of the entire building's vertical fenestration is replaced, RSHGC and VT requirements of TABLE 141.0-A shall not apply.

EXCEPTION 2 to Section 141.0(b)2Aii: In an alteration, where 50 square feet or less of vertical fenestration is added, RSHGC and VT requirements of TABLE 140.3-B, C or D shall not apply.

EXCEPTION 3 to Section 141.0(b)2Aiii: In an alteration, where 50 square feet or less of skylight is added, SHGC and VT requirements of TABLE 140.3-B, C or D shall not apply.

NOTE: Glass replaced in an existing sash and frame or sashes replaced in an existing frame are considered repairs. In these cases, Section 141.0(c) requires that the replacement be at least equivalent to the original in performance.

Table 141.0-A Altered Vertical Fenestration Maximum U-Factor and Maximum RSHGC

Climate Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
U-factor	0.47	0.47	0.58	0.47	0.58	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
RSHGC	0.41	0.31	0.41	0.31	0.41	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.41
VT	See TABLE 140.3-B, C, and D for all Climate Zones															

B. Existing roofs being replaced, recovered or recoated, of a nonresidential, high-rise residential and hotels/motels shall meet the requirements of Section 110.8(i). Roofs with more than 50 percent of the roof area or more than 2,000 square feet of roof, whichever is less, is being altered the requirements of i and ii ~~through iii~~ below apply:

i. Roofing Products shall comply with requirements in Section 140.3(a)1A. ~~Nonresidential buildings:~~

~~a. Low-sloped roofs in Climate Zones 1 through 16 shall have a minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75, or a minimum SRI of 75.~~

~~b. Steep-sloped roofs in Climate Zones 1 through 16 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.~~

EXCEPTION 1 to Section 141.0(b)2Bi~~a~~: An aged solar reflectance less than 0.63 is allowed for low-sloped roofs provided the maximum roof/ceiling U-factor in TABLE 141.0-B is not exceeded.

~~ii. Roofing Products. High-rise residential buildings and hotels and motels:~~

~~a. Low-sloped roofs in Climate Zones 10, 11, 13, 14 and 15 shall have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.~~

~~b. Steep-sloped roofs Climate Zones 2 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.~~

EXCEPTION 2 ~~1~~ to Section 141.0(b)2Bi ~~and ii~~: Roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

EXCEPTION 3 ~~2~~ to Section 141.0(b)2Bi ~~and ii~~: Roof constructions with a weight of at least 25 lb/ft² are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

Table 141.0-B Roof/Ceiling Insulation Tradeoff for Low-Sloped Aged Solar Reflectance

Aged Solar Reflectance	Climate Zone 1, 3-9 U-factor	Climate Zone 2, 10-16 U-factor
0.62-0.60	0.043 ~~0.075~~	0.035 ~~0.052~~
0.59-0.55	0.038 ~~0.066~~	0.032 ~~0.048~~
0.54-0.50	0.034 ~~0.06~~	0.03 ~~0.044~~
0.49-0.45	0.032 ~~0.055~~	0.028 ~~0.041~~
0.44-0.40	0.029 ~~0.051~~	0.026 ~~0.039~~
0.39-0.35	0.027 ~~0.047~~	0.025 ~~0.037~~
0.34-0.30	0.025 ~~0.044~~	0.024 ~~0.035~~
0.29-0.25	0.024 ~~0.042~~	0.023 ~~0.034~~

ii~~i~~. For nonresidential buildings, ~~high-rise residential buildings~~ and hotels/motels when low-sloped roofs ~~are exposed to the roof deck or to the roof recover boards, and~~ meet~~s~~ Section 141.0(b)2Bi~~a~~ or ii~~a~~, the ~~exposed~~ area of the roof replacement or roof recover shall meet the following requirements: ~~be insulated to the levels specified in TABLE 141.0-C.~~

e. Insulation shall be installed by the insulation installer and verified by a qualified third-party.

f. For both roof replacements and recovers, the altered roof shall have at least R-10 insulation above deck.

g. The area of the roof replacement or roof recover shall be insulated to the levels specified in TABLE 141.0-C; or

h. Insulation of at least R-10 shall be installed above deck during the roof recover.

EXCEPTION to Section 141.0(b)2Biii

~~a. Existing roofs that are insulated with at least R-7 insulation or that has a U-factor lower than 0.089 are not required to meet the R-value requirement of TABLE 141.0-C.~~

b. If mechanical equipment is located on the roof and will not be disconnected and lifted as part of the roof replacement, insulation added may be limited to the maximum insulation thickness that will allow a height in accordance with manufacturers' instructions ~~of 8 inches (203 mm)~~ from the roof membrane surface to the top of the base flashing or R-10, whichever is greater.

~~c. If adding the required insulation will reduce the base flashing height to less than 8 inches (203 mm) at penthouse or parapet walls, the insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (203 mm) from the roof membrane surface to the top of the base flashing, provided that the conditions in Subsections i through iv apply:~~

~~i. The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material; and~~

~~ii. The penthouse or parapet walls have exterior cladding material that must be removed to install the new roof covering membrane to maintain a base flashing height of 8 inches (203 mm); and~~

~~iii. For nonresidential buildings, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for Climate Zones 2, and 10 through 16, and less than 100 square feet per linear foot for Climate Zones 1, and 3 through 9; and~~

~~iv. For high-rise residential buildings, hotels or motels, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for all Climate Zones.~~

b. ~~d~~ Tapered insulation may be used which has a thermal resistance less than that prescribed in TABLE 141.0-C at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds the value that is specified in TABLE 141.0-C.

TABLE 141.0-C INSULATION REQUIREMENTS FOR ROOF ALTERATIONS

Climate Zone	Continuous Insulation R-value	U-factor
1-5, 9-16	R-23	0.037
6-8	R-17	0.047

~~TABLE 141.0-C INSULATION REQUIREMENTS FOR ROOF ALTERATIONS~~

	~~**Nonresidential**~~	~~**High-Rise Residential and Guest Rooms of Hotel/Motel Buildings**~~

~~Climate Zone~~	~~Continuous Insulation R-value~~	~~U-factor~~	~~Continuous Insulation R-value~~	~~U-factor~~
~~1~~	~~R-8~~	~~0.082~~	~~R-14~~	~~0.055~~
~~2~~	~~R-14~~	~~0.055~~	~~R-14~~	~~0.055~~
~~3-9~~	~~R-8~~	~~0.082~~	~~R-14~~	~~0.055~~
~~10-16~~	~~R-14~~	~~0.055~~	~~R-14~~	~~0.055~~

(sections omitted)

3. Performance approach.

A. The altered envelope, space–conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of Sections 110.0 through 110.9, Sections 120.0 through 120.6, and Sections 120.9 through 130.5.

EXCEPTION 1 to Section 141.0(b)3A Window Films. Applied window films installed as part of an alteration complies with the U-factor, RSHGC and VT requirements of TABLE 141.0-E.

EXCEPTION 2 to Section 141.0(b)2: The requirements of Section 120.2(i) shall not apply to alterations of space-conditioning systems or components.

B. The standard design for an altered component shall be the higher efficiency of existing conditions or the requirements of Section 141.0(b)2. For components not being altered, the standard design shall be based on the unaltered existing conditions such that the standard and proposed designs for these components are identical.

C. When the third-party verification option is specified, all components proposed for alteration, for which the additional credit is taken, must be verified. Existing roof/ceiling insulation shall be verified. The Executive Director shall determine the qualifications required by the third-party inspector.

TABLE 141.0-E – The Standard Design For An Altered Component

Altered Component	Standard Design Without Third-party Verification of Existing Conditions Shall be Based On	Standard Design With Third-party Verification of Existing Conditions Shall be Based On
Roof/Ceiling Insulation, Wall Insulation, and Floor/Soffit Insulation	The requirements of Section 141.0(b)1 and 141.0(b)2Biii.	Existing insulation levels may be used to help meet the requirements of Section 141.0(b)1.
Fenestration The allowed glass area shall be the smaller of the a. or b. below: a. The proposed glass area: or b. The larger of: 1.The existing glass area that remains; or 2.The area allowed in Section 140.3(a)5A.	The U-factor and RSHGC requirements of TABLE 141.0-A.	The existing U-factor and RSHGC levels.
Space-Conditioning System Equipment and Ducts	The requirements of Sections 141.0(b)2C, 141.0(b)2Di or Section 141.0(b)2Dii, and Section 141.0(b)2E.	
Window Film	The U-factor of 0.40 and SHGC value of 0.35.	The existing fenestration in the alteration shall be based on TABLE 110.6-A and Table 110.6-B.
Service Water Heating Systems	The requirements of Section 140.5 without solar water heating requirements.	
Roofing Products	The requirements of Section 141.0(b)2B.	
Lighting System	The requirements of Sections 141.0(b)2F, through 141.0(b)2K.	
All Other Measures	The proposed efficiency levels.	

D. The proposed design shall be based on the actual values of the altered components.

NOTES TO SECTION 141.0(b)3:

1. If an existing component must be replaced with a new component, that component is considered an altered component for the purpose of determining the energy budget and must therefore meet the requirements of Section 141.0(b)3.

2. The standard design assumes the same geometry and orientation as the proposed design.
3. The “existing efficiency level’ modeling rules, including situations where nameplate data is not available, are described in the Nonresidential ACM Reference Manual.

EXCEPTION 1 to Section 141.0(b): When heating, cooling or service water heating for an alteration are provided by expanding existing systems, the existing systems and equipment need not comply with Sections 110.0 through 120.9 and Section 140.4 or 140.5.

EXCEPTION 2 to Section 141.0(b): When existing heating, cooling or service water heating systems or components are moved within a building, the existing systems or components need not comply with Sections 110.0 through 120.9 and Section 140.4 or 140.5.

EXCEPTION 3 to Section 141.0(b): Where an existing system with electric reheat is expanded when adding variable air volume (VAV) boxes to serve an alteration, total electric reheat capacity may be expanded not to exceed 20 percent of the existing installed electric capacity in any one permit and the system need not comply with Section 140.4(g). Additional electric reheat capacity in excess of 20 percent may be added subject to the requirements of the Section 140.4(g).

EXCEPTION 4 to Section 141.0(b): The requirements of Section 120.2(i) shall not apply to alterations of space-conditioning systems or components.

NOTE: Relocation or moving of a relocatable public school building is not, by itself, considered an alteration for the purposes of Title 24, Part 6.

(c) **Repairs.** Repairs shall not increase the preexisting energy consumption of the repaired component, system, or equipment.

(d) **Alternate Method of Compliance.** Any addition, alteration, or repair may comply with the requirements of Title 24, Part 6 by meeting the applicable requirements for the entire building.

Reference Appendices

Joint Appendix JA4

Appendix JA4 – U-factor, C-factor, and Thermal Mass Data

(sections omitted)

JA4.2 Roofs and Ceilings

Table 4.2.2 – U-factors of Wood Framed Rafter Roofs

Rafter Spacing	R-value of Cavity Insulation	Nominal Framing Size		Rated R-value of Continuous Insulation[5]										
				None	R-2	R-4	R-6	R-7	R-8	R-10	R-14	R-17	R-20	R-23
				A	B	C	D	E	F	G	H	I	J	K
16 in. OC	None	Any	**1**	0.297	0.186	0.136	0.107	0.096	0.088	0.075	0.058	0.049	0.043	0.038
	R-11[2]	2x4	**2**	0.084	0.072	0.063	0.056	0.053	0.050	0.046	0.039	0.035	0.031	0.029
	R-13[2]	2x4	**3**	0.075	0.065	0.058	0.052	0.049	0.047	0.043	0.037	0.033	0.030	0.028
	R-15[2]	2x4	**4**	0.068	0.060	0.053	0.048	0.046	0.044	0.040	0.035	0.032	0.029	0.027
	R-19[2]	2x4	**5**	0.075	0.065	0.058	0.052	0.049	0.047	0.043	0.037	0.033	0.030	0.028
	R-19[2,3]	2x4	**6**	0.062	0.055	0.050	0.045	0.043	0.041	0.038	0.033	0.030	0.028	0.026
	R-11	2x6	**7**	0.076	0.066	0.058	0.052	0.050	0.047	0.043	0.037	0.033	0.030	0.028
	R-13	2x6	**8**	0.069	0.061	0.054	0.049	0.047	0.044	0.041	0.035	0.032	0.029	0.027
	R-15	2x6	**9**	0.062	0.055	0.050	0.045	0.043	0.041	0.038	0.033	0.030	0.028	0.026
	R-19[2]	2x6	**10**	0.056	0.050	0.046	0.042	0.040	0.039	0.036	0.031	0.029	0.026	0.024
	R-21[2]	2x6	**11**	0.052	0.047	0.043	0.040	0.038	0.037	0.034	0.030	0.028	0.025	0.024
	R-19[2]	2x8	**12**	0.051	0.046	0.042	0.039	0.038	0.036	0.034	0.030	0.027	0.025	0.023
	R-21	2x8	**13**	0.048	0.044	0.040	0.037	0.036	0.035	0.032	0.029	0.026	0.024	0.023
	R-22	2x10	**14**	0.044	0.040	0.037	0.035	0.034	0.033	0.031	0.027	0.025	0.023	0.022
	R-25	2x10	**15**	0.041	0.038	0.035	0.033	0.032	0.031	0.029	0.026	0.024	0.023	0.021
	R-30[4]	2x10	**16**	0.036	0.034	0.031	0.030	0.029	0.028	0.026	0.024	0.022	0.021	0.020
	R-30	2x12	**17**	0.035	0.033	0.031	0.029	0.028	0.027	0.026	0.023	0.022	0.021	0.019
	R-38[4]	2x12	**18**	0.029	0.027	0.026	0.025	0.024	0.024	0.022	0.021	0.019	0.018	0.017
	R-38[4]	2x14	**19**	0.028	0.027	0.025	0.024	0.023	0.023	0.022	0.020	0.019	0.018	0.017
24 in. OC	None	Any	**25**	0.237	0.161	0.122	0.098	0.089	0.082	0.070	0.055	0.047	0.041	0.037
	R-11[2]	2x4	**26**	0.081	0.070	0.061	0.055	0.052	0.049	0.045	0.038	0.034	0.031	0.028
	R-13[2]	2x4	**27**	0.072	0.063	0.056	0.050	0.048	0.046	0.042	0.036	0.032	0.030	0.027
	R-15[2]	2x4	**28**	0.065	0.058	0.052	0.047	0.045	0.043	0.039	0.034	0.031	0.028	0.026
	R-19[2]	2x4	**29**	0.072	0.063	0.056	0.050	0.048	0.046	0.042	0.036	0.032	0.030	0.027
	R-19[2,3]	2x4	**30**	0.059	0.053	0.048	0.044	0.042	0.040	0.037	0.032	0.029	0.027	0.025
	R-11	2x6	**31**	0.075	0.065	0.058	0.052	0.049	0.047	0.043	0.037	0.033	0.030	0.028
	R-13	2x6	**32**	0.067	0.059	0.053	0.048	0.046	0.044	0.040	0.035	0.031	0.029	0.026
	R-15[2]	2x6	**33**	0.060	0.054	0.048	0.044	0.042	0.041	0.038	0.033	0.030	0.027	0.025
	R-19[2]	2x6	**34**	0.054	0.049	0.044	0.041	0.039	0.038	0.035	0.031	0.028	0.026	0.024
	R-21[2]	2x6	**35**	0.049	0.045	0.041	0.038	0.036	0.035	0.033	0.029	0.027	0.025	0.023
	R-19[2]	2x8	**36**	0.049	0.045	0.041	0.038	0.036	0.035	0.033	0.029	0.027	0.025	0.023
	R-21	2x8	**37**	0.046	0.042	0.039	0.036	0.035	0.034	0.032	0.028	0.026	0.024	0.022
	R-22	2x10	**38**	0.043	0.040	0.037	0.034	0.033	0.032	0.030	0.027	0.025	0.023	0.022
	R-25	2x10	**39**	0.039	0.036	0.034	0.032	0.031	0.030	0.028	0.025	0.023	0.022	0.021
	R-30[4]	2x10	**40**	0.034	0.032	0.030	0.028	0.027	0.027	0.025	0.023	0.022	0.020	0.019
	R-30	2x12	**41**	0.033	0.031	0.029	0.028	0.027	0.026	0.025	0.023	0.021	0.020	0.019
	R-38 [4]	2x12	**42**	0.028	0.027	0.025	0.024	0.023	0.023	0.022	0.020	0.019	0.018	0.017
	R-38[4]	2x14	**43**	0.027	0.026	0.024	0.023	0.023	0.022	0.021	0.020	0.019	0.018	0.017

NA7.4.5 Interior and Exterior Horizontal Slats for PAF

NA7.4.5.1 Procedures

These procedures detail the installation and verification protocols necessary to meet acceptance requirements of interior and exterior horizontal slats ~~for PAF~~. In addition, the responsible person shall fill out Certificate of Acceptance. The responsible person shall verify the horizontal slat to be installed matches the energy compliance documentation (Certificate of Compliance) and building plans. A copy of the Installation and Acceptance certificate shall be given to the building owner and the enforcement agency for their records.

For buildings with up to and including seven (7) horizontal slat assemblies that claim the Interior and Exterior Horizontal Slats for PAF or RSHGC for exterior horizontal slats, all horizontal slat assemblies shall be tested by the person responsible for the Certificate of Acceptance. For buildings with more than seven (7) horizontal slat assemblies ~~claiming the PAF~~, random sampling may be done to select the seven horizontal slat assemblies. If any of the horizontal slat assemblies in the sample group or seven horizontal slat assemblies fails the acceptance test, another group of seven horizontal slat assemblies must be tested.