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Codes and Standards Enhancement (CASE) Initiative

2025 California Energy Code

Multifamily Envelope

Multifamily Envelope
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Final CASE Report

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Executive Summary

The Codes and Standards Enhancement (CASE) Initiative recommends revisions to Title 24, Part 6 to improve energy efficiency and energy performance in California buildings. This CASE report proposes changes to three sections of the code that address multifamily residential buildings — cool roof, minimum wall insulation, and high-performance window — and contains pertinent information supporting the code changes, including lower long-term systemwide cost (LSC) and statewide greenhouse gas (GHG) emissions reductions.

LSC Savings from these changes would be of particular benefit to people in low-income households and low-income census tracts, who spend a higher percentage of their income on energy and rent than the general population. They would also contribute to maintaining residential temperatures and comfort:

- The cool roof reduces cooling needs by reflecting radiant heat and preventing transfer through the building envelope.
- The minimum wall insulation measure reduces conductive heat transfer between indoor and outdoor environments, reducing heating and cooling needs.
- The improved windows performance would reduce heat gain/loss and would also improve thermal comfort for people in the rooms with windows. This measure also includes changes to relative solar heat gain coefficient (RSHGC), which would allow for beneficial heat transfer during heating season and may impact cooling loads during the cooling season.

Stakeholder feedback has informed and helped to refine this proposal. The Statewide CASE Team gathered input and conducted 18 stakeholder interviews with building designers, developers, energy consultants, Home Energy Rating System (HERS) Raters, industry associations, regional and national manufacturers, national laboratory researchers, and regulatory agencies. Details about the stakeholder engagement activities can be found in Appendix F.

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today.[1] Including impacted communities in the decision-making process, ensuring that the benefits and

[1] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (CPUC, n.d.). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

burdens of the energy sector are evenly distributed, and facing the unjust legacies of the past serve as critical steps to achieving energy equity. To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences of proposals on DIPs.

The Statewide CASE Team assessed the potential impacts of the proposed envelope measures, and based on a preliminary review there may be improvements in comfort and quality-of-life aspects of living in an impacted multifamily building. The Statewide CASE Team does not recommend further research or action at this time but is open to receiving feedback and data. Please reach out to Avani Goyal (agoyal@trccompanies.com) and Marissa Lerner (mlerner@energy-solution.com) for further engagement. Further details addressing energy equity and environmental justice can be found in Section 3.6, Section 4.6, and Section 5.6 of this report.

Cool Roof

Proposed Code Change

This measure would change prescriptive requirements for roof surface properties of multifamily buildings. Roofs are the largest surface of a building in direct line of solar radiant heat. In many California climate zones, a large portion of a building's energy consumption goes to cooling the interior spaces. Interior temperatures increased by solar conduction from the roof increases this load. The peak temperature reduction because of cool roofs also supports demand side management by reducing peak demand loads.

For buildings with steep-sloped roof applications it would increase minimum aged solar reflectance (ASR) from 0.20 to 0.25, and thermal emittance (TE) from 0.75 to 0.8, in Climate Zones 10,11,13. This is shown to be cost effective in these cooling-dominated climate zones.

For low-sloped roof applications it would expand cool roof requirements that currently apply to Climate Zones 9 through 11 and 13 through 15, to include Climate Zones 2, 4, 6 through 8, and 12. The requirements are a minimum ASR of 0.63 and a TE of 0.75 or a solar reflectance index (SRI) of 75.

The proposed code changes would align more closely with the 2022 Title 24, Part 6 nonresidential or single family residential cool roof requirements and would impact new construction, with some exceptions.

The proposal would not add requirements to systems or technology not previously covered, and it would not modify or add to the field verification tests already required. It would require changes to compliance software to the extent of updating the standard design. The Statewide CASE Team is also proposing a minor clarification update by adding “roof area covered with” as a prefix to the code exception language related to building-integrated solar photovoltaic (PV).

Based on stakeholder input and market research, there are cool roof products currently on the market that can meet the proposed requirements with little additional cost to builders and owners. Used in climate zones with a high number of cooling degree days, these can achieve significant energy savings. Los Angeles County is considering a similar increase in ASR and TE for steep-sloped cool roof requirements. Stakeholder advocacy groups have voiced support for the proposed increase in stringency of ASR and TE or SRI, citing the cost effectiveness and long-term energy savings they provide.

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 Manuals, and compliance documents would be modified as a result of the proposed change(s).

Table 1: Scope of Cool Roof Code Change Proposal

Type of Requirement	Prescriptive
Applicable Climate Zones	Steep-sloped: Climate Zones 10, 11, 13, 15 Low-sloped: Climate Zones 2, 4, 6–8, 12
Modified Section(s) of Title 24, Part 6	Section 170.2(a)1A
Modified Title 24, Part 6 Appendices	-
Would Compliance Software Be Modified	Yes ACM Standard Design to be updated
Modified Compliance Document(s)	2022-LMCC-ENV-E, 2022-NRCC-ENV-E

Cost Effectiveness

The proposed code changes were found to be cost effective for all climate zones where they are proposed. California consumers and businesses would save more money on energy than they would spend to finance this measure. As a result, over time, this proposal would leave more money available for discretionary and investment purposes once the initial cost is paid off.

Among the relevant climate zones, the benefit-to-cost (B/C) ratio over the 30-year period of analysis ranges between 1.19 and 2.98 for the steep-sloped roof measure and

1.33 and 3.11 for the low-sloped roof measure, depending on climate zone. See more details in Section 3.4: Cost and Cost Effectiveness.[2]

Improved Minimum Wall Insulation Requirements

Proposed Code Change

This measure proposes increasing existing multifamily mandatory insulation requirements for walls in alignment with the concurrent proposals for single family residential wall insulation requirements. Better envelope insulation reduces space conditioning load and increases occupant comfort with little impact to building aesthetics. Lower wall insulation U-factors reduce heat transfer in the solid portions of the walls in a building; this code change would decrease the area-weighted average mandatory U-factor of wall insulation.

Title 24, Part 6 multifamily mandatory requirements use an area-weighted average U-factor metric for a wall insulation for different wall categories. To align multifamily wall insulation requirements with the single family proposal, this measure proposes to:

- Decrease the mandatory maximum U-factor for metal-framed walls from 0.151 to 0.148.
- Decrease the mandatory maximum U-factor for wood-framed and others,
    - 2x4 framing from 0.102 to 0.095 and
    - 2x6 framing from 0.071 to 0.069.

The U-factor of above-grade walls separating conditioned from unconditioned spaces has a significant impact on a building's energy performance. Because multifamily buildings come in a wider variety of architectural forms than single family residential buildings, the insulation requirements must be more adaptable to a variety of framing and insulation in wall assemblies. Many designers and builders interviewed suggested that the proposed levels of wall insulation are already standard practice. The products are readily available on the market without much incremental costs.

The increased cavity insulation requirements proposed by this measure are likely to lock in higher performance wall insulation for the life of new multifamily buildings. Feedback received by the Statewide CASE Team implies that there are practical ways, such as exterior insulation, of reaching the proposed U-factor requirements without the need to open existing walls. Stakeholders also indicated that making these standards a

[2] The B/C ratio compares the benefits or cost savings to the costs over the 30-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from LSC Savings.

mandatory requirement would ensure that these cost-effective insulation levels are installed for all buildings pursuing the performance path.

Scope of Code Change Proposal

Table 2 summarizes the scope of the proposed changes and which sections of standards, Reference Appendices, ACM Reference Manuals, and compliance documents that would be modified as a result of the proposed change(s).

Table 2: Scope of Code Change Proposal

Type of Requirement	Mandatory
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	Section 160.1(b)
Modified Title 24, Part 6 Appendices	-
Would Compliance Software Be Modified	Yes The maximum wall U-factor to be updated
Modified Compliance Document(s)	-

Cost Effectiveness

The code change proposal would not modify the stringency of the existing California Energy Code, so the CEC does not require a complete cost-effectiveness analysis to approve the proposed change. The average incremental cost for increasing fiberglass batt insulation from R-13 to R-15 in 2x4 framed cavity is estimated as \$0.36 per ft^2 and from R-20 to R-21 in 2x6 framed cavity as \$0.16 per ft^2. Please refer to Section 4.4 Cost and Cost Effectiveness and the 2025 Single Family Envelope CASE Study for more details. These costs correspond to only one potential pathway to meet the proposed mandatory wall U-factors, which can be achieved through other pathways such as increasing exterior continuous rigid installation.

High Performance Windows

Proposed Code Change

This measure revisits the U-factor and solar heat gain coefficient (SHGC) prescriptive requirements for all multifamily window categories including curtainwall/storefront, NAFS 2017 Performance Class AW, and the All Other fenestration category. This includes both new construction and alterations prescriptive requirements. It would improve prescriptive U-factor requirements for some climate zones for the All Other fenestration category. The proposal also adjusts the RSHGC requirements for all window types to make the same requirements apply to both the ‘three or less’ and the ‘four or more’ habitable stories conditions.

These focused improvements are based on the specific energy needs of each climate zone and the impact that changes in U-factor and SHGC would have on annual energy demand and space conditioning costs. The proposed measures would save energy by reducing the amount of heating and/or cooling needed to keep indoor air temperatures in the desired comfort range for the functions of multifamily residential buildings. They are designed to align multifamily fenestration requirements with the existing and proposed prescriptive requirements for similar single family residential and nonresidential vertical fenestrations where possible.

The measure proposal is based on product research and cost data collection the U.S. EPA, which recently published ENERGY STAR® Version 7 specification for windows, doors, and skylights.[3] Aligning this measure with ENERGY STAR requirements is supported by high market penetration of qualified products that meet those requirements. Regional suppliers will be stocking ENERGY STAR compliant products as a result of Version 7 implementation.

These code changes would:

- **Lower U-factor from 0.30 to 0.28 in All Other window category.** This measure proposes a slightly improved U-factor of 0.28 in climate zones where it is shown to be cost effective.
- **Remove RSHGC prescriptive requirement in Climate Zones 1, 3, 5, and 16 for four habitable stories or more.** This change would remove current maximum RSHGC requirement for curtainwalls, NAFS Class AW, and All Other window types in these heating-dominated climate zones. This measure would also unify multifamily prescriptive fenestration requirements for buildings with three or fewer habitable stories with requirements for buildings with four or more habitable stories across all window categories.

The proposed change requires updates in prescriptive requirement tables, compliance documents, ACM Reference Manual Standard Design, and compliance software algorithm. For four habitable stories or more, the ACM Standard Design would be updated to 0.35 instead of the current prescriptive maximum for the four climate zones where RSHGC requirement is removed. The proposed change allows for a flexibility of +/- 0.01 RSHGC difference between modeled value in compliance documents and installation certificates.

[3] More information on ENERGY STAR 7.0 Windows, Doors, & Skylights can be found here: ES_Residential_WDS_V7_Final

Scope of Code Change Proposal

Table 3 summarizes the scope of the proposed changes and which sections of standards, Reference Appendices, ACM Reference Manuals, and compliance documents that would be modified because of the proposed change(s).

Table 3: Scope of Code Change Proposal

Type of Requirement	Prescriptive
Applicable Climate Zones	New Construction: Climate Zones 1, 3-5, 11, 13-16 Alterations: Climate Zones 1, 3-5, 11, 13, 14, 16
Modified Section(s) of Title 24, Part 6	New Construction: Section 170.2(a)3A Alterations: Section 180.2(b)1C
Modified Title 24, Part 6 Appendices	-
Would Compliance Software Be Modified	Yes ACM Standard Design to be updated.
Modified Compliance Document(s)	2022-LMCC-ENV-E, 2022-NRCC-ENV-E

Explanation of a narrow range of flexibility allowance between modeled and installed RSHGC values of +/-0.01 would need to be added in the compliance process.

Cost Effectiveness

The proposed code changes were found to be cost effective for all climate zones where it is proposed to be required; Climate Zones 1, 3-5, 11 and 13-16 for new construction, and 1, 3-5, 11, 13-14, and 16 for alterations. For the climate zones where the measure is proposed, the B/C ratio over the 30-year period of analysis ranges between 1.21 and 5.81 depending on climate zone for new construction, and between 2.74 and 25.18 for alterations. See more details in Section 5.4 Cost and Cost Effectiveness.[4]

[4] The B/C ratio compares the benefits or cost savings to the costs over the 30-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from LSC Savings.

1. Introduction

The goal of the Multifamily Envelope CASE Report is to propose code changes for cool roofs, mandatory wall insulation, and high-performance windows in multifamily buildings. These measures would align more closely with the 2022 Title 24, Part 6 nonresidential or single family residential cool roof requirements, and with concurrent proposals for single family residential wall insulation requirements. It would also align multifamily fenestration requirements with the existing and proposed prescriptive requirements for similar single family residential and nonresidential vertical fenestrations, where possible, and with ENERGY STAR® Version 7 specifications.

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (CEC) efforts to update California's Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The 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's goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The CEC is the state agency that has authority to adopt revisions to Title 24, Part 6. One of the ways the Statewide CASE Team participates in the CEC's code development process is by submitting code change proposals to the CEC for consideration. The CEC will evaluate proposals submitted by the Statewide CASE Team and other stakeholders and may revise or reject proposals. See the CECs 2025 Title 24 website for information about the rulemaking schedule and how to participate in the process.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with many industry stakeholders including designers, builders, manufacturers, builders, HERS Raters, industry associations, federal, state and non-governmental regulatory agencies, energy and environmental consultants, trade associations, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on February 14, 2023.

The following is a summary of the content of this report:

Section 2 – **Addressing Energy Equity and Environmental Justice** presents the potential impacts of proposed code changes on disproportionately impacted populations (DIPs), as well as a summary of research and engagement methods.

Sections 3 through 5 cover individual multifamily measures:

Section 3 – **Cool Roof**

Section 4 – **Improved Minimum Wall Insulation**

Section 5 – **High Performance Windows**

Sections 3 through 5 each include the following subsections:

Sections x.1 – **Measure Description** provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.

Sections x.2 – **Market Analysis** includes a review of the current market structure. Section x.2.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards such as fire, seismic, and other safety standards, as well as whether technical, compliance, or enforceability challenges exist.

Sections x.3 – **Energy Savings** presents the per unit energy, demand reduction, and Long-term Systemwide Cost (LSC) savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per unit energy, demand reduction, and LSC savings.

Sections x.4 – **Cost and Cost-effectiveness** presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs (i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis).

Section x.5 – **First-Year Statewide Impacts** presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2025 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. Statewide water consumption impacts are also reported in this section.

Section 6 – **Proposed Revisions to Code Language** concludes the report with specific recommendations with strikeout (deletions) and underlined (additions) language for the Standards, Reference Appendices, and Alternative Calculation Method (ACM) Reference Manual. Generalized proposed revisions to sections are included for the Compliance Manual and compliance documents.

Section 7: Bibliography presents the resources that the Statewide CASE Team used when developing this report.

Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.

Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.

Appendix C: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).

Appendix D: Environmental Analysis presents the methodologies and assumptions used to calculate impacts on greenhouse gas (GHG) emissions and water use and quality.

Appendix E: Discussion of 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: LSC Savings in Nominal Dollars presents LSC savings over the period of analysis in nominal dollars.

Appendix H: Parametric Analysis: LSC Energy vs SHGC Trends shows the results of parametric energy simulations conducted for the four multifamily prototypes and how the LSC energy varies with SHGC for different U-factor levels of windows.

2. Addressing Energy Equity and Environmental Justice

2.1 General Equity Impacts

The Statewide CASE Team recognizes, acknowledges, and accounts for a history of prejudice and inequality in disproportionately impacted populations (DIPs) and the role this history plays in the environmental justice issues that persist today. While the term disadvantaged communities (DACs) is often used in the energy industry and state agencies, the Statewide CASE Team chose to use terminology that is more acceptable to and less stigmatizing for those it seeks to describe (DC Fiscal Policy Institute, 2017). Similar to the California Public Utilities Commission (CPUC) definition, DIPs refer to the populations throughout California that “most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes, as well as high incidence of asthma and heart disease” (CPUC, n.d.). DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[5]

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and facing the unjust legacies of the past all serve as critical steps to achieving energy equity. Recognizing the importance of engaging DIPs and gathering their input to inform the code change process and proposed measures, the Statewide CASE Team is working to build relationships with community-based organizations (CBOs) to facilitate meaningful engagement. A participatory approach allows individuals to address problems, develop innovative ideas, and bring forth a different perspective. Please reach out to Avani Goyal (AGoyal@trccompanies.com) and Marissa Lerner (mlerner@energy-solution.com) for engagement.

Energy equity and environmental justice (EEEJ) is a newly emphasized component of the Statewide CASE Team’s work and is an evolving dialogue within California and

[5] Environmental disparities have been shown to be associated with unequal harmful environmental exposure correlated with race/ethnicity, gender, and socioeconomic status. For example, chronic diseases, such as respiratory diseases, cardiovascular disease, and cancer, associated with environmental exposure have been shown to occur in higher rates in the LGBTQ+ population than in the cisgender, heterosexual population (CPUC, n.d.). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

beyond.[6] To minimize the risk of perpetuating inequity, code change proposals are being developed with intentional consideration of the unintended consequences of proposals on DIPs. The Statewide CASE Team identified potential impacts via research and stakeholder input. While the listed potential impacts should be comprehensive, they may not yet be exhaustive. As the Statewide CASE Team continues to build relationships with CBOs, these partnerships will inform and further improve the identification of potential impacts. The Statewide CASE Team is open to additional peer-reviewed studies that contribute to or challenge the information on this topic presented in this report. The Statewide CASE Team is currently continuing outreach with CBOs and EEEJ partners. Results of that outreach as well as a summary of the 2025 code cycle EEEJ activities will be documented in the 2025 EEEJ Summary Report that is expected to be published on title24stakeholders.com by the end of 2023.

2.1.1 Procedural Equity and Stakeholder Engagement

As mentioned, representation from DIPs is crucial to considering factors and potential impacts that may otherwise be missed or misinterpreted. The Statewide CASE Team is committed to engaging with representatives from as many affected communities as possible. This code cycle, the Statewide CASE Team is focused on building relationships with CBOs and representatives of DIPs across California. To achieve this end, the Statewide CASE Team is prioritizing the following activities:

- Identification and outreach to relevant and interested CBOs
- Holding a series of working group meetings to solicit feedback from CBOs on code change proposals
- Developing a 2025 EEEJ Summary Report

In support of these efforts, the Statewide CASE Team is also working to secure funds to provide fair compensation to those who engage with the Statewide CASE Team. While the 2025 code cycle will come to an end, the Statewide CASE Team's EEEJ efforts will continue, as this is not an effort that can be "completed" in a single or even multiple code cycles. In future code cycles, the Statewide CASE Team is committed to furthering relationships with CBOs and inviting feedback on proposed code changes with a goal of

[6] The CEC defines energy equity as "the quality of being fair or just in the availability and distribution of energy programs" . American Council for an Energy-Efficient Economy (ACEEE) defines energy equity as that which "aims to ensure that disadvantaged communities have equal access to clean energy and are not disproportionately affected by pollution. It requires the fair and just distribution of benefits in the energy system through intentional design of systems, technology, procedures and policies". Title 7, Planning and Land Use, of the California Government Code defines environmental justice as "the fair treatment and meaningful involvement of people of all races, cultures, incomes, and national origins, with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies."

engagement with these organizations representing DIPs throughout the code cycle. Several strategies for future code cycles are being considered, including:

- Creating an advisory board of trusted CBOs that may provide consistent feedback on code change proposals throughout the development process.
- Establishing a robust compensation structure that enables participation from CBOs and DIPs in the Statewide CASE Team's code development process.
- Holding equity-focused stakeholder meetings to solicit feedback on code change proposals that seem more likely to have strong potential impacts.

2.1.2 Potential Impacts on DIPs in Multifamily Buildings

2.1.2.1 Health Impacts

Understanding the influences that vary by demographics, location, or type of housing is critical to developing equitable code requirements.

Several of the potential negative health impacts from buildings on DIPs are addressed by energy efficiency (Norton, 2014.; Cluett, 2015; Rose, 2020). For example, indoor air quality (IAQ) improvements through ventilation or removal of combustion appliances can lessen the incidents of asthma, chronic obstructive pulmonary disease (COPD), and some heart problems. Water heating and building shell improvements can lower stress levels associated with energy bills by lowering utility bill costs. Better insulation and tighter building envelopes can reduce the health impacts from intrusion of dampness and contaminants, as well as providing a measure of resilience during extreme conditions. Electrification can reduce the health consequences resulting from NOx, SO2, and PM2.5. Studies have shown that not only do the effects of urban heat islands lead to higher mortality during heat waves, but those in large buildings are disproportionately affected (Smargiassi, 2008; Laaidi, 2012). These residents tend to be the elderly, people of color, and low-income households (Drehobl, 2020; Blankenship, 2020; IEA, 2014).

2.1.2.2 Energy Efficiency and Energy Burden

Because low-income households have a higher energy burden (percent of income spent on energy) than average households, energy efficiency alone can benefit them more acutely compared to the average. Numerous studies have shown that low-income households spend a much higher proportion of their income on energy (two to five times) than the average household (Power, 2007; Norton, 2014.; Rose, 2020). See Sections 3.4, 4.4, and 5.4 for estimates of LSC Savings from the current proposals.

Moreover, utility cost stability is typically more important to these households compared to average households; for households living paycheck to paycheck, an unexpectedly high energy bill can keep that household cyclically impoverished (Drehobl, 2020). Energy burdened households are 175 to 200 percent more likely to remain impoverished for longer than households not experiencing energy burden (Drehobl, 2020). The impact of a rate increase or weather-related spike is more easily handled the greater the efficiency of the home. The cost impacts of efficiency and renewables can be significantly different for those in subsidized housing (where the total of rent plus utilities is controlled) versus those in single-family homes or market rate multifamily buildings.

The measures would result in LSC Savings in almost all climate zones through reduced heating and cooling energy from the lower loads associated with a more efficient building envelope.

2.1.2.3 First Cost and New Construction

One potential negative consequence to DIPs of code-based efficiency improvements is the potential for increased housing costs. While this CASE report did find the proposed code measures would increase construction costs in some circumstances, this increase is likely to be small compared with total development and construction costs. However, a study found that increased construction costs do not have a statistically significant impact on home prices, as prices in the new home market are driven overwhelmingly by demand (Stone, Nickelsburg, & Yu, 2018). According to a peer-reviewed study done for the California Tax Credit Allocation Committee (CTCAC), land costs and developer characteristics (size, experience, and profit structure of the firm) have the most significant effect on affordable housing costs (CTCAC, 2014). The 2014 study echoes the same findings in CTCAC's cost study prepared in 1996 as well as the 2015 study by Stone, et al (Stone, Nickelsburg, & Yu, 2015). Similarly, developers of market-rate apartments conduct studies to investigate rent history and other information for comparable multifamily properties, which informs rent levels for specific projects.[7]

2.1.2.4 Cost Impacts for Renters

Renters within DIPs can also benefit from home energy efficiency improvements. Whether market rate or affordable, utility bills will be lower in homes that are more energy efficient. However, the utility bill impacts of energy efficiency in subsidized affordable housing are less clear since CTCAC staff regularly review tax credit properties to assure that affordable housing renters pay utility bills virtually equal to the utility cost estimates that were used when establishing rents (Internal Revenue Service, Treasury 2011). Renters of market-rate housing seldom ask about energy efficiency and

[7] As examples, Yardi-Matrix: https://www.yardimatrix.com/Property-Types/Multifamily, HCA: https://apartmentstudy.gr8.com/, and Foley & Puls: http://foleypuls.com/apartment_market_research.html conduct market studies.

utility bills,[8] so efficiency has little impact on rents, whereas it can have a large impact on utility bills (NMHC 2022).

2.2 Specific Impacts of the Proposed Measures

The Statewide CASE Team anticipates the proposed measures have the following potential impacts to DIPs.

2.2.1 Reduction in Energy Costs

The measures would result in LSC Savings through reduced heating and cooling energy from improvements to the requirements for cool roof, wall insulation, and windows. This would provide a higher benefit to people in low-income households and low-income census tracts who spend a higher percentage of their income on energy and rent than the general population.

2.2.2 Temperature and Comfort Maintenance

Many Americans die each year from overheating and extreme heat disproportionately impacts low-income residents and people of color (Shivaram, 2021), the Statewide CASE Team considered the impact of this measure on cooling needs during heat waves. As described below, the measures proposed in this report better maintain temperature through weather extremes, without use of air conditioning or heat. These measures are beneficial from an energy bill perspective and improved comfort, in addition to reducing the potential for extreme heat fatalities or hospitalization.

- The cool roof reduces cooling needs by reflecting radiant heat and preventing transfer through the building envelope.
- The minimum wall insulation measure reduces conductive heat transfer between indoor and outdoor environments, reducing heating and cooling needs.
- The improved windows performance would reduce heat gain/loss and would also improve thermal comfort for people in the rooms with windows. This measure also includes changes to RSHGC, which would allow for beneficial heat transfer during heating season and may impact cooling loads during the cooling season.

Further details for each measure's potential equity impacts can be found in Section 3.6, Section 4.6, and Section 5.6.

[8] According to manager and renter surveys conducted by the Multi-Housing Council in 2022, residents are interested in internet connectivity, package delivery services, gyms, and similar amenities. Smart thermostats were the only energy related feature they reported as essential or nearly so.

3. Cool Roof

3.1 Measure Description

The cool roof measure would increase prescriptive aged solar reflectance (ASR), thermal emittance (TE) and solar reflectance index (SRI) value requirements for multifamily roof materials. Cool roofs reduce the heat absorption into the roof materials, reducing the cooling loads in the building.

The cool roof measure proposes:

- Increase ASR, TE, and SRI for multifamily Option B steep-sloped roof requirements in climate zones, where cost effective.
- Extend Title 24, Part 6 multifamily Option D low-sloped cool roof requirements to more climate zones, where cost effective.

Proposed code changes are based on the potential for unrealized low-cost energy savings available for certain climate zones and roofing types.

Compliance with the proposed measure would be achieved using the higher SRI roofing products in construction, which are currently available on the market. Compliance verification with these proposed changes would require minor changes to compliance documents and current modelling software.

3.1.1 Proposed Code Change

This measure would change prescriptive requirements for roof surface properties of multifamily buildings. It would increase ASR, TE, and SRI value requirements for multifamily steep-sloped roof applications in some cooling dominated climate zones where it can be shown cost effective. It would expand cool roof requirements for multifamily low-sloped roof applications to more climate zones. These proposed changes would impact new construction with some exceptions.

The proposed code changes intend to align more closely with the 2022 Title 24 nonresidential or single family residential cool roof requirements.

- For steep-sloped roofs (Option B construction type as defined in Section 170.2(a)), the proposed changes would increase the requirement for Climate Zones 10, 11, 13 and 15 from an ASR of 0.20 to 0.25, a TE of 0.75 to 0.8.
- For low-sloped roofs (Option D construction type as defined in Section 170.2(a)), the current prescriptive code for roof requires multifamily low-sloped roofs have a minimum ASR of 0.63, a TE of 0.75, and an SRI of 75 in Climate Zones 9-11 and 13-15. Proposed code changes would expand these requirements to other Climate Zones 2, 4, 6-8, and 12.

The proposal would not add requirements to systems or technology not previously covered, and it would not modify or add to the already required field verification tests. It would require changes to compliance software to the extent of updating the standard design. The Statewide CASE Team is also proposing a minor clarification update of adding "roof area covered with" as a prefix to the code exception language related to building-integrated solar photovoltaic (PV).

3.1.2 Justification and Background Information

3.1.2.1 Justification

According to the National Solar Radiation database, much of California receives the highest average daily solar radiation in the United States.[9] Unobstructed solar radiation that is not reflected or re-emitted by a roof is absorbed by the roof and can travel by conduction through the roofing materials to the interior side of the roof. The heat then transfers through radiation to the cooler interior surfaces, including the roof surface; heating, ventilation, and air conditioning (HVAC) ducts located within the attic; and attic floors. Solar radiation also can cause heat gains through walls, windows, and skylights. However, solar heat gains at the roof are of special concern, because there typically is a larger area in direct line of the radiant heat. In many California climate zones, a large portion of a building's energy consumption goes to cooling the interior spaces and increased interior temperatures through solar conduction increases this load. The peak temperature reduction because of cool roofs also supports demand side management by reducing peak demand loads.

Based on stakeholder input and market research, there are cool roof products currently on the market that can meet the proposed requirements with little additional cost to builders and owners. The available steep-sloped products, such as reflective asphalt shingles, are also available in some of the desirable color aesthetics. The low-sloped or flat roofs in multifamily buildings typically use modified bitumen or single-ply membranes such as thermoplastic polyolefin (TPO) or polyvinyl chloride (PVC), which are already of lighter colors and readily available with cool roof compliant specifications.

If these products are used in climate zones with high number of cooling degree days, they can achieve significant energy savings. The proposed changes are a relatively small modification to the current Title 24, Part 6 Section 170.2 code requirements, also aligned with the 2022 Title 24 single family residential requirements for steep-sloped roof option and nonresidential prescriptive requirements for low-sloped roof option. Los Angeles County is considering a similar increase in ASR and TE for steep-sloped cool roof requirements to save energy and reduce urban heat island effects. Stakeholder

[9] Visit the National Renewable Energy Laboratory's NSRDB: National Solar Radiation Database for more information https://nsrdb.nrel.gov/.

advocacy groups such as the Natural Resources Defense Council (NRDC) have voiced support for the proposed increase in stringency of ASR, TE, and SRI for steep sloped roofs and the expansion of ASR, TE, and SRI requirements for low-sloped roofs citing the cost effectiveness and long-term energy savings they provide.

3.1.2.2 Background Information

Energy efficient roofs, also known as cool roofs, save HVAC cooling energy by reflecting or emitting more heat from the exterior roof surface than a traditional roof. These roofs are designed to reflect more sunlight and absorb less heat than a standard roof. Energy efficient roofing products have high ASR and TE properties. These properties help lower roof and attic temperatures on hot, sunny days to reduce the need for air conditioning and associated energy demand. The expansion of cool roof requirements would help prepare current construction for future efficiency needs as cooling demand rises in response to rising temperatures.

The Statewide CASE Team investigated cool roof prescriptive requirements for the purpose of multifamily alignment in the 2022 code cycle. Several internationally recognized building codes have included cool roof standards, including American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 and 90.2, and the International Energy Conservation Code (IECC) beginning in 1999. Other cool roof standards programs include the U.S. EPA's ENERGY STAR program, and local jurisdictional standards such as in Florida, Texas, and California cities such as Chula Vista and the Los Angeles County Green Building Standards Code.[10]

While the EPA's ENERGY STAR cool roof program is being sunset, interviews conducted with stakeholders associated with the ENERGY STAR program have made it clear that the program is sunsetting its cool roof program not due to a lack of technology potential or value, but due to regional building standards programs being able to handle the necessary variations in code required to maximize the functionality and benefit of cool roof technology. This feedback from the EPA places the impetus of furthering specialized regional cool roof standards on state and municipal programs where these technologies are the most impactful. Making small changes to the current Title 24, Part 6 cool roof requirements would help the state keep pace with the projected climate change driven increases in outdoor air temperature. Expanding the current low-sloped roofing cool roof requirements to more climate zones where cost effectiveness can be proven would help to mitigate these issues, while keeping the cool roofs market active in the state.

Many cool roof performance requirements were improved in the 2022 Title 24, Part 6 code cycle for multifamily and nonresidential buildings. For steep-sloped roofs, a

[10] https://coolroofs.org/resources/codes-programs-standards

minimum ASR value of 0.20 and a minimum TE of 0.75 were adopted in Climate Zones 10-15 in options B and C roof construction types and in Climate Zones 1-15 in option D. For low-sloped roofs, a minimum ASR value of 0.63 and TE of 0.75 were adopted in Climate Zones 13 and 15 for options B and C roof construction types, and in Climate Zones 9-11 and 13-15 for option D. The proposed steep-sloped cool roof requirement for 0.25 ASR and 0.8 TE was proposed and adopted in some climate zones for nonresidential buildings in 2022 code cycle. The proposed extension of low-sloped cool roof requirements was explored by 2022 single family alterations CASE study and got adopted in additional climate zones.

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.[11] See Section 6 of this report for detailed proposed revisions to code language.

3.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1, and Part 6 as well as the reference appendices to Part 6 are described below. See Section 6.2 of this report for marked-up code language.

Section 170.2 – Prescriptive Approach

Section 170.2(a) - Envelope Component Requirements:

Specific Purpose: The purpose of this change is to update the minimum ASR, TE, and SRI levels for applicable climate zones and introduce cool roof requirements in climate zones with no existing roof surface requirement. This would include modifying table 170.2-A to reflect the applicable minimum ASR, TE, and SRI requirements.

Necessity: This change is necessary to increase energy efficiency via cost-effective building design standards, as mandated by California Public Resources Code, Sections 25213, and 25402.

3.1.3.2 Specific Purpose and Necessity of Changes to the Nonresidential and Multifamily ACM Reference Manual.

The proposed code change would not modify the ACM Reference Manual.

[11] Visit EnergyCodeAce.com for trainings, tools, and resources to help people understand existing code requirements.

3.1.3.3 Summary of Changes to the Nonresidential and Multifamily Compliance Manual

Chapter 3 of the Nonresidential and Multifamily Compliance Manual would need to be revised. Section 3.1.1 would need to be updated to reflect the changes that have been implemented between the 2022 and 2025 California Energy Code. Section 3.2.5.2 Prescriptive Requirements would need to be updated to reflect implemented changes to ASR, TE, and SRI requirements.

3.1.3.4 Summary of Changes to Compliance Forms

The proposed code change would modify the compliance forms listed below.

- 2022-LMCC-ENV-E: Multifamily buildings with three habitable stories or fewer
- 2022-NRCC-ENV- E: Multifamily buildings with four habitable stories or more

3.1.4 Regulatory Context

3.1.4.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

To comply with existing multifamily prescriptive cool roof requirements, a roof must either meet both the minimum ASR and TE requirements or meet the minimum SRI level. The SRI is a calculated value derived from ASR, TE, product type, and aging characteristics. Existing cool roof requirements apply to new construction, additions, and alterations for all multifamily buildings, but they vary by climate zone. 2022 cool roof requirements do not distinguish buildings by the number of habitable stories, but instead, apply separate requirements to steep and low-sloped roof applications. The 2022 multifamily Title 24 code offers three options, Option B, C, and D, for compliance with cool roof requirements distinguished by the building's roof construction type. The prescriptive compliance options B and C follow the same R-value requirements for attic roof assemblies as those in the 2019 Energy Code Prescriptive requirements for multifamily buildings of three habitable stories or fewer. Compliance option D applies to low-sloped non-attic roofs and expands on the 2022 prescriptive roof and ceiling requirements for multifamily buildings of four habitable stories or more. 2022 option D modifies the 2019 code by applying it to all multifamily buildings and adjusting the ASR and TE in Climate Zones 9-11, and 13-15. The current Title 24, Part 6 multifamily prescriptive cool roof requirements are presented below in Table 4.

Table 4: Current 2022 Title 24 Multifamily Prescriptive Cool Roof Requirements

Option	Slope	Climate Zones	Aged Solar Reflectance	Thermal Emittance	SRI
B	Low	13 and 15	0.63	0.75	75
	Steep	10–15	0.20	0.75	16
C	Low	13 and 15	0.63	0.75	75
	Steep	10–15	0.20	0.75	16
D	Low	9–11 and 13–15	0.63	0.75	75
	Steep	2–15	0.20	0.75	16

There are two exceptions to the prescriptive multifamily cool roof requirements. The first exception, which applies to both low- and steep-sloped roofs, exempts buildings with integrated PV panels and buildings with integrated solar thermal panels from the minimum requirements for ASR and TE or SRI. A second exception states that roof constructions with a weight of at least 25 lb/ft² are exempt from the minimum requirements for ASR and TE or SRI.

This proposal would impact the Title 24, Part 6 Section 170.2, multifamily buildings prescriptive approach outlined above, but it does not impact other sections of the California Building Standards Code. However, it is related to Title 24, Part 2 Section 1202.3 of the California Building Code, which includes insulation requirements for condensate control that apply to unvented enclosed wood frame assemblies.

2022 California Green Building Standards Code, Title 24, Part 11 (CALGreen), has mandatory and voluntary tiers for envelope requirements, the voluntary tiers are often referred to by local jurisdictions to adopt a more stringent requirement in their territory. The CALGreen Tier 2 specification, Section A4.106.5.1, has a higher requirement for ASR and TE standards for low-rise and high-rise residential buildings. The County of Los Angeles has established reach codes that are more stringent than the 2022 Title 24 cool roof standards.[12] The County of Los Angeles 2019 Local Building Standards Ordinance requires roofing materials to comply with the ASR and TE requirements seen in Table 5 with the following exceptions: roof repair; roof replacement of less than 50 percent of the total area; installation of PV; steep-sloped roof installation in Climate Zone 16 other than low-rise multifamily; additions with roof areas less than 500 square feet; and roof construction with a thermal mass over the roof membrane including vegetated (green) roofs weighing at least 25 lb/ft². The cities of Brisbane and San Mateo also have ordinances that require higher ASR and TE standards for new construction.[13]

[12] More information on Los Angeles County Title 31 - GREEN BUILDING STANDARDS CODE can be found here: Municode.com/ca/los-angeles

[13] More information on City of Brisbane Ordinance No. 613 and City of San Mateo Ordinance No. 2016-5 can be found in the following locations: brisbaneca.org; aw.cityofsanmateo.org

Table 5: California Cool Roof Codes and Standards

State/Jurisdiction	Building Type	Slope (Low/Steep)	ASR	TE	SRI
State of California - 2022 Title 24, Part 6	Residential/Single family	Low	0.63	0.75	75
State of California - 2022 Title 24, Part 6	Residential/Single family	Steep	0.20	0.75	16
State of California - 2022 CalGreen	Low-Rise Residential	Low	0.65	0.85	78
State of California - 2022 CalGreen	Low-Rise Residential	Steep	0.23	0.85	27
2022 LA County	High-Rise Residential	Low	0.65	0.75	78
2022 LA County	Low-Rise Residential	Low	0.65	0.85	78
2022 LA County	High-Rise Residential	Steep	0.25	0.75	20
2022 LA County	Low-Rise Residential	Steep	0.25	0.85	20
Brisbane, CA	Residential	Low	0.7	0.85	85
San Mateo, CA	Residential	Low	0.7	0.85	85

However, where possible, the Multifamily Statewide CASE Team has aligned cool roof prescriptive requirements for multifamily buildings of three habitable stories or fewer with Title 24, Part 6 Section 150.1, single family residential buildings cool roof requirements, and with 2022 Title 24, Part 6 Section 140.3, nonresidential requirements for multifamily buildings with four habitable stories or more.

3.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal laws or regulations.

3.1.4.3 Difference From Existing Model Codes and Industry Standards

2019 ASHRAE 90.1 has similar or lower cool roof requirements, 0.55 ASR and 0.75 TE, as compared to current 2022 Title 24, Part 6 roof ASR and TE prescriptive requirements for multifamily buildings. 2021 IECC standards has a uniform standard baseline of 0.25 ASR and 0.9 TE.

Solar reflective properties of roofing products are determined by American National Standards Institute / CRRC S100- “Standard Test Methods for Determining Radiative Properties of Materials” (CRRC 2016). The procedure was formerly called CRRC-1 Standard. These standards are used to determine if roofing products meet the prescriptive ASR, TE requirements of Title 24, Part 6.

3.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how 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 current compliance and enforcement process are conducted by the builder and enforcement agency respectively per the typical permitting process outlined in 2022 Title 24 Energy Code.

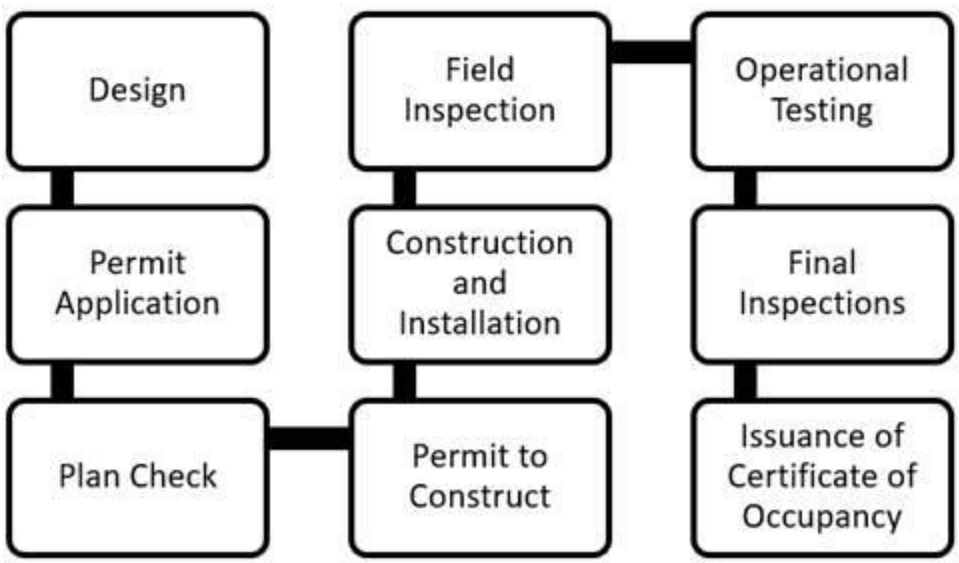

Figure 1: Idealized International Code Council permitting process for building permit applications

Source: [EnergyCodeAce website]

The compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** Architects/Designers make design decisions on the layout geometry and construction materials for the envelope, and they finalize plans with construction specifications to be used by contractors to inform installation. The design decisions on building geometry include roof type—if it has an attic, roof slope, and layout distribution across different orientations and roof construction assembly includes ceiling insulation material and location, roof deck insulation material and location, and exterior roofing surface products (if any). They also provide pertinent information to fill out compliance documents LMCC or NRCC for multifamily buildings with three habitable stories or less, or four habitable stories or more respectively.

- **Permit Application Phase:** The permitting process for all buildings is outlined in the factsheet on Energy Code Ace.[14] To obtain a permit, building inspector and/or plans examiner reviews the documentation submitted by building owner with support from designers, architects, or energy consultants. An energy consultant may be included in the design process to support energy code compliance requirements and help prepare the required compliance documents.
- **Construction Phase:** The building contractor will review and organize construction plans and specifications to prepare for installation. They would then coordinate the construction stages of the building including procurement of equipment and materials from distributors and/or manufacturers. In this case, the roofing contractor would procure the roofing surface material and install it per the construction plans. The roofing contractor would ensure the product meets the energy properties specifications identified during design phase planning and modeled by the energy consultant in code compliance software. The contractor/installer would finally complete certificates of installation such as LMCI or NRCI for three habitable stories or less or four habitable stories or more, respectively. Sometimes, the installation documents are preliminarily filled out during bid process to ensure the equipment and material selection is code compliant.
- **Inspection Phase:** The building owner or designer submits to the building department all the final documentation including compliance documents such as LMCC/LMCI/LMCV or NRCI/NRCA/NRCV for three habitable stories or less or four habitable stories or more, respectively. The full list of compliance documents for multifamily buildings are available at Energy Code Ace's Forms Ace webpage.[15] The building inspector conducts the final on-site verification of the roof comparing the certificates of installation containing roof surface properties against the procured material's specification sheet and/or visual inspection to confirm the installed product matches in style, material, and color to the specification sheets.

No change in compliance documents is expected as a result of this measure proposal. The measure does not require increased collaboration in design or installation teams, except some climate zones for low-sloped roof measure where there was no cool roof requirement before may require some additional design consideration.

[14] https://energycodeace.com/download/35782/file_path/fieldList/FactSheet.NR.Res-PermitProcess.2019.pdf

[15] https://energycodeace.com/LowriseMultifamilyForms/2022

The roof surface is generally not covered or blocked by another building system and therefore does not require inspections during construction phase. No change to field verification and diagnostic test requirements are required.

The only change to compliance software is the ACM Reference Manual standard design assumptions related to roof surface properties. CRRC rating of roof material is required to confirm the ASR and TE of the product. The corresponding SRI calculation is evaluated through the CEC tool. The proposed cool roof measure does not introduce any additional burden for compliance and enforcement or cause any major changes in the process. No additional inspections by HERS Raters or Acceptance Test Technicians are required for this measure.

3.2 Market Analysis

3.2.1 Current 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. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure, and they identified estimates of market size and measure applicability through research and outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on February 14, 2023.

According to industry experts and stakeholders interviewed by the Statewide CASE Team, the roofing materials category used in construction are determined by the slope of the roof, rather than the function or style of the building.

According to Western Roofing Magazine’s 2021 Market Survey, western regional steep-sloped roofing is dominated by fiberglass shingles at 63.5 percent of the market, followed by metal architectural at 10.3 percent, concrete tile shows 7.4 percent, clay tiles have 6.0 percent, and slate holds 5.8 percent of the market (Dodson, 2022).

Information gathered by the Statewide CASE Team through stakeholder interviews indicates that the steep-sloped new construction market in California is dominated by asphalt shingles and tiles. According to the CRRC, there are high SRI product lines available in these roofing materials. However, market information gathered through stakeholder interviews indicates that the adoption of higher SRI shingles and tile in new construction is limited, due to builder concerns for consumer aesthetic preferences and the higher cost of roofing products with currently popular aesthetics. According to the manufacturers and designers interviewed, the current trend in most U.S. steep-slope roofing markets is to construct with darker color materials outside of a few small regional markets. However, higher SRI steep-slope products are available at lower costs in lighter less popular colors.

Among low-slope roofing products, the National Roofing Contractors Association's *State of the Industry* survey 2022 reports most low-sloped roofing contractors in North America anticipate single-ply products to continue to dominate low-sloped applications (Aisner, 2022). Among those surveyed, many low-sloped roofers expressed a preference for using TPO single-ply roofing membranes (47 percent), followed by ethylene propylene diene terpolymer (EPDM) (32 percent), and then PVC (13 percent) (Aisner, 2022).

According to Western Roofing Magazine's 2021 Low-Slope Roofing Market Survey, in the western U.S., single-ply roofing product sales are composed of 34 percent TPO, 10 percent SBS-modified bitumen products, 10 percent EPDM, and 10 percent liquid applied products (Dodson, 2022).

Interviews conducted by the Statewide CASE Team, which focused on the California multifamily construction market, have produced similar feedback. According to interviews, TPO has gained popularity for low-sloped applications due to its lower costs and the avoidance of safety concerns presented by the bituminous low-sloped product application process.

Information gathered through Statewide CASE Team interviews also indicates that high SRI versions of the low-sloped roofing products have been adopted in all warm and temperate climate zones. These products most often come standard with 0.70 to 0.90 ASR, and the incremental cost to reach these high ASR levels is minimal. The practice of using darker single-ply products is present in colder climates where builder concerns over moisture accumulation below the product often deter the use of high SRI products.

For multifamily buildings, steep-sloped roofs are more common among buildings with three or fewer habitable stories, whereas low-sloped roofs are more common among multifamily buildings with four or more habitable stories. While discussing the reason the ENERGY STAR program is sunsetting its cool roof program with employees of the EPA, the Statewide CASE Team was told that the use of these technologies is standard practice in commercial and low-sloped applications, and regional programs were getting better traction in the steep-sloped market.

3.2.2 Technical Feasibility and Market Availability

The technical feasibility of the cool roof measure is determined by interviewing relevant stakeholders of roofing industry and multifamily market. Based on the stakeholder interviews conducted by the Statewide CASE Team, the use of cool roof technology in building design strategy is largely determined by two factors. First, the choice to use cool roof products is most often determined by the slope of the roof rather than the building type, function, or even climate. In steep-sloped applications, cool roof technology is often avoided during the design strategy. This is due to the popularity of dark roofing products for visible roofing applications and the higher incremental cost of darker cool roof products. For low-sloped roof applications, dominant roofing technologies allow for high SRI applications with very little incremental cost and no impact on the aesthetics or curb appeal of the building.

The second most impactful factor in cool roof technology in building design is the climate zone. In California's hot-dry climates, designing buildings to include cool roof technology is the standard practice for all low-sloped applications, and it is sometimes included in the design of steep-sloped buildings as well. In colder and more moist climates, cool roof technology is often avoided due to lower levels of annual space conditioning energy savings and moisture concerns. For steep-sloped applications, designers often use trade-offs to avoid the use of high SRI roofing products. According to industry and designer feedback received by the Statewide CASE Team, this practice is driven by the high cost and low energy savings achieved by high SRI steep-sloped cool roof products. Using the Title 24, Part 6 performance pathway, the efficiency losses that are caused by using low SRI roofing products are compensated for by low U-factor attic space insulation.

It is a standard design strategy to install high SRI roofing products on low-sloped buildings in warm climates because there is little to no cost for increasing SRI with the most common low-sloped roofing products.

The use of high SRI low-sloped membranes is often avoided in cold climates where moisture build-up below the membrane can be a concern and captured heat can reduce winter energy demand, mitigating the loss of cool roof benefits. Based on stakeholder feedback, builders in these climate zones often choose black EPDM products when designing low-sloped roofing due to the long-term moisture damage concerns.

The product availability for the proposed cool roof measure is determined by reviewing CRRC directory for qualified products and stakeholder feedback including manufacturers, distributors, designers, and other subject matter experts in the industry. The Statewide CASE Team accessed the CRRC product database on December 6, 2022. It included a total of 1,531 low-sloped and 1,888 steep-sloped roof products. Apart from roof coatings, which require the installation of other roofing materials and are not a standalone new construction roofing solution, the database includes 788 low-sloped and 1,349 steep-sloped roofing products.

Among these, 1,261 of the steep-sloped products reported a three-year ASR value, of which 982 (77.8 percent) report a three-year ASR of 0.25 or higher.[16] For steep-sloped multifamily buildings, there is market resistance to using high ASR products due to the

[16] The CRRC products database is available here: https://www.coolroofs.org

aesthetic limitations of these products. While there is a distinct reduction in the number of dark color options available to meet the proposed standards, asphalt shingles, metal products, and tiles are available in several color categories, see Table 6 below.

Table 6: Steep-slope Cool Roof Products-0.25 ASR or Higher (CRRC Directory)

Color Option	Asphalt	Metal	Tile
Bright White	32	34	3
Off-White	30	29	1
Multicolor	12	1	34
Gray	11	94	8
Tan	6	46	17
Brown	5	85	22
Blue	4	49	0
Green	0	82	10
Red	0	60	22
Orange	0	5	39
Black	0	7	0

Among the 788 non-coating low-sloped roofing products in the CRRC database with reported three-year ASR values (including asphaltic membranes, foam, liquid applied roof covering, polymer/composite, and single-ply), 28 percent have an ASR of 0.63 or higher. However, these products include 89 different TPO and PVC product options. According to the manufacturers and industry professionals interviewed by the Statewide CASE Team, these products dominate the low-sloped cool roof market. TPO and PVC have also been in use long enough for designers and builders to reliably estimate product life expectancy and cool roof functionality.

It should be noted that among the 788 low-sloped, and 1,261 steep-sloped products included in this analysis, 49.6 percent of low-sloped and 34.3 percent of steep-sloped used a *CRRC Rapid Ratings* estimated three-year ASR value. *CRRC Rapid Ratings* are interim laboratory-aged ASR values that simulate weathered values for newer products and that would be replaced with measured, three-year aged values upon completion of the weathering process.

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 2025 code cycle. It is normal 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 comprises approximately 93,000 business establishments and 943,000 employees (see Table 7 on the next page). For 2022, total estimated payroll will be about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 7: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establish-ments	Employ-ment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, & Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0
Commercial	**All**	**17,621**	**368,810**	**35.0**
Commercial	Building Construction Contractors	4,919	83,028	9.0
Commercial	Foundation, Structure, & Building Exterior	2,194	59,110	5.0
Commercial	Building Equipment Contractors	6,039	139,442	13.5
Commercial	Building Finishing Contractors	4,469	87,230	7.4
Industrial, Utilities, Infrastructure, & Other (Industrial+)	**All**	**4,206**	**101,002**	**11.4**
Industrial+	Building Construction	288	3,995	0.4
Industrial+	Utility System Construction	1,761	50,126	5.5
Industrial+	Land Subdivision	907	6,550	1.0
Industrial+	Highway, Street, and Bridge Construction	799	28,726	3.1
Industrial+	Other Heavy Construction	451	11,605	1.4
Total Combined	**All**	**93,716**	**942,786**	**77.6**

Source: (State of California, n.d.)

The proposed change to the multifamily cool roof measure would likely affect multifamily builders, but it 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 8 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report.

Builders sometimes cover both the design and construction of a multifamily building. This section covers the impacts on the construction portion. The next section discusses the impacts for the design portion. Builders are responsible for understanding the design requirements and ensuring all subcontractors are aware of these requirements for proper cool roof installation. Those working in relevant subsectors, such as roofing contractors, will need to decide on the appropriate cool roofing material if a proposed design alternate is being considered. They would need to be more familiar with the proposed measure requirements and ensure all cool roof standards are met by the installers. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.2.4 Economic Impacts.

Table 8: Specific Subsectors of the California Residential Building Industry by Subsector in 2022 (Estimated)

Residential Building Subsector	Establishments	Employment	Annual Payroll (Billions $)
New Multifamily General Contractors	421	6,344	0.7
Residential Structural Steel Contractors	275	3,207	0.2
Residential Framing Contractors	741	25,028	1.3
Residential Roofing Contractors	2,600	18,918	1.1
Other Residential Exterior Contractors	628	2,875	0.2

Source: (State of California, n.d.)

3.2.3.2 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 changes to design practices and building codes.

Building designers and energy consultants would need to identify the best strategies for implementing a cool roof for multifamily projects in the climate zones in which the requirements apply. Building designers are responsible for developing the building plans, determining the building materials and installation methods, researching building regulations and requirements, and calculating material and labor costs. They must understand the rules and industry standards to ensure safety and compliance.

Building designers would also work with energy consultants to ensure that the proposed cool roof requirements are met. They would guide the designers in determining the most cost-effective approach for implementing a cool roof while complying with residential building codes, which require that roofing materials meet certain values for ASR, TE, or SRI for low-sloped and steep-sloped roofs depending on the climate zone. Further, building designers would need to review alternate products as proposed by the contractors to ensure compliance with the original specification and the code.

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 9 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 multifamily cool roof to affect firms that focus on multifamily construction.

There is no NAICS code specific to energy consultants.[17] 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.[18] 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 9 provides an upper bound indication of the size of this sector in California.

Table 9: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

Sector	Establishments	Employment	Annual Payroll (Millions $)
Architectural Services[19]	4,134	31,478	3,623
Building Inspection Services[20]	1,035	3,567	281

Source: (State of California, n.d.)

[17] 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.

[18] 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.

[19] Architectural services (NAICS 541310) comprise private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures.

[20] 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 (DOSH). 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 (Including Homeowners and Potential First-Time Homeowners)

Residential Buildings

According to U.S. Census data, American Community Survey, there were more than 14.5 million housing units in California in 2021 and nearly 13.3 million were occupied, as shown in Table 10. Most housing units (nearly 9.42 million) were single family homes (either detached or attached), approximately 2 million homes were in buildings containing two to nine units, and 2.5 million homes were in multifamily buildings containing 10 or more units. The California Department of Revenue estimated that building permits for 67,300 single family and 54,900 multifamily homes will be issued in 2022, up from 66,000 single family and 53,500 multifamily permits issued in 2021.

Table 10: California Housing Characteristics in 2021[21]

Housing Measure	Estimate
Total housing units	14,512,281
Occupied housing units	13,291,541
Vacant housing units	1,220,740
Homeowner vacancy rate	0.7%
Rental vacancy rate	4.3%
Number of 1-unit, detached structures	8,388,099
Number of 1-unit, attached structures	1,030,372
Number of 2-unit structures	348,295
Number of 3- or 4-unit structures	783,663
Number of 5- to 9-unit structures	856,225
Number of 10- to 19-unit structures	740,126
Number of 20+ unit structures	1,828,547
Mobile home, RV, etc.	522,442

Sources: (United States Census Bureau, n.d.), (Federal Reserve Economic Data (FRED), n.d.)

[21] Total housing units as reported for 2021; all other housing measures estimated based on historical relationships.

Table 11 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59 percent of the total) were built between 1950 and 1989, a period of rapid population and economic growth in California. Finally, about 2.1 million homes in California were built before 1950. According to Kenney et al, 2019, more than half of California's existing multifamily buildings (those with five or more units) were constructed before 1978 when there was no California Energy Code (Kenney, 2019).

Table 11: Distribution of California Housing by Vintage in 2021 (Estimated)

Home Vintage	Units	Percent	Cumulative Percent
Built 2014 or later	348,296	2.4	2.4
Built 2010 to 2013	261,221	1.8	4.2
Built 2000 to 2009	1,581,839	10.9	15.1
Built 1990 to 1999	1,596,351	11.0	26.1
Built 1980 to 1989	2,191,354	15.1	41.2
Built 1970 to 1979	2,539,649	17.5	58.7
Built 1960 to 1969	1,915,621	13.2	71.9
Built 1950 to 1959	1,930,133	13.3	85.2
Built 1940 to 1949	841,712	5.8	91.0
Built 1939 or earlier	1,306,105	9.0	100.0
Total housing units	**14,512,281**	**100.0**	**–**

Sources: (United States Census Bureau, n.d.)

Table 12 shows the distribution of owner- and renter-occupied housing by household income. Overall, about 55 percent of California housing is owner-occupied, and the rate of owner-occupancy generally increases with household income. The owner-occupancy rate for households with an income below $50,000 is only 37 percent, whereas the owner occupancy rate is 71 percent for households earning $100,000 or more.

Table 12: Owner- and Renter-Occupied Housing Units in California by Income in 2021 (Estimated)

Household Income	Total	Owner Occupied	Renter Occupied
Less than $5,000	353,493	113,315	240,178
$5,000 to $9,999	254,304	74,939	179,366
$10,000 to $14,999	495,287	134,633	360,654
$15,000 to $19,999	412,498	144,064	268,435
$20,000 to $24,999	467,694	169,431	298,264
$25,000 to $34,999	906,996	355,968	551,028
$35,000 to $49,999	1,319,892	560,453	759,438
$50,000 to $74,999	2,036,560	990,769	1,045,791
$75,000 to $99,999	1,662,032	920,607	741,425
$100,000 to $149,999	2,307,889	1,490,247	817,642
$150,000 or more	3,074,895	2,337,651	737,244
Total Housing Units	**13,291,541**	**7,292,076**	**5,999,465**

Source: (United States Census Bureau, n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 11 and Table 12 provide the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 11 and Table 12.

Estimating Impacts

For California residents, the proposed code changes would result in lower energy bills. The Statewide CASE Team estimates that, on average, the proposed change to Title 24, Part 6 would increase construction cost by about $44 per multifamily residence. There would be a very minimal increased construction cost per month based on a 30-year mortgage (assuming a five percent interest rate). The measure would also result in an average energy and maintenance cost savings of about $10 per year, depending on climate zone, or less than $1 per month reduction in energy costs. Overall, the Statewide CASE Team expects the proposed 2025 Title 24, Part 6 Standards changes to save homeowners about $10 per year compared to homeowners whose multifamily residences are minimally compliant with the 2022 Title 24, Part 6 requirements.

When homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy.

Energy cost savings can be particularly beneficial to low-income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors, 2011).

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

The proposed measure would impact manufacturers developing cool roofing materials, distributors selling these products to retailers, and these retailers selling directly to consumers. There will be various brands and types of cool roofing materials, such as shingles, tiles, metals, membranes, and coatings with high solar reflectance, available in the market. However, there would only be a change in demand for products to meet the proposed requirements, since cool roofing materials that can meet the proposed requirements are readily available in the current market. As more multifamily properties are required to install roofing products to meet the proposed measure, there would be less demand for standard roofing materials or those that previous were minimally compliant but no longer meet the new proposed performance thresholds. Depending on the type of roofing material used, the cost of selecting a cool roof with higher solar reflectance would cost slightly more than standard materials, and manufacturers, distributors, and retailers are likely to have slightly higher sales revenue.

3.2.3.6 Impact on Building Inspectors

Table 13 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 education and 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 13: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

Sector	Govt.	Establishments	Employment	Annual Payroll (Million $)
Administration of Housing Programs[22]	State	18	265	29.0
	Local	38	3,060	248.6
Urban and Rural Development Admin[23]	State	38	764	71.3
	Local	52	2,481	211.5

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

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 individual 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 from this measure 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 multifamily cool roof would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.2.4 Economic Impacts

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software[24], 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. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment (jobs created in the manufacturing plant), indirect employment (jobs created in the sectors that provide raw materials to the manufacturing plant), and

[22] 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.

[23] 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.

[24] IMPLAN employs economic data and advanced economic impact modeling to estimate economic impacts for interventions like changes to the California Title 24, Part 6 code. For more information on the IMPLAN modeling process, see www.IMPLAN.com.

induced employment (jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant). Eventually, IMPLAN computes the total number of jobs created due to a code. The assumptions of IMPLAN include constant returns to scale, fixed input structure, industry homogeneity, no supply constraints, fixed technology, and constant byproduct coefficients. The model is also static in nature and is a simplification of how jobs are created in the macroeconomy.

The economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. The IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that the direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the economic impacts presented below represent lower bound estimates of the actual benefits 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 residential building and remodeling industry, architects, energy consultants, and building inspectors, as well as indirectly as residents spend all or some of the money saved through lower utility bills on other economic activities.[25] There may also be some nonresidential customers that are impacted by this proposed code change; however, the Statewide CASE Team does not anticipate such impacts to be materially important to the building owner and would have measurable economic impacts.

The estimated impact is based on the relative incremental cost and the estimated proportion of new multifamily units that would be impacted by the proposed change in 2026. The incremental cost is weighted by the applicable climate zones and building prototypes. Also, the Statewide CASE Team does not expect additional labor hours for building designers, energy consultants, and/or building inspectors for the proposed change. The estimated economic impacts from the proposed cool roof measure are shown in Table 14 through Table 16.

[25] For example, for the lowest income group, the Statewide CASE Team assumes 100 percent of money saved through lower energy bills will be spent, while for the highest income group, they assume only 64 percent of additional income will be spent.

Table 14: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income (Million $)	Total Value Added (Million $)	Output (Million $)
Direct Effects (Additional spending by Residential Builders)	10.1	0.80	1.06	1.3
Indirect Effect (Additional spending by firms supporting Residential Builders)	1.2	0.09	0.15	0.26
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	3.8	0.26	0.46	0.73
Total Economic Impacts	**15.1**	**1.1**	**1.7**	**2.3**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[26]

Table 15: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (Jobs)	Labor Income (Million $)	Total Value Added (Million $)	Output (Million $)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	0	0	0	0
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	0	0	0	0
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0	0	0	0
Total Economic Impacts	**0**	**0**	**0**	**0**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

[26] IMPLAN® model, 2020 Data, IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

Table 16: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (Jobs)	Labor Income (Million $)	Total Value Added (Million $)	Output (Million $)
Direct Effects (Additional spending by Building Inspectors)	0	0	0	0
Indirect Effect (Additional spending by firms supporting Building Inspectors)	0	0	0	0
Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	0	0	0	0
Total Economic Impacts	**0**	**0**	**0**	**0**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

3.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 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.

3.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to the use of specific roofing products, which would not excessively burden or competitively disadvantage California businesses—nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.2.4.3 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.[27] Therefore,

[27] 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.

the Statewide CASE Team does not anticipate that these measures proposed for the 2025 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[28] As Table 17 shows, between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020, due to the worldwide economic slowdowns associated with the COVID 19 pandemic, to a high of 35 percent in 2019, with an average of 26 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 17: 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 (Percent)
2017	518.4	1,882.4	28
2018	636.8	1,977.4	32
2019	690.8	1,952.4	35
2020	343.6	1,908.4	18
2021	506.3	2,619.9	19
5-Year Average	**539.2**	**2,068.1**	**26**

Source: (Federal Reserve Economic Data (FRED), 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, directly or indirectly, in any affected sectors of California's economy. Nevertheless, the Statewide CASE Team can derive a reasonable estimate of the change in investment by California businesses based on the estimated change in economic activity associated with the proposed measure and its expected effect on proprietor income, which the Statewide CASE Team uses a conservative estimate of

[28] 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.

corporate profits, a portion of which they assume will be allocated to net business investment.[29]

3.2.4.5 Incentives for Innovation in Products, Materials, or Processes

The Statewide CASE Team does not anticipate the proposed code change would impact innovation. A portion of the market is already using roofing materials that have a higher solar reflectance and TE, and some are using cool roofs in multifamily buildings.

3.2.4.6 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 California's General Fund, any state special funds, or local government funds.

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 measure would not impact state buildings since it is a residential measure.

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 2025 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.

[29] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 17.

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, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences.

The proposed code changes are likely to impact DIPs. Refer to Section 2 for more details regarding DIPs as well as energy equity and environmental justice.

3.2.5 Fiscal Impacts

3.2.5.1 Mandates on Local Agencies or School Districts

There are no mandates for local agencies, because the requirements would be specified at the statewide level through Title 24, Part 6. There are also no relevant mandates to school districts, since this measure only impacts multifamily buildings.

3.2.5.2 Costs to Local Agencies or School Districts

There would be minor cost increases for local agencies employing building inspectors who would enforce the measure. Inspectors would need to ensure that the roofs of multifamily buildings meet the minimum requirements for the style of roof and climate zone. This change would only occur in climate zones that do not currently have a cool roof requirement. There are no costs to school districts since this measure only impacts multifamily buildings.

3.2.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies, because they would not be involved in enforcement of the measure.

3.2.5.4 Other Non-Discretionary Cost or Savings Imposed on Local Agencies

There are no added non-discretionary costs or savings to local agencies.

3.2.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings in federal funding to the state. The proposed measure would have a small impact on incremental cost. California would not require federal funding to implement the proposed measure.

3.3 Energy Savings

This section presents the methodology, assumptions, and results of the energy savings analysis.

The Statewide CASE Team gathered stakeholder input to inform the energy savings analysis. See Appendix F for a summary of stakeholder engagement.

Energy savings benefits may have potential to disproportionately impact DIPs. Refer to Section 2 for more details addressing energy equity and environmental justice.

3.3.1 Energy Savings Methodology

3.3.1.1 Key Assumptions for Energy Savings Analysis

The final 2026 LSC factors were used in the analysis presented here.

The prototypical building models used for energy models were sourced from the California Building Energy Code Compliance for Commercial/Nonresidential Buildings (CBECC) software for multifamily buildings (CBECC 2025). The prototypes were modified to create baseline and proposed models. The baseline model is based on the 2022 Title 24, Part 6 mandatory and prescriptive requirements. The proposed model reflects the proposed changes to the energy standards.

The proposed changes are categorized using roof slope, proposing a separate measure for steep-sloped and low-sloped roof applications. The roof slope is defined as the ratio of roof height to length. If this ratio is greater than or equal to 2:12 (height: length), it is considered a steep-sloped roof, if it is below the ratio, it is considered a low-sloped roof.

The Low-Rise Garden prototype energy model was used to model steep-sloped roof with an attic to evaluate proposed code changes in steep-sloped roof surface category. This choice was made based on feedback from stakeholders. The Statewide CASE Team's research and stakeholder feedback from industry associations and designers indicates the prevalence of steep-sloped building construction among multifamily residential buildings of two or less stories in California.

Similarly, low-sloped roof products and proposed code changes were used for the other three multifamily prototypes: Loaded Corridor, Mid-rise Mixed Use, and High-rise Mixed Use. This choice was made based on feedback from stakeholders, which indicates the prevalence of low-sloped roof building construction among all buildings of three or greater stories in California. All proposed code changes by building type are shown below in Table 19.

No specific roof material was chosen for these energy models due to the variety of products and technologies available that meet the proposed changes to ASR and TE.[30]

The Statewide CASE Team simulated the energy impacts across all climate zones and applied the climate-zone specific LSC hourly factors when calculating energy and

[30] A comprehensive list of Cool Roof products is found on the CRRC website: https://coolroofs.org/directory/roof

energy cost impacts for the Low-rise Garden model applying steep-sloped roof code change proposals. The Statewide CASE Team simulated the energy impacts in Climate Zones 1-8, 12, and 16 and applied the climate-zone specific LSC hourly factors when calculating energy and energy cost impacts for all other building prototype models applying low-sloped roof code change proposals. The climate zones chosen for proposal modeling were based on the climate zones that would be impacted by these proposals.

3.3.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per-unit energy savings expected from the proposed code changes in several ways to quantify key impacts. First, savings are calculated by fuel type. Electricity savings are measured in terms of both energy usage and peak demand reduction. Natural gas savings are quantified in terms of energy usage. Second, the Statewide CASE Team calculated source energy savings. Source energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly source energy values provided by the CEC are strongly correlated with GHG emissions. Finally, the Statewide CASE Team calculated LSC Savings, formerly known as Time Dependent Valuation (TDV) LSC Savings. LSC Savings are calculated using hourly energy cost metrics for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building and incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO2 emissions. The CEC directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent building geometries for different types of buildings. More information on CBECC Title 24 compliance software and full list of building prototypes are available at CBECC Title-24 Compliance Software. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 18.

Table 18: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Low-Rise Garden	2	7,320	2-story, 8-unit apartment building. Average dwelling unit size: 960 ft^2. Individual gas instantaneous DHW.
Loaded Corridor	3	39,264	3-story, 36-unit apartment building. Average dwelling unit size: 960 ft^2. Individual gas instantaneous DHW.
Mid-rise Mixed Use	5	112,641	4-story (4-story residential, 1-story commercial), 88-unit building. Avg dwelling unit size: 870 ft^2. Central gas storage DHW.
High-rise Mixed Use	10	125,400	10-story (9-story residential, 1-story commercial), 117-unit building. Avg dwelling unit size: 850 ft^2. Central gas storage DHW

The Statewide CASE Team estimated LSC, source energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in EnergyPlus using prototypical buildings and rulesets from the 2025 Research Version of the CBECC software.

CBECC generates two models based on user inputs: the Standard Design and the Proposed Design.[31] The Standard Design represents the geometry of the prototypical building and a design that uses a set of features that result in a LSC budget and Source Energy budget that is minimally compliant with 2022 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2022 Nonresidential and Multifamily 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 with the Standard Design representing compliance with 2022 code and the Proposed Design representing compliance with the proposed 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 2022 Title 24, Part 6 requirements.

There is an existing Title 24, Part 6 requirement that covers the building system in question and applies to both new construction/additions and alterations, so the Standard Design is minimally compliant with the 2022 Title 24, Part 6 prescriptive

[31] CBECC creates a third model, the Reference Design, that represents a building similar to the Proposed Design, but with construction and equipment parameters that are minimally compliant with the 2006 IECC. The Statewide CASE Team did not use the Reference Design for energy impacts evaluations.

requirements. Current prescriptive code requirements for low-sloped multifamily buildings include three pathways, options B, C, and D, which are divided by roof slope. The two pathways related to the proposed measure are Option B steep-sloped and Option D low-sloped. Option B steep-sloped requires a minimum SRI of 16, an ASR of 0.20 and a TE of 0.75 in Climate Zones 10-15. Option D low-sloped requires a minimum SRI of 75, an ASR of 0.63, and a TE of 0.75 in Climate Zones 9-11 and 13-15.

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 19 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume that the measure would impact 100 percent of all newly constructed floorspace represented by all four building prototypes and 100 percent of all new construction and additions in all impacted climate zones. Please note that this table includes all climate zones where the measure was analyzed, however the code change is proposed for a subset of climate zones only where it is cost-effective.

Table 19: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Measure Category	Prototype ID	Climate Zone*	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Steep-Slope Option B	Low-Rise Garden	10-15	Roof/Ceiling Construction	ASR/TE	0.20/0.75	0.25/0.80
Steep-Slope Option B	Low-Rise Garden	1-9,16	Roof/Ceiling Construction	ASR/TE	0.10/0.75	0.25/0.80
Low-Slope Option D	Loaded Corridor	1-8, 12,16	Ceiling Construction	ASR/TE	NR	0.63/0.75
Low-Slope Option D	Mid-rise Mixed Use	1-8, 12,16	Ceiling Construction	ASR/TE	NR	0.63/0.75
Low-Slope Option D	High-rise Mixed Use	1-8, 12	Ceiling Construction	ASR/TE	NR	0.63/0.75

*The measure is analyzed for cost-effectiveness in all applicable climate zones described in this table, but the final proposal is made for select climate zones that are cost-effective only.

CBECC calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/y) and therms per year (therms/y). It then applies the 2025 LSC hourly factors to calculate LSC in 2026 present value dollars (2026 PV$), Source Energy hourly factors to calculate Source Energy use in kilo British thermal units per year (kBtu/y), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent per year (MT or "tonnes" CO_2e/y). CBECC also calculates annual peak electricity demand measured in kilowatts (kW). A recording of the CEC's that took place on 11/10/2022 is available at the CEC Final Staff Workshop on Energy Accounting for the 2025.

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

Per-unit energy impacts for multifamily buildings are presented in savings per residential dwelling unit. Annual energy and peak demand impacts for each prototype building were translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building. This step enables a calculation of statewide savings using the construction forecast that is published in terms of number of multifamily dwelling units by climate zone.

3.3.1.3 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the statewide construction forecasts that the CEC provided. The statewide construction forecasts estimate new construction/additions that would occur in 2026, the first year that the 2025 Title 24, Part 6 requirements are in effect. They also estimate the amount of total existing building stock in 2026, which the Statewide CASE Team used to approximate savings from building alterations (California Energy Commission, 2022). The construction forecast provides construction (new construction/additions and existing building stock) by building type and climate zone, as shown in Appendix A and additional information about the methodology and assumptions used to calculate statewide energy impacts.

3.3.2 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 20 through Table 23. The presented savings account for new construction only. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Modeled per-unit electricity savings for the first year range from -8.76 to 24.83 kWh/y for steep-sloped roofs and from -9.02 to 68.83 kWh/y for low-sloped roofs, depending on climate zone. Modeled per-unit source energy savings for the first year range from -99.37 to 22.33 kBtu/y for steep-sloped roofs and -172.65 to 73.98 kBtu/y for low-sloped roofs, depending upon climate zone. Demand reductions range between -5.08 to 2.39, depending on climate zone and building type. Please note that these ranges include all climate zones where the measure was analyzed, however the code change is proposed for a subset of climate zones only where it is cost-effective.

As described in Section 3.3.1, the Statewide CASE Team simulated energy impacts of proposed varying stringency levels for steep and low-sloped roof applications based on climate zone. These proposals were selected based on both cost effectiveness and modeled energy savings, across all modeled. Energy models were run across all climate zones using the prototypical buildings identified in Table 20 through Table 23. Please note that the results are presented for all climate zones including those where no changes are currently recommended. The measure is proposed only in climate zones, where cost effective.

Energy impacts per dwelling unit of a building are presented in the tables below. Electricity savings are shown in kWh/unit. Peak demand reduction is shown in Watts/unit. Natural gas savings and Source energy savings are shown in kBtu/unit.

In climate zones where the proposed code change would increase energy use, the negative energy savings are depicted in red font and with a negative (-) sign. The Statewide CASE Team evaluated energy savings of all prototypical buildings in all climate zones and reviewed results to inform recommended code changes.

The energy savings are potentially conservative since the analysis uses three year ASR as performance parameter. However, the energy savings could be impacted by the maintenance of roof surface if it is not appropriately cleaned to ensure optimum performance.

Demand management impacts would be minimal under the proposed measure. Some building types in some climate zones would see a peak demand reduction, and others would see a peak demand increase, but the peak demand shift ranges only from -5.08 W to 2.39 W per dwelling unit.

Table 20: First-Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - Cool Roof

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	-6.69	-0.88	-5.80	6.90	-8.76	4.71	8.63	24.8	21.3	10.8	11.4	7.61	12.6	6.44	24.0	12.9
LoadedCorridor	-7.22	22.8	-5.98	36.1	-9.02	24.0	68.8	67.1	0.00	0.00	0.00	63.0	0.00	0.00	0.00	48.6
MidRiseMixedUse	1.14	35.7	-0.58	34.6	-2.06	25.4	38.8	57.1	0.00	0.00	0.00	48.6	0.00	0.00	0.00	27.2
HighRiseMixedUse	-2.13	6.69	-2.38	10.0	-3.91	3.73	6.82	19.6	0.00	0.00	0.00	14.8	0.00	0.00	0.00	5.41

Table 21: First-Year Peak Demand Reduction (W) Per Dwelling Unit by Climate Zone (CZ) - Cool Roof

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	-0.98	-2.02	-1.95	-3.19	-2.93	-0.02	0.38	0.16	-0.57	-0.48	-0.16	-0.29	-0.09	-1.24	0.82	0.58
LoadedCorridor	-1.44	-1.67	-3.15	-3.44	-5.08	0.48	1.92	1.28	0.00	0.00	0.00	0.76	0.00	0.00	0.00	2.26
MidRiseMixedUse	-0.40	0.65	-1.91	-1.86	-3.02	1.16	1.48	2.39	0.00	0.00	0.00	1.13	0.00	0.00	0.00	1.04
HighRiseMixedUse	-0.58	-0.64	-0.87	-0.90	-1.74	0.11	0.21	0.30	0.00	0.00	0.00	0.04	0.00	0.00	0.00	-0.13

Table 22: First-Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Cool Roof

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	-12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-127
LoadedCorridor	-18.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-250
MidRiseMixedUse	-7.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-55.3
HighRiseMixedUse	-6.58	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-22.1

Table 23: First-Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - Cool Roof

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	-26.0	-17.3	-18.8	-19.7	-25.4	0.18	4.67	13.1	8.33	3.48	5.95	1.37	7.69	-5.31	22.3	-99.4
LoadedCorridor	-37.5	0.65	-31.2	-5.8	-39.5	16.9	57.8	50.1	0.00	0.00	0.00	43.7	0.00	0.00	0.00	-173
MidRiseMixedUse	-9.47	33.8	-14.6	17.9	-18.7	31.7	50.9	74.0	0.00	0.00	0.00	52.9	0.00	0.00	0.00	-16.6
HighRiseMixedUse	-13.5	0.75	-9.43	2.25	-13.8	2.68	7.07	18.2	0.00	0.00	0.00	10.4	0.00	0.00	0.00	-15.9

3.4 Cost and Cost Effectiveness

The cost assumptions for this measure are derived from previous studies and cross checked against information provided by stakeholders. The cost estimates were also reviewed by stakeholders including the feedback gathered during the stakeholder workshop conducted on February 14, 2023. Appendix F summarizes stakeholder engagement.

3.4.1 LSC Savings Methodology

Energy cost savings were calculated by applying the factors to the energy savings estimates that were derived using the methodology described in Section 3.3.1. LSC hourly factors are a normalized metric to calculate LSC 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.

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost-effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost effectiveness using 2026 PV$ are presented in Section 3.4 of this report. The CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents LSC savings results in nominal dollars.

These proposed changes to solar radiative properties of roofing products apply to new construction only. Since the incremental costs between baseline and proposed reflectance levels only depend on changes to roofing materials, there would be no difference between costs in new construction.

The decision to model cost savings for steep-sloped roof applications for low-rise buildings and low-sloped application for other building prototypes is based on the input of designer, builder, supplier, and manufacturer stakeholder interviews. Stakeholders informed the Statewide CASE Team that in multifamily roofing applications above two stories, steep-sloped roofing is built for visual appeal above the actual roof. Thus, it does not share a direct thermal connection with the occupied spaces within the building.

3.4.1.1 LSC Savings Results

Per-unit LSC Savings for newly constructed buildings, and additions in terms of LSC savings realized over the 30-year period of analysis are presented 2026 precent value dollars (2026 PV$) in Table 24 shows savings impact for the Steep-sloped roof applications modeled with the Low-rise Garden model. Table 25 shows the savings impact for low-sloped applications modeled with the Loaded Corridor, Mid-rise Mixed use, and High-rise Mixed Use models.

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

Any time code changes impact cost, there is potential to disproportionately impact DIPs. Refer to Section 2 for more details addressing energy equity and environmental justice.

Table 24: 2026 PV LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction – Cool Roof Improvements – LowRiseGarden, Steep-Sloped

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	-46.3	-15.0	-61.3
2	-22.0	0.00	-22.0
3	-45.8	0.00	-45.8
4	40.4	0.00	40.4
5	-67.5	0.00	-67.5
6	332	0.00	32.0
7	73.2	0.00	73.2
8	153	0.00	153
9	130	0.00	130
10	62.7	0.00	62.7
11	71.2	0.00	71.2
12	48.4	0.00	48.4
13	81.0	0.00	81.0
14	31.9	0.00	31.9
15	150	0.00	150
16	78.3	-155	-76.8

Table 25: 2026 PV LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction & Additions – Cool Roof Improvements – Weighted Average (LoadedCorridor, MidRiseMixedUse, HighRiseMixedUse), Low-Sloped

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	-19.0	-14.5	-33.4
2	162	0.00	162
3	-28.4	0.00	-28.4
4	219	0.00	219
5	-46.7	0.00	-46.7
6	164	0.00	164
7	336	0.00	336
8	375	0.01	376
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	347	0.00	347
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	202	-148	54.2

3.4.2 Incremental First Cost

The incremental first cost for cool roof includes material impacts only. The labor cost is not assumed to be impacted; therefore, it is not included in the incremental cost estimate. It is based on the 2022 Title 24, Part 6 prescriptive requirements as baseline, Option B steep-sloped roof and Option D low-sloped roof surface properties.

The incremental cost is determined by the cost collection efforts as a part of 2022 Nonresidential Envelope CASE Report and 2022 Single family Envelope Alterations CASE Report. It is based on costs collected from manufacturers and distributors for a wide base of qualifying products across the country. The Statewide CASE Team used the final cost estimates including the wider cost collection database and reviewed them with stakeholders to understand the impact of changes in market economy since then. The stakeholders suggested that the supply chain and the costs have generally increased for roof products since the 2022 CASE studies. However, the cost increase is proportional across products and does not affect the incremental cost considerably. The cost per square foot of roof material is applied to the actual roof area of each prototype to estimate the amount of roof material. The actual roof area could be determined from the prototype directly for low-sloped or flat roofs. However, the LowRiseGarden prototype with 5:12 slope had a projected ceiling area only, the actual roof material area was calculated based on the slope and assumptions on the steep roof overhang. The Statewide CASE Team further vetted the cost estimates and assumptions by industry experts and stakeholders for potential refinement. Based on an open survey from stakeholder workshop conducted on February 14, 2023, the assumed incremental cost estimates were lower than assumed by the analysis.

Table 26 below summarizes the incremental cost estimates for cool roofs for the four prototypes evaluated including LowRiseGarden, LoadedCorridor, MidRiseMixedUse, HighRiseMixedUse. The incremental cost for steep-sloped measure is primarily based on asphalt shingle product. For low-sloped measure, the baseline assumes a modified bitumen cap sheet, while the proposed assumes a TPO.

Table 26: Incremental Cost Estimate for Cool Roof

Prototype	Climate Zones	Roof Slope	Baseline	Proposed	Incremental Cost ($/ft2)
LowRiseGarden	10-15	Steep-sloped	0.20/0.75	0.25/0.80	0.07
LowRiseGarden	1-9,16	Steep-sloped	0.10/0.85	0.25/0.80	0.26
LowRiseLoadedCorridor	1-8,12,16	Low-sloped	0.10/0.85	0.63/0.75	0.33
MidRiseMixedUse	1-8,12,16	Low-sloped	0.10/0.85	0.63/0.75	0.33
HighRiseMixedUse	1-8,12,16	Low-sloped	0.10/0.85	0.63/0.75	0.33

Presented costs were vetted by stakeholders during interviews including manufacturers, designers, builders, and other subject matter experts. The Statewide CASE Team also collected cost information from around eight suppliers based across different locations of California that suggested that the costs above are on the conservative side.

The Statewide CASE Team collected additional cost data from distributors across California to get a more accurate estimate and adjusted incremental costs by climate zone. The Statewide CASE Team calculated the factors in Table 27 based on the representative cities in each climate zone, the different trades that are involved, and the climate zone that they received costs for. The adjustment factors for material and labor. The cost for envelope new construction is adjusted with respect to Climate Zone 12.

Table 27: Incremental Climate Zone Material Cost Adjustment Factors

Climate Zone	Material Adjustment
1	0.92
2	0.93
3	0.96
4	0.96
5	1.00
6	0.97
7	1.00
8	0.95
9	0.94
10	0.96
11	0.96
12	1.00
13	1.00
14	0.92
15	0.92
16	0.92

3.4.3 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 (or savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2025 LSC hourly factors. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

$$Present\ Value\ of\ Maintenance\ Cost = Maintenance\ Cost \times \left[\frac{1}{1+d}\right]^n$$

The expected useful life of the measure is assumed to be around 20 years and hence incremental replacement costs were considered for this analysis. The replacement cost is considered the same as first cost, but the residual value at the end of 30-year analysis period is deducted from the cost analysis, so the resultant maintenance cost is one-half of the initial incremental cost.

Table 28 below summarizes the incremental cost estimates for maintenance of cool roofs for the four prototypes evaluated including LowRiseGarden, LoadedCorridor, MidRiseMixedUse, HighRiseMixedUse. The incremental cost for steep-sloped measure is primarily based on asphalt shingle product. For low-sloped measure, the baseline assumes a modified bitumen cap sheet, while the proposed assumes a TPO.

Table 28: Incremental Cost Estimate for Maintenance of Cool Roof

Prototype	Climate Zones	Roof Slope	Baseline	Proposed	Incremental Cost ($/ft2)
LowRiseGarden	10-15	Steep-sloped	0.20/0.75	0.25/0.80	0.04
LowRiseGarden	1-9,16	Steep-sloped	0.10/0.85	0.25/0.80	0.13
LowRiseLoadedCorridor	1-8,12,16	Low-sloped	0.10/0.85	0.63/0.75	0.17
MidRiseMixedUse	1-8,12,16	Low-sloped	0.10/0.85	0.63/0.75	0.17
HighRiseMixedUse	1-8,12,16	Low-sloped	0.10/0.85	0.63/0.75	0.17

3.4.4 Cost Effectiveness

This measure proposes a primary prescriptive requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

The CEC establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with CEC 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 LSC savings from electricity and natural gas were also included in the evaluation. Design costs were not included nor were the incremental costs of code compliance verification.

According to the CEC's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The assumed life of asphalt shingles is 20 years, which is representative of a reasonable median point in both high-quality three tab and architectural shingles. The assumed life of flat TPO roofing is 20 years, which represents an industry average expectation for life of a quality membrane roof. The B/C ratio was calculated using 2026 PV costs and cost savings.

Results of the per unit cost-effectiveness analyses are presented in Table 29 and

Table 30 for the four new construction prototypes.

The proposed measure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change to Roof/Ceiling option B steep-sloped roofing applications is cost effective in Climate Zones 10, 11, 13, and 15. The proposed code change to Roof/Ceiling option D low-sloped roofing applications is cost effective in Climate Zones 2, 4, 6-8, and 12.

Table 29: 30-Year Cost-Effectiveness Summary Per Dwelling Unit - New Construction – Cool Roof Improvements – LowRiseGarden, Steep-Sloped

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	B/C Ratio
1	-61.3	187	-0.33
2	-22.0	189	-0.12
3	-45.8	195	-0.23
4	40.4	195	0.21
5	-67.5	203	-0.33
6	32.0	197	0.16
7	73.2	203	0.36
8	153	193	0.79
9	130	191	0.68
10	62.7	52.6	1.19
11	71.2	52.6	1.35
12	48.4	54.8	0.88
13	81.0	54.8	1.48
14	31.9	50.4	0.63
15	150	50.4	2.98
16	-76.8	187	-0.41

Table 30: 30-Year Cost-Effectiveness Summary Per Dwelling Unit - New Construction – Cool Roof Improvements – Weighted Average (LoadedCorridor, MidRiseMixedUse, HighRiseMixedUse), Low-Sloped

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	B/C Ratio
1	-33.4	117	-0.29
2	162	118	1.37
3	-28.4	122	-0.23
4	219	122	1.79
5	-46.7	127	-0.37
6	164	123	1.33
7	336	127	2.64
8	376	121	3.11
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	347	127	2.73
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	54.2	117	-0.46

a. **Benefits: LSC Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (Energy + Environmental Economics, 2016, pp. 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis if PV of proposed costs is greater than PV of current costs. Costs are discounted at a real (inflation-adjusted) three percent rate. 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.

3.5 First-Year Statewide Impacts

Typically, the Statewide CASE Team presents a detailed analysis of statewide energy and cost savings associated with the proposed change. As discussed in Section 3.3, although the energy savings are limited, the measure would also promote urban heat island reduction, reduced impact on grid due to reduced peak temperatures.

3.5.1 Statewide Energy and LSC Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by multiplying the per unit savings, which are presented in Section 3.3.2, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2026 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 2026. The 30-year LSC Savings represent the LSC 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 31 and Table 32 below present the first-year statewide energy and LSC Savings from newly constructed buildings and additions.

While a statewide analysis is crucial to understanding broader effects of code change proposals, there is potential to disproportionately impact DIPs that needs to be considered. Refer to Section 2 for more details addressing energy equity and environmental justice.

Table 31: Statewide Energy and Energy Cost Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Dwelling Units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	N/A	N/A	N/A	N/A	N/A	N/A
2	1,335	0.04	-0.00	0.00	0.03	0.22
3	N/A	N/A	N/A	N/A	N/A	N/A
4	3,280	0.11	-0.01	0.00	0.03	0.72
5	N/A	N/A	N/A	N/A	N/A	N/A
6	2,153	0.05	0.00	0.00	0.05	0.35
7	4,950	0.23	0.01	0.00	0.25	1.66
8	8,256	0.48	0.02	0.00	0.52	3.10
9	N/A	N/A	N/A	N/A	N/A	N/A
10	172	0.00	-0.00	0.00	0.00	0.01
11	47	0.00	-0.00	0.00	0.00	0.00
12	5,316	0.28	0.01	0.00	0.25	1.85
13	40	0.00	-0.00	0.00	0.00	0.00
14	N/A	N/A	N/A	N/A	N/A	N/A
15	15	0.00	0.00	0.00	0.00	0.00
16	N/A	N/A	N/A	N/A	N/A	N/A
Total	**25,565**	**1.20**	**0.02**	**0.00**	**1.14**	**7.92**

a. First-year savings from all buildings completed statewide in 2026.

Table 32: Statewide Energy and Energy Cost Impacts

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	1.20	0.02	0.00	1.14	7.92
Alterations	N/A	N/A	N/A	N/A	N/A
Total	1.20	0.02	0.00	1.14	7.92

3.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that the CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric tons of carbon dioxide equivalent emissions (metric tons CO2e).

The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs).[32] The cost-effectiveness analysis presented in Section 3.4 of this report does not include the cost savings from avoided GHG emissions. 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. Table 33 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 55 metric tons CO2e would be avoided.

Table 33: First-Year Statewide GHG Emissions Impacts

Construction Type	Electricity Savings[a] (GWh/y)	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 GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
New Construction	1.20	60.8	0.00	0.00	60.8	7,490
TOTAL	**1.20**	**60.8**	**0.00**	**0.00**	**60.8**	**7,490**

a. GHG emissions savings were calculated using hourly GHG emissions factors published alongside the LSCC hourly factors and Source Energy hourly factors by the CEC here:https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

b. The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs) derived from the 2022 TDV Update Model published by CEC here: https://www.energy.ca.gov/files/tdv-2022-update-model

3.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

3.5.4 Statewide Material Impacts

The current multifamily cool roof code in California requires the use of reflective roofing products. This proposal simply extends and raises the prescriptive radiative requirements of roofing products that would otherwise be used. It is unlikely to significantly change any of the material impacts in California.

3.5.5 Other Non-Energy Impacts

Cool roofs reduce the amount of heat transferred from a roof to the local air which reduces 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

[32] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

air temperature in a city with a million or more people is 1.8°F to 5.4°F warmer than its surroundings. 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.[33] Increasing roof reflectance lessens the urban heat island effect.

Another important non-energy impact of cool roof technology is the reduction of smog levels in urban settings. Photochemical reactions that occur more frequently in higher temperatures create smog. By reducing ambient air temperatures in urban areas, the rate of smog formation is also decreased. This reduction in smog would also lead to decreases in frequencies of heat stroke and asthma.[34]

3.6 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team assessed the potential impacts of the proposed measure, and based on a preliminary review, the measure provides a small benefit in monthly energy bills but would not have a large impact in other non-energy impacts. General impacts of all the proposals in this report can be found in Section 2: Addressing Energy Equity and Environmental Justice.

3.6.1 Potential Impacts of the Proposed Measure

The Statewide CASE Team evaluated the measure for its potential impacts to health, cost, resiliency, and comfort. This measure does impact general comfort in the building slightly, but the benefit would likely be felt unevenly in the building (as would the savings). The energy savings benefit is calculated per unit (equally across all the units in the prototype buildings), but the cool roof benefit would mostly be felt on the top floor of the multifamily housing, where it may have significant comfort and energy benefit for occupants.

[33] EPA: Heat Island Effect: Visit: https://www.epa.gov/heatislands.

[34] Cool Roof Ratings Council: Visit: https://coolroofs.org/resources/home-and-building-owners

4. Improved Minimum Wall Insulation

4.1 Measure Description

This measure would decrease the area-weighted average mandatory U-factor of wall insulation to 0.148 for metal framed, 0.095 for wood-framed 2x4 construction, and 0.069 for wood-framed 2x6 construction, establishing a new backstop for buildings using the performance compliance pathway across all climate zones in California. Lower wall insulation U-factors reduce heat transfer in the solid portions of the walls in a building. Because wall insulation also has a prescriptive aspect that exceeds this maximum level (but is tradeable with other building systems in the performance compliance pathway), there would be no energy savings associated with this change to the mandatory portion of the code. This measure proposal is coordinated with proposed changes to the residential wall insulation R-value requirements.

4.1.1 Proposed Code Change

This measure proposes to update the mandatory requirements for wall insulation in multifamily buildings in alignment with the similar measure proposal by Statewide CASE Team for single family buildings. The single family proposal would update mandatory U-factor requirements corresponding to an increase in mandatory minimum cavity insulation for all insulation types from R-13 to R-15 in 2x4 construction and from R-20 to R-21 in 2x6 construction.

Because multifamily buildings come in a wider variety of architectures than single family residential buildings, the insulation requirements must be adaptable to a variety of framing applications by maintaining alignment with nonresidential requirements. Therefore, Title 24, Part 6 multifamily mandatory requirements for wall insulation use an area-weighted average U-factor metric for a wall insulation separately for different wall categories. To align multifamily wall insulation requirements with the single family proposal outlined above, this measure proposes to,

- Decrease the mandatory maximum U-factor for metal-framed walls from 0.151 to 0.148.
- Decrease the mandatory maximum U-factor for wood-framed and others,
    - 2x4 from 0.102 to 0.095 and
    - 2x6 from 0.071 to 0.069.

The proposed values align with the values calculated and provided in Tables 4.3.1 and 4.3.3 in Appendix JA4.

4.1.2 Justification and Background Information

4.1.2.1 Justification

The U-factor of above-grade walls separating conditioned from unconditioned spaces has a significant impact on building energy performance. The Title 24, Part 6 multifamily mandatory requirements for wall insulation use an area-weighted average U-factor of a wall assembly for this metric.

The Statewide CASE Team reviewed market studies and collected feedback from the experts in multifamily industry regarding current practices in wall assemblies of multifamily buildings. Many designers and builders interviewed suggested that the proposed levels of wall insulation are already standard practice. The products are readily available on the market without much incremental cost.

It was also brought to the Statewide CASE Team's attention that during future additions and alterations, contractors avoid opening walls if possible. The increased cavity insulation requirements proposed by this measure is likely to lock in higher performance wall insulation for the life of new multifamily buildings. This measure would create a more challenging requirement for building alterations; however, the feedback received by the Statewide CASE Team implies that there are practical ways, such as exterior insulation, of reaching the proposed U-factor requirements without the need to open existing walls.

4.1.2.2 Background Information

This measure proposes increasing existing multifamily mandatory insulation requirements for walls in alignment with the concurrent proposals for single family residential cavity insulation requirements. Better envelope insulation reduces space conditioning load and increases occupant comfort with little impact to building aesthetics. A wall assembly U-factor quantifies the rate of heat transfer though the opaque envelope. This proposal would improve existing mandatory U-factor requirements for wall insulation, across all state climate zones.

The 2018 IECC (5^{th} version Nov 2021) Residential, Section R402 Building Thermal Envelope requirements are set higher than current Title 24, Part 6 minimums. The IECC code prescriptive maximum U-factor for wall assemblies in IECC climate zones that are California applicable is 0.084 in Climate Zone 2 and 0.060 in Climate Zones 3, 4, and 5. The mandatory minimum U-factors proposed here would not reach these international standards.

Advancements in high density cavity insulation, minor incremental performance pricing, and market availability of higher R-value cavity insulation products has driven many designers in California to install high performance cavity insulation at or above Title 24, Part 6 prescriptive code as a matter of standard practice. The proposed increase in mandatory minimum area-weighted average U-factor would not affect builders and designers that are using prescriptive U-factor standards, and it would only impact those using the performance approach to trade-off wall insulation requirements.

Incentive programs and other data collection from project databases show a prevalence of products that meet the proposed requirements in market, supporting the measure change. Mandatory wall insulation was not investigated in the 2022 code cycle, but the prescriptive requirements of wall cross-section performance were evaluated. Mandatory minimum wall performance was not changed in the 2022 code cycle. However, because of the creation of the multifamily section in 2022, edits to this section were made to accommodate the different occupancy requirements of some wall types (associated with fire rating and establishing new criteria for these wall types).

The wall cavity insulation market is dominated by product lines that are available at multiple levels of R-value. Products that meet these proposed standards are readily available in the California markets.

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.[35] See Section 6 of this report for detailed proposed revisions to code language.

4.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 as well as the reference appendices to Part 6 are described below. See Section 6.2 of this report for marked-up code language.

Section 160.1 – Mandatory Requirements for Building Envelopes

Section 160.1(b) – Wall Insulation

Specific Purpose: The purpose of this change is to update the maximum area-weighted U-factor of Metal Framed and Wood framed wall assemblies. This would include modifying Section 160.1(b) – Wall Insulation (1) and (2) to reflect the improved wall insulation requirements.

Necessity: This change is necessary to increase energy efficiency via cost-effective building design standards, as mandated by California Public Resources Code, Sections 25213, and 25402.

[35] Visit EnergyCodeAce.com for trainings, tools, and resources to help people understand existing code requirements.

4.1.3.2 Specific Purpose and Necessity of Changes to the Nonresidential and Multifamily ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

4.1.3.3 Summary of Changes to the Nonresidential and Multifamily Compliance Manual

Chapter 3 of the Nonresidential and Multifamily Compliance Manual would need to be revised. Section 3.1.1 would need to be updated to reflect the changes that have been implemented between the 2022 and 2025 California Energy Code. Section 3.2.8 Mandatory Requirements would need to be updated to reflect implemented changes to maximum U-factor requirements.

4.1.3.4 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below.

- 2022-LMCC-ENV-E - Low-Rise Multifamily
- 2022-NRCC-ENV-E - Nonresidential & High-rise Multifamily Envelope

4.1.4 Regulatory Context

4.1.4.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

Existing Title 24, Part 6 Section 160.1 mandatory maximum, area-weighted assembly U-factor for opaque portions of above-grade walls in multifamily buildings requirements in can be seen below in Table 34. These values do not vary by climate zone, because they represent the backstop for new construction wall assemblies throughout the state.

Table 34: Current Multifamily Mandatory Maximum U-factors by Wall Type.

Multifamily Mandatory (Title 24 Section 160.1)	Maximum Area-weighted Assembly U-factor
Metal building	0.113
Metal Framed	0.151
Wood-framed & other 2x4	0.102
Wood-framed & other 2x6 or greater	0.071
Light Mass	0.440
Heavy Mass	0.690
Spandrel & Curtain wall	0.280
Demising (wood frame)	0.099
Demising (metal frame)	0.151

This proposal is relevant to Section 170.1 – Performance Approach of the California building code standards. The proposed mandatory requirements would impact the minimum performance threshold of products used in buildings using the Section 170.1 – Performance Approach to comply with Title 24, Part 6 requirements. The proposed changes to Title 24, Part 6 would primarily impact Multifamily Section 160.1 – Mandatory Requirements for Building Envelopes. The proposed changes to mandatory standards for wall insulation are developed in consultation with the Title 24, Part 6 wall insulation standards for nonresidential and single family buildings for the purpose of code alignment. The mandatory wall insulation requirements are aligned with the existing mandatory minimum wall insulation for wood-framed assemblies in exterior wall for single family residential buildings. The 2025 single family envelope also proposes to increase mandatory minimum wall insulation U-factor requirements that correspond to cavity insulation increase from R-13 to R-15 in 2x4 framing, and from R-20 to R-21 in 2x6 framing. However, there would be no authority overlap with the standards for these other building types. There are no other relevant state or local ordinances, laws, or regulations in California. Changes outside of Title 24, Part 6 are not needed.

4.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal laws or regulations.

4.1.4.3 Difference From Existing Model Codes and Industry Standards

The proposed changes to Title 24, Part 6 multifamily wall insulation mandatory minimums do not exceed the minimum insulation requirements set forth by ASHRAE 90.1. The proposed requirements, as mandatory minimums, are not best practices standards, but rather the performance backstop for construction. California includes ASHRAE designated Climate Zones 2, 3, 4, 5, and 6. The 2019 ASHRAE standards set the maximum U-factor for above grade wall assemblies in residential buildings are summarized in Table 35.

Table 35: 2019 ASHRAE 90.1 Residential Above-grade Wall Insulation Standards

Walls (above grade), Residential	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6
Mass	0.123	0.104	0.09	0.08	0.071
Metal building	0.094	0.072	0.05	0.05	0.05
Steel-framed	0.064	0.064	0.064	0.055	0.049
Wood-framed & other	0.089	0.064	0.064	0.051	0.051

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 compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** Architects/Designers make design decisions on the layout geometry, construction materials for envelope and finalize plans with specifications to be used by contractors to inform installation. The wall assembly thickness is an important part of the design, and this proposal would not have significant impact on that design decision. This is because the prescriptive standard for 2022 (U=0.051 to 0.065 for framed walls depending on wall type) all are far more efficient than the proposed mandatory maximum of 0.069 and 0.095. Building with mandatory minimum wall insulation is only possible using the performance method and results in such a large compliance penalty that it is not cost effective in most cases. The mandatory maximum U-factor thus becomes an issue mainly of education, so that architects and designers are aware of the mandatory maximum wall U-factor and take it into account when making their plans.
- **Permit Application Phase:** The permitting process for all buildings is outlined in the factsheet on Energy Code Ace.[36] To obtain a permit, the building inspector and/or plans examiner reviews the documentation submitted by building owner with support from designers, architects or energy consultants. An energy consultant may be included in the design process to support energy code compliance requirements and help prepare the required compliance documents. Both the plans examiner and building inspector would need to be aware of the mandatory maximum U-factors, as would the energy consultants. The current education infrastructure in California through Energy Code Ace and other actors is capable of this education.
- **Construction Phase:** The building contractor would review and organize construction plans and specifications to prepare for installation. They would coordinate the various construction stages of the building including procurement of equipment and materials from distributors and/or manufacturers. Insulation contractors would need to be aware of the new mandatory minimum U-factor requirement in the cavity, so that they do not purchase the incorrect product, and thus would also need education on the proposed change. A Home Energy Rating

[36] https://energycodeace.com/download/35782/file_path/fieldList/FactSheet.NR.Res-PermitProcess.2019.pdf

System (HERS) rater doing the Quality Insulation Installation (QII) checks may be looking for cavity insulation to meet the CF1R as they currently are, and this proposal does not add to the tasks required.

- **Inspection Phase:** The building owner or designer submits to the building department all the final documentation including compliance documents such as LMCC/LMCI/LMCV or NRCI/NRCA/NRCV for three habitable stories or less, or four habitable stories or more respectively. The full list of compliance documents for multifamily buildings are available at Energy Code Ace's Forms Ace website.[37] The building inspector conducts the final on-site verification of the installed walls using the certificates of installation containing wall specifications against the documentation.

No change in compliance documents is expected as a result of this measure proposal. The compliance and enforcement process for walls does require some collaboration with other design and installation teams. However, the proposed measure change of slightly increased minimum wall insulation levels does not impose an additional requirement on teams to coordinate. No change to field verification and diagnostic test requirements required.

The only change to compliance software is to update the minimum threshold of wall insulation that can be installed. The proposed wall measure does not introduce any additional burden for compliance and enforcement or cause any major changes in the process.

4.2 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 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, CEC staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on February 14, 2023.

4.2.1 Current Market Structure

The current market is commonly buying, selling, stocking, and installing insulation to meet or exceed the proposed maximum wall U-factor for wood and metal framed walls

[37] https://energycodeace.com/LowriseMultifamilyForms/2022

categories. The current market is commonly buying, selling, stocking, and installing insulation to meet or exceed the proposed maximum wood- and metal-farmed wall assembly U-factor requirements. There are several market actors that are involved in designing, installing or inspection of exterior wall construction. The developers, owners, architects/designers, and/or contractors make design decisions regarding wall construction and ensure that the required building codes and standards are followed. The energy consultants review the Title 24, Part 6 energy code compliance requirements. The contractors, distributors, and manufacturers support the procurement of appropriate wall construction materials and installation in the building. The HERS Raters and building inspectors then perform on-site review of the installation and construction quality.

2019 Title 24 code standard for wall extensions set R-15 (2x4 walls) and R-21 batts (2x6 walls) as a minimum to qualify for an exception, which helped drive market adoption of the denser batts. 2x6 R-21 walls have also become a common wall assembly in California, because they have a similar U-factor to the prescriptively required 0.051 at and the prescriptive 0.048 in other climate zones for single family is based on 2x6 R-21 batts plus rigid foam. Note that the mandatory maximum U factor in single family 2x6 walls for 2019 was set at U = 0.071, which corresponds to 2x6 R-20, but R-20 batts are not a commonly available size in the United States, according to our discussions with industry distributors. The market trends were evaluated using Dodge and CalCERTS compliance document data that confirmed similar findings of prevalence of R-15 and R-21 in multifamily buildings.

4.2.2 Technical Feasibility and Market Availability

Title 24, Part 6 prescriptive requirements for minimum wall insulation and area-weighted average U-factor of the wall assembly are met as a standard practice by builders and designers in California. Based on multifamily stakeholder interviews, increased wall insulation is considered a low-hanging fruit of building efficiency for new construction, and the mandatory minimums are never approached by honest designers and builders. The products that are required to meet these standards with cavity insulation are readily available and are already used by designers who use the performance approach to Title 24, Part 6 compliance. Increasing the R-value of installed cavity insulation is easily accomplished with high-density batt and blown-in products. There is limited availability of blown-in insulation companies in some regions of the state, but required batt is readily available through suppliers and big-box home improvement retailers.

Some stakeholders voiced concern that increased mandatory minimum U-factors would lead to greater increases in the future that would mandate the use of exterior rigid insulation. For designers and builders that do not currently use continuous insulation this would represent a large increase in cost and would require significant changes in exterior wall construction. Other concerns were also raised related to the high lifecycle emissions associated with rigid insulation.

For multifamily dwellings with four or more habitable stories, some designers use continuous insulation as a standard practice, while others avoid it. These stakeholders also did not voice concerns over the technical feasibility or the market availability of required products for the proposed changes to mandatory minimum assembly U-factors. There was some concern that increased wall insulation standards for large multifamily buildings with less exterior wall surface would produce less energy savings than anticipated and may not prove to be cost effective in the long run.

4.2.3 Market Impacts and Economic Assessments

The code change proposal introduces mandatory requirements that are less stringent than the existing prescriptive requirements, which sets the energy budget for a given building project. As such, some existing level of uptake of the proposed requirements within the industry is presumed such that any statewide market impacts associated with this measure are relatively marginal. This is supported by the Statewide CASE Team analysis and stakeholder feedback, as described in section 4.4. Section 4.4 also considers direct costs that may be experienced by certain market actors as a result of this proposal. While those impacts are not inconsequential to those market actors, they are unlikely to amount to the level of statewide impacts typically conveyed in this section of the report. As such, this Market Impacts and Economic Assessments section has been truncated for this measure.

4.2.4 Economic Impacts

The code change proposal introduces mandatory requirements that are less stringent than the existing prescriptive requirements. As such, there are no direct energy, market, economic, or fiscal impacts.

4.2.5 Fiscal Impacts

The code change proposal introduces mandatory requirements that are less stringent than the existing prescriptive requirements. As such, there are no direct energy, market, economic, or fiscal impacts.

4.3 Energy Savings

The code change proposal introduces mandatory requirements that are less stringent than current prescriptive requirements. The proposed change in mandatory wall insulation requirement increases the overall minimum requirement for the building envelope performance. However, the code change proposal would not modify the stringency of the existing California Energy Code prescriptive requirements, so there would be no savings on a per-unit basis. Section 4.3 of the CASE Report, which typically presents the methodology, assumptions, and results of the per-unit energy impacts, has been truncated for this proposal. See Appendix F for a summary of stakeholder engagement.

4.4 Cost and Cost Effectiveness

This measure proposes a mandatory requirement. The code change proposal would not modify the stringency of the existing California Energy Code, so the CEC does not require a complete cost-effectiveness analysis to approve the proposed change. Section 4.4 of the CASE Reports typically presents a detailed cost-effectiveness analysis. For this proposed change, the Statewide CASE Team is presenting information on the cost implications in lieu of a full cost-effectiveness analysis.

The Statewide CASE Team engaged with insulation distributors, manufacturers, and design experts to understand the use of insulation materials in wall construction for multifamily buildings and their associated cost impacts. Appendix F summarizes stakeholder engagement.

The incremental cost data collection is aligned with 2025 Title 24 CASE study pursued by Single Family team for the similar measure. The retailers provided the cost information depending on several factors such as faced kraft vs. unfaced or regular vs. bulk/discount pricing. The provided incremental cost encompassed multiple manufacturers and pricing structure ranging from $0.13 to $0.45 per sqft. for 2x4 framing measure proposal and $0.01 to $0.20 for 2x6 framing proposal. The average incremental cost for increasing fiberglass batt insulation from R-13 to R-15 in 2x4 framed cavity is estimated as $0.36 per sqft. and from R-20 to R-21 in 2x6 framed cavity as $0.16 per sqft. Please refer to the 2025 Single Family Envelope CASE Study for more details.

These costs correspond to only one potential pathway to meet the proposed mandatory wall U-factors, which can be achieved through other pathways such as increasing exterior continuous rigid installation. These costs include material cost difference including markup but do not include labor cost differences. Based on feedback from stakeholders, the differences in labor installation cost should be minimal. The high-density fiberglass batt is commonly used in the market, which may increase further following the adoption of code change. That may lead to a decrease in incremental cost over time as they get discounted and competitive bulk pricing. The expected useful life is 20 to 30 years for wall insulation installation.

4.5 First-Year Statewide Impacts

The code change proposal would not modify the stringency of the existing California Energy Code, as it would introduce mandatory requirements that are less stringent than existing prescriptive requirements, so associated savings would be minimal. Typically, this section of the CASE Report presents a detailed analysis of statewide energy and cost savings associated with the proposed change. In lieu of such an analysis, an overview of benefits is provided.

By requiring higher minimum wall insulation levels, small but persistent savings can add up over the product's lifetime. Because cavity insulation inside exterior walls typically remains untouched over the building's lifetime, insulation installed at the time of construction will often determine future thermal performance. Through incremental code changes, the mandatory minimum performance is adjusted in a way that allows the market to adjust with minimal impact on disruption in costs. Associated non-energy benefits of higher insulation performance include increased long-term occupant comfort, and more overall robust construction that would help with building longevity.

The current multifamily prescriptive wall insulation requirement in California requires the use of higher performance insulating products than is proposed here. This proposal simply improves the mandatory minimum exterior wall insulation performance and is unlikely to have any significant non-energy impacts in California.

4.6 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team assessed the potential impacts of the proposed measure, and based on a preliminary review, the measure should not have a large direct impact on DIPs. The proposed measure is a change to the minimum envelope insulation requirements backstop for the performance method. This change would not likely impact any building performance initially because the performance method permits tradeoffs of energy performance of one system with another.

Since this tradeoff is always permitted and the minimum whole-building performance level is not changed by this proposal, no energy savings is anticipated, and no cost effectiveness is calculated.

However, there is one benefit to this proposal that can impact people over time. If higher building performance is secured in the wall envelope energy efficiency, then it would be ensured for the duration of the building's existence, since exterior walls are rarely impacted during any renovation activity. Because of this, it ensures that the durable shell of the building would perform better throughout the life of the building and the somewhat less permanent building mechanical systems (in particular, the HVAC system) would gain improvements over time that would further raise the building performance, aided by the higher performance in the wall insulation.

This is a long-term benefit that would ensure an energy savings benefit for the occupants throughout the life of the building.

5. High Performance Windows

5.1 Measure Description

Windows have a significant influence on a building's occupant comfort and energy performance. The structural, thermal, and optical performance of vertical fenestration influence a conditioned interior space's functionality and cost. High performance windows are defined by the U.S. DOE as fenestrations that allow buildings to consume less energy while increasing comfort, and they are a key component in building envelope design. The appropriate performance of a window is defined not only by the function of the interior space it serves but by the climate of the building's location.

Due to the complex interactions associated with thermal lag between buildings and outside air, improving (lowering) a window's U-factor would not necessarily reduce a building's annual energy consumption or LSC. There are conditions where the lower U-factor might reduce annual heating energy but increase the annual cooling energy so that the total energy consumption would increase. Complexities of thermal comfort introduced by California's varied climate zones create the need for more nuanced building envelope codes that consider the conditions in each climate zone. This is especially important for windows, which influence both the envelope thermal conduction and the building solar heat gain properties. In cooling-dominated climates, decreasing solar heat gain has the positive impact of decreasing the annual energy demand of HVAC systems; however, in heating-dominated climates, decreasing solar heat gain can increase the annual energy demand.

This measure would improve prescriptive U-factor requirements for some climate zones for the All Other fenestration category. The proposal also adjusts the RSHGC requirements for all window types to make the same requirements apply to both the 'three or less' and the 'four or more' habitable stories conditions so that these separate portions of the tables can be combined. These focused improvements are based on the specific energy needs of each climate zone and the impact that changes in U-factor and SHGC would have on annual energy demand and space conditioning costs. The proposed measures would save energy by reducing the amount of heating and/or cooling needed to keep indoor air temperatures in the desired comfort range for the functions of multifamily residential buildings. The proposed measures are designed to align multifamily fenestration requirements with the existing and proposed prescriptive requirements for similar single family residential and nonresidential vertical fenestrations where possible.

5.1.1 Proposed Code Change

This measure revisits the U-factor and SHGC prescriptive requirements for all multifamily window categories including curtainwall/storefront, NAFS 2017 Performance Class AW, and the All Other fenestration category. This includes both new construction and alterations prescriptive requirements.

- **Lower U-factor from 0.30 to 0.28 in All Other window category.** This measure proposes a slightly improved U-factor of 0.28 in climate zones where it is shown to be cost effective. For New Construction this includes Climate Zones 01, 03-05, 11, and 13-16. For Alterations this includes Climate Zones 01, 03-05, 11, 13, 14, and 16.
- **Remove Relative Solar Heat Gain Coefficient (RSHGC) requirement in Climate Zones 1, 3, 5, and 16 for four habitable stories or more.** This change would remove current maximum RSHGC requirement for curtainwalls, NAFS Class AW, and All Other window types in these heating dominated climate zones. This measure would also unify multifamily prescriptive fenestration requirements for buildings with three or fewer habitable stories with requirements for buildings with four or more habitable stories across all window categories, so the separate rows in the Table 170.2-A can be combined. This change is applicable to New Construction and Alterations.

The proposed change requires updates in prescriptive requirement tables, compliance documents, ACM Reference Manual Standard Design, and compliance software algorithm. For four habitable stories or more, the ACM Standard Design would be updated to 0.35 instead of the current prescriptive maximum for the four climate zones where RSHGC requirement is removed. The proposed change allows for a flexibility of +/- 0.01 RSHGC difference between modeled value in compliance documents and installation certificates.

5.1.2 Justification and Background Information

5.1.2.1 Justification

Current Title 24 California Energy Code for high performance windows are often limited not by technological limitations, but by the need for requirements to remain cost effective. As the component technologies and materials that make high efficiency fenestration products become more widely available, economies-of-scale change the cost effectiveness of the products compared to baseline performance windows. Due to this evolution of the fenestration market, Title 24, Part 6 high performance window codes and standards must be periodically evaluated for changes in the cost effectiveness of higher efficiency products. This may result in improvements to prescriptive high-performance windows requirements.

The U.S. EPA recently published ENERGY STAR Version 7 specification for windows, doors, and skylights.[38] These new standards present higher thresholds for windows U-factors across the ENERGY STAR defined climate zones of North-Central and South-Central, predominant climate zones that align with California region. EPA decreased U-factor requirements from 0.30 to 0.24 in North-Central and from 0.30 to 0.28 in South-Central zones. These changes are based on four years of research and development in collaboration with the U.S. DOE's Lawrence Berkeley National Laboratory (LBNL). The new specifications, which were finalized in October 2022, include publicly published data on product availability in the current window market and the incremental costs required to achieve these new standards. Most of California falls under the South-Central zone of the ENERGY STAR requirement, which aligns with the proposed U-factor for this measure. The proposal is supported by the market research conducted by the Statewide CASE Team, stakeholder feedback, and building simulation results. The other predominant North Central climate zone has an ENERGY STAR requirement of 0.25 U-factor. However, the measure proposes a more relaxed requirement of 0.28 U-factor to avoid requiring triple pane windows and higher costs.

Current Title 24, Part 6 multifamily buildings with three or less habitable stories in Climate Zones 1, 3, 5, and 16 do not include an RSHGC performance requirement for all fenestration types categorized as All-Other. However, multifamily buildings with four habitable stories or more currently have maximum prescriptive RSHGC requirements that range from 0.23 to 0.35for All Other, NAFS Class AW or curtainwall/storefront for most climate zones including the heating dominated Climate Zones 1, 3, 5, and 16. This measure would remove the maximum RSHGC requirements for Climate Zones 1, 3, 5, and 16 in the four or more habitable stories category to improve energy efficiency in these buildings and simplify the code by streamlining the different categories.

The Statewide CASE Team performed parametric simulations for varying window performance (U-factor and SHGC) to determine energy savings opportunities, see Figure 2 below. For multifamily buildings with three habitable stories or less, the LSC energy calculated by the simulation continually decreases with increase in SHGC in heating dominated Climate Zones 1, 3, 5, and 16. For multifamily buildings with four habitable stories or more, the LSC energy decreases as SHGC increases from 0.23 to an optimal point and increase slightly beyond that while still being lower consumption than at 0.23. These results suggest that mid to high gain SHGCs are more energy efficient in heating dominated climate zones based on the prototype designs. Refer to Appendix H for further details.

[38] More information on ENERGY STAR 7.0 Windows, Doors, & Skylights can be found here: ES_Residential_WDS_V7_Final

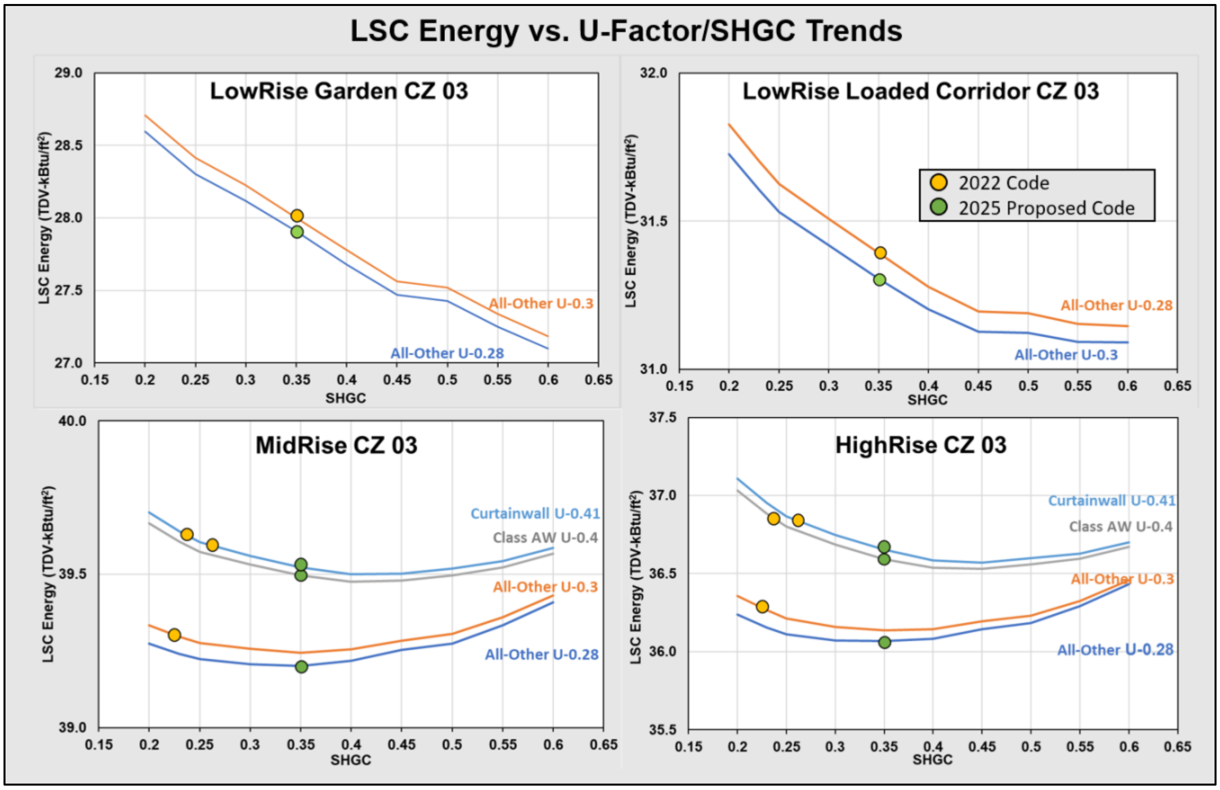

Figure 2: LSC energy vs. SHGC simulation trends

However, the actual performance could vary considerably depending on the façade design, orientation, and internal loads of the building. The current 2022 Title24 code does not have any prescriptive requirements for SHGC for three habitable stories or less, and the Statewide CASE Team proposes to extend the same to four habitable stories or more to move away from inefficient prescriptive requirement and allow the designers flexibility to make tailored decisions for the building.

5.1.2.2 Background Information

Title 24, Part 6 already sets certification requirements for U-factors, SHGCs, and Visual Transmittance (VT) for multifamily fenestration products in Sections 160.1 and 170.2. Title 24, Part 6 fenestration requirements were first established in 2001 and are regularly updated to keep pace with changes in the fenestration market. Developments in building envelope performance and fenestration technology and pricing have allowed for a steady progression of increased efficiency standards throughout the history of building codes such as the ASHRAE 90.1 Standard, the IECC code, and the EPA's ENERGY STAR certification program.

The measure proposal is based on product research and cost data collection by EPA for ENERGY STAR specification. ENERGY STAR program is recognized widely by majority of households, retailers, manufacturers, government agencies. Aligning this measure with ENERGY STAR requirements is supported by high market penetration of qualified products that meet those requirements. The regional suppliers would already be stocking ENERGY STAR compliant products as a result of Version 7 implementation.

The Statewide CASE Team collected compliance forms from appropriate listings in new multifamily construction from across California in the Dodge Construction Network database.[39] The data from approximately 30 buildings designed under the 2019 version of Title 24 shows that about 85 percent of the multifamily buildings reviewed were already meeting or exceeding the 2022 Title 24 code requirements for U factor and RSHGC. Of these, approximately 25 percent of the multifamily buildings are installing windows with lower U-factors that exceed the 0.30 U factor requirement.

The Statewide CASE Team also reviewed the CalCERTS database (years 2020-22) and found approximately 450 buildings that suggests similar market trends to the Dodge data, with the percentage of multifamily building installing high performance windows (windows better than the code minimum requirements about 25 percent.[40] The data in CalCERTS is mostly based on multifamily buildings with three habitable stories or fewer. Table 36 below shows median U-factor of around 0.3 being installed and SHGC of around 0.23 in most climate zones where that is a maximum prescriptive requirement and relatively higher SHGCs in heating dominated climate zones where there is no prescriptive requirement.

[39] https://leads.construction.com/dodge-reports-bm/

[40] Compliance forms information from CalCERTS, Inc. registry.

Table 36. CalCERTS Multifamily Compliance Forms 2020-2022 Summary

Climate Zone	U-factor Median	SHGC Median	SHGC Minimum	SHGC Maximum
1	0.3	0.35	0.35	0.35
2	0.32	0.25	0.21	0.25
3	0.31	0.41	0.16	0.50
4	0.3	0.23	0.23	0.23
5	0.3	0.35	0.23	0.63
6	0.3	0.23	0.19	0.64
7	0.3	0.23	0.16	0.67
8	0.31	0.23	0.17	0.26
9	0.30	0.22	0.13	0.73
10	0.29	0.22	0.00	0.25
11	0.31	0.23	0.20	0.25
12	0.29	0.21	0.18	1.00
13	0.30	0.23	0.22	0.25
14	0.30	0.21	0.21	0.25
15	0.30	0.20	0.16	0.25
16	-	-	-	-

During the 2022 code cycle, the Statewide CASE Team developed the multifamily specific sections of Title 24, Part 6 with a focus on aligning code with single family residential and nonresidential code where possible, but deviated where construction methods, cost effectiveness, or other limitations created a need to develop distinct requirements for the multifamily code. The proposed measures in this report are a continuation of ongoing Title 24, Part 6 envelope efficiency improvements developed in the nonresidential and residential sections and continued in the multifamily section of the 2022 code. The creation of the 2022 multifamily code allowed for more specialized requirements for these building types. It also created the need to attentively maintain code language and standard alignment with nonresidential and residential codes whenever possible. Window performance requirements were improved in the 2022 code cycle, and because of the creation of the multifamily section, a new fenestration designation "architectural window" (AW) was included.

5.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manual, and compliance documents would be modified by the proposed change.[41] See Section 6 of this report for detailed proposed revisions to code language.

[41] Visit EnergyCodeAce.com for trainings, tools, and resources to help people understand existing code requirements.

5.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 as well as the reference appendices to Part 6 are described below. See Section 6.2 of this report for marked-up code language.

Section 170.2 – Prescriptive Approach

Section 170.2(a) - Envelope component requirements

Specific Purpose: The purpose of this change is to update the prescriptive U-factor and RSHGC requirements for applicable climate zones. This would include modifying table 170.2-A and 180.2-B to reflect the applicable minimum or maximum U-factor and RSHGC requirements.

Necessity: This change is necessary to increase energy efficiency via cost-effective building design standards, as mandated by California Public Resources Code, Sections 25213, and 25402.

5.1.3.2 Specific Purpose and Necessity of Changes to the Nonresidential and Multifamily ACM Reference Manual

The proposed code change would modify the ACM Reference Manual the Nonresidential and Multifamily ACM Reference Manual requiring Standard Design ACM for window input to be 0.28 U factor in certain climate zones for All Other window category and 0.35 RSHGC in Climate Zones 1, 3, 5, and 16 across all categories.

5.1.3.3 Summary of Changes to the Nonresidential and Multifamily Compliance Manual

Chapter 3 of the Nonresidential and Multifamily Compliance Manual would need to be revised. Section 3.1.1 would need to be updated to reflect the changes that have been proposed for the 2025 California Energy Code. Section 3.3.8.1 Vertical Fenestration Prescriptive Requirements would need to be updated to reflect proposed changes to U-factor and RSHGC requirements. Explanation of a narrow range of flexibility allowance between modeled and installed RSHGC values of +/-0.01 would need to be added.

5.1.3.4 Summary of Changes to Compliance Forms

The proposed code change would modify the compliance documents listed below.

- 2022-LMCC-ENV-E – Multifamily buildings with three habitable stories or fewer
- 2022-NRCC-ENV-E – Multifamily buildings with four habitable stories or more

5.1.4 Regulatory Context

Title 24, Part 6 Section 170.2 sets prescriptive standards for Multifamily building fenestration installation U-factors, RSHGC, VT. This form of fenestration requirement first appeared in Title 24, Part 6 in 2001.

Title 24, Part 6 uses an RSHGC rather than an SHGC that gives solar heat gain credits when an overhang and/or exterior horizontal slates are included in the fenestration design. This distinction allows designers extra flexibility when choosing a fenestration, allowing for either an SHGC that aligns with the maximum RSHGC or a higher SHGC but includes a sufficient overhang in the building design.

In 2022 when a multifamily buildings-specific section of the code was created these fenestration standards were included. The multifamily section of Title 24, Part 6 was developed to accommodate the special construction requirements of multifamily buildings and to ensure that regulations for these specialized structures remain cost effective. To accomplish this, multifamily fenestration standards must encompass products that are designed for traditional residential punched openings, as well as those designed to meet the needs of commercial applications. To accomplish this, multifamily prescriptive fenestration requirements are divided into two applications, buildings with three habitable stories or fewer, and buildings with four or more habitable stories. Because these building types can have different fenestration needs, multifamily prescriptive standards are often aligned with single family residential code wherever possible for buildings with three habitable stories or fewer and aligned with nonresidential code wherever possible for buildings with four or more habitable stories.

5.1.4.1 Determination of Inconsistency or Incompatibility with Existing State Laws and Regulations

The proposed measure would impact Title 24, Part 6 Section 170.2 and 180.2, which sets fenestration prescriptive requirements for multifamily buildings in three fenestration categories, curtainwall/storefront, NAFS 2017 Performance Class AW, and All Other. The current requirements are further divided where appropriate by the number of habitable stories. The fenestration requirements include individual prescriptive standards for maximum U-factor and maximum RSHGC for each Title 24 California climate zone. Curtainwall/storefront requirements set a maximum U-factor of 0.38 for Climate Zones 1 and 16, and 0.41 for Climate Zones 2-15. NAFS Class AW requirements set a maximum U-factor of 0.38 for Climate Zones 1 and 16, and 0.40 for Climate Zones 2-15. All Other fenestration standard is a maximum U-factor of 0.34 for Climate Zones 6 and 7, and 0.30 for all other climate zones.

The RSHGC prescriptive standard for curtainwall/storefront windows is 0.35 for Climate Zone 1, 0.25 for Climate Zones 2-13, 15, and 0.24 for Climate Zones 14 and 16 for four or more habitable stories; however, for NAFS Class AW windows it is 0.35 for Climate

Zone 1, and 0.24 for Climate Zones 2-16. There is no RSHGC requirement for the heating-dominated Climate Zones 1, 3, 5, and 16 in buildings with three or less habitable stories across each of the three window categories; however, for other Climate Zones 2, 4, and 6-15 it is 0.23 for All Other fenestration.

This proposal would not impact other parts of the California Building Standards Code. However, where appropriate the proposed measure would align with proposed changes to Title 24, Part 6 Section 150.1, single family residential buildings fenestration requirements.

There are no jurisdictions or local ordinances within California that would interact directly with the proposed measure, and changes outside of Title 24, Part 6 are not needed. There are no relevant federal laws or regulations.

5.1.4.2 Difference From Existing Model Codes and Industry Standards

The proposed changes to Title 24, Part 6 Multifamily fenestration prescriptive U-factor maximums exceed the requirements set forth by ASHRAE 90.1 2019 that are seen in the IECC 2021 standards but do not match the standards of ENERGY STAR 7 in the North-Central Climate Zone. California includes ASHRAE designated Climate Zones 2, 3, 4, 5, and 6. However, the state is composed almost entirely of IECC Climate Zones 3 and 4. A summary of the related IECC 2021, and ENERGY STAR 7 codes and standards are listed below in Table 37.

Table 37: Measures Related Fenestration Codes and Standards

Codes & Standards	U-factor	SHGC	Climate Zone
ENERGY STAR V7	0.25	0.40	North-Central
ENERGY STAR V7	0.28	0.23	South-Central
IECC 2021* Fixed:	0.45 (CZ 2), 0.42 (CZ 3)	0.25	2&3
IECC 2021* Fixed:	0.36	0.36 (CZ 4 non-marine), 0.38 (CZ 4-marine & 5)	4&5
IECC 2021* Fixed:	0.34	0.38	6
IECC 2021* Operable:	0.60 (CZ 2), 0.54 (CZ 3)	0.23	2&3
IECC 2021* Operable:	0.45	0.33	4&5
IECC 2021* Operable:	0.42	0.34	6

* IECC 2021 standards align with ASHRAE 90.1, 2019 and use national numbered climate zones established by the US Department of Energy Building Technologies Office.

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 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 current compliance and enforcement process are conducted by the builder and enforcement agency respectively per the typical permitting process outlined in 2022 Title 24 Energy Code.

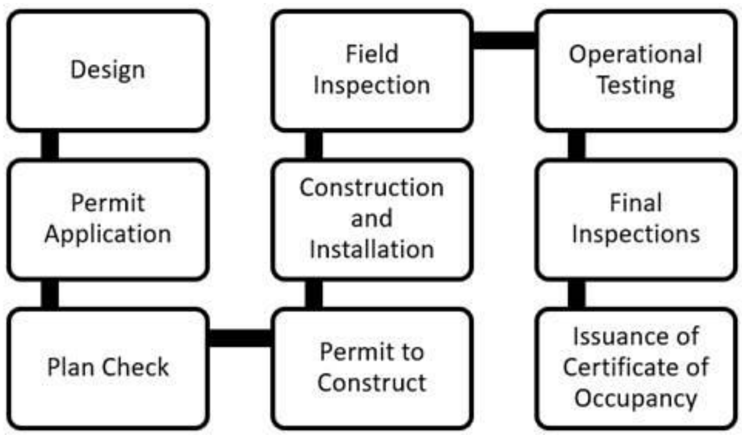

Figure 3: Idealized International Code Council permitting process for building permit applications.

Source: EnergyCodeAce website

The compliance verification activities related to this measure that need to occur during each phase of the project are described below:

- **Design Phase:** Architects/Designers make design decisions on the layout geometry, construction materials for envelope and finalize plans with specifications to be used by contractors to inform installation. The design decisions on building geometry include fenestration area across different orientations while trying to meet the code requirement on window ratios, the fenestration material composition depending on the desired aesthetic and energy performance. They also provide pertinent information to fill out the LMCC or NRCC compliance documents for multifamily buildings with three habitable stories or less, or four habitable stories or more respectively.
- **Permit Application Phase:** The permitting process for all buildings is outlined in the factsheet on Energy Code Ace.[42] To obtain a permit, building inspector and/or plans examiner reviews the documentation submitted by building owner with support from designers, architects or energy consultants. An energy consultant may be included in the design process to support energy code

[42] https://energycodeace.com/download/35782/file_path/fieldList/FactSheet.NR.Res-PermitProcess.2019.pdf

compliance requirements and help prepare the required compliance documents. The designer may also make window selection decisions based on factors apart from energy performance by specifying a NAFS Class AW window to account for structural, wind loads, rain resistance, safety, or aesthetic purpose.

- **Construction Phase:** The building contractor would review and organize construction plans and specifications to prepare for installation. They would coordinate the various construction stages of the building including procurement of equipment and materials from distributors and/or manufacturers. In this case, the general contractor would procure the appropriate window products and install it per the construction plans at the desired locations. The proposed measure allows only a narrow gap of +/- 0.01 between weighted average SHGC as modeled and as constructed. The general contractor is required to ensure appropriate NFRC labels (or other certificates such as NFRC's Component Modeling Approach Software Tool) are added to the required documentation. If NAFS Class AW windows are installed in the building, the contractor should include relevant NAFS Performance Class certificate as well. The contractor/installer would finally complete certificates of installation such as LMCI or NRCI for three habitable stories or less, or four habitable stories or more respectively. Sometimes the installation documents are completed in draft form during the bid process to ensure the material selection is code compliant.
- **Inspection Phase:** The building owner or designer submits to the building department all the final documentation including compliance documents such as LMCC/LMCI/LMCV or NRCI/NRCA/NRCV for three habitable stories or less, or four habitable stories or more respectively. The full list of compliance documents for multifamily buildings are available at Forms Ace website.[43] The building inspector conducts the final on-site verification of the installed windows using the certificates of installation containing fenestration properties against the NFRC or NAFS labels and visual inspection. Historically, inspection allows for installed windows to comply with the prescriptive minimum requirements (or performance modeled) if their thermal properties are equal to, *or are lower than,* the specified values. However, the proposed measure allows only a +/- 0.01 difference, which needs to be verified by the building inspector for compliance. No change in compliance documents is expected as a result of this measure proposal. The compliance and enforcement process for windows does require some collaboration with other design and installation teams. However, the proposed measure change does not lead to any increased collaboration in design or installation teams. The window installation is generally not covered or blocked by another building system and therefore does not require inspections during

[43] https://energycodeace.com/LowriseMultifamilyForms/2022

construction phase. No change to field verification and diagnostic test requirements required.

The only change to compliance software is the ACM standard design assumptions related to fenestration requirements.

The proposed window measure does not introduce any additional burden for compliance and enforcement or cause any major changes in the process. There would be a training component to adding a minimum RSHGC in some climate zones, and Energy Code Ace is well positioned to handle this in its 2025 code cycle training work.

5.2 Market Analysis

5.2.1 Current Market Structure

The Statewide CASE Team performed a market analysis with the goal of identifying current market trends related to fenestration technology, products, and user preferences. 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, CEC staff, and a wide range of industry actors. In addition to conducting direct outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on February 14, 2023.

Multifamily buildings have three different types of windows as categorized by Title 24, Part 6, Curtain wall/Storefront, NAFS Class AW, and All Other. According to stakeholder interviews, the market for All Other multifamily windows is dominated by double-pane, vinyl-framed windows with low-e coatings designed to meet the minimum qualifications of ENERGY STAR criteria. These windows are mass produced, readily available throughout the market, and relatively inexpensive. This has driven market adoption of the 0.30 maximum U-factor that is the current standard for code compliance in most climate zones.

In some larger multifamily buildings, curtain walls or storefront windows are more dominant. According to interviewed designers and architects, the prescriptive U-factors are most often used for energy modelling with these windows, as manufacturers do not provide specification for these products. This is often the case for NAFS Class AW as well in some other large multifamily buildings, particularly above six stories, where punched windows are used instead of curtainwall construction. The designers specify NAFS Class AW windows to ensure durability in the face of higher windshear and rain penetration forces on the larger and more exposed building facades. Though most designers interviewed choose thermally broken AW, it is hard to get manufacturer specifications for these metal framed windows.

Current multifamily fenestration market structure is comprised of a variety 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. Building designers and architects are most often responsible for the choice of fenestration products that are installed in a multifamily building. Designers plan the fenestration system for buildings to meet project goals such as budget constraints, code requirements, aesthetics, and energy performance. Designers would collaborate with installers, manufacturers, or fabricators to refine the design for construction. When the design is complete and the manufacturer selected, compliance documentation is completed for review by the plan's examiners. It is then up to the contractors to assemble and install the chosen fenestration systems. Simple punched-opening fenestrations would be installed by the general contractor, while the curtainwalls and more complex systems would be installed by a glazing installer. After installation, the inspector would verify the system meets all code requirements. In the case of most prefabricated multifamily windows, this simply involves checking the NFRC stickers on the installed products.

5.2.2 Technical Feasibility and Market Availability

This section discusses technical and market barriers realized from the stakeholder engagement and literature review along with potential solutions. High-performance windows are considered best practice for new construction and alterations. Meeting the current Title 24, Part 6 prescriptive requirements is a standard practice for multifamily building design due to advancements in glazing and frame technology and the market availability of energy-efficient building components. The Statewide CASE Team conducted interviews with stakeholders such as manufacturers, distributors, or designers to understand current practices and potential barriers to improved performance codes. In addition, the Statewide CASE Team also reviewed the existing literature from manufacturers or distributors' product database and EPA's product research for ENERGY STAR Version 7 specification.

Based on market research and stakeholder interviews, there are many window products from multiple manufacturers on the market today that can meet higher performance standards. The interviewed manufacturers indicated that there are double-pane window products on the market that can meet U-factors as low as 0.25 with argon gas and added low-e coatings. Fenestration products with SHGC as low as 0.23 are feasible and readily available based on market research. Manufacturers are resistant to producing windows with a lower SHGC than 0.23 at scale as these have been shown to change the VT of the product enough to discourage consumers.

For punched All Other window category, proposed decrease in U-factors from 0.30 to 0.28 is technically feasible by adding just an argon layer or fourth surface low-e coating for double pane windows. The stakeholders indicated that achieving 0.28 U-factor is straightforward with the available technology and going below 0.27 is achieved by adding a fourth surface low-e coating. The removal of RSHGC requirement in some climate zones for all multifamily buildings is supported by a wide range of window products available by the manufacturers. The standard design reference in the performance approach is 0.35, and the CalCERTS data in Table 36 (above) suggests that the designers are selecting RSHGCs around 0.35 in climate zones where there is no requirement currently. Figure 4 below shows a distribution of window products database of two leading manufacturers.

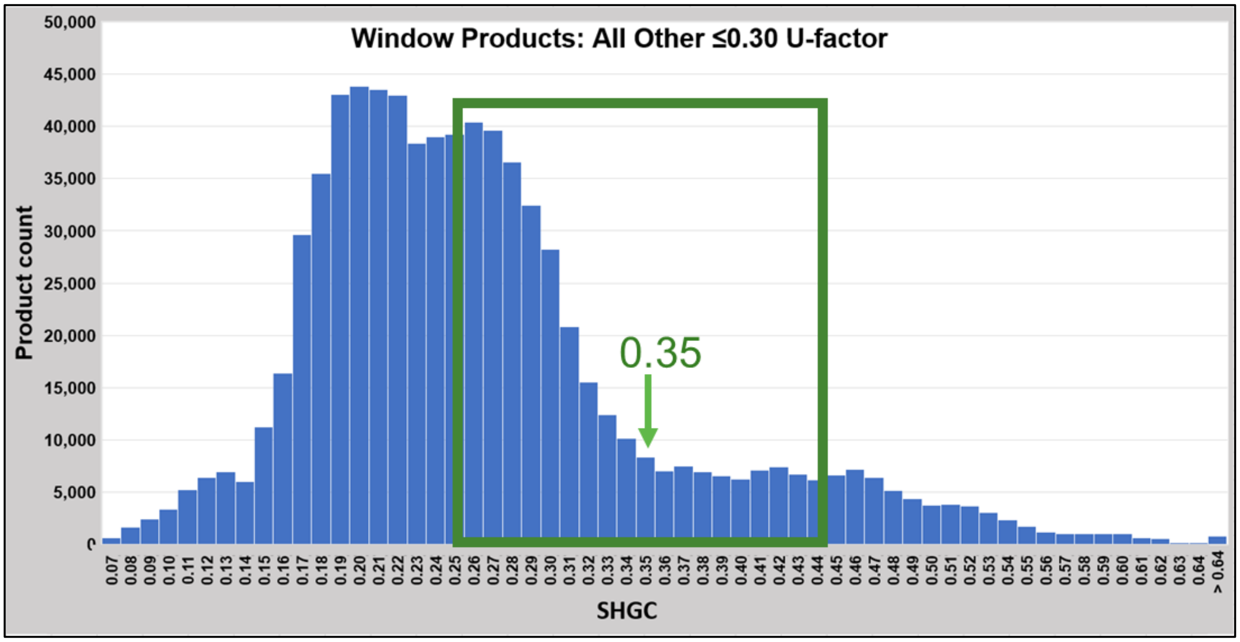

Figure 4: SHGC of windows products database

The prescriptive maximum U-factor for curtainwall/storefront and NAFS Class AW fenestration is between 0.38 and 0.41 depending on climate zones, which is higher than that of the All Other category. Higher SHGCs than current prescriptive minimum requirements, which ranges from 0.23 to 0.35 is more easily achieved with high U-factor in fenestration products as the added coatings decreases both U-factor and SHGC. Below U-factor of 0.25, triple pane fenestration maybe required and would potentially conflict with wall design since thicker assembly would be required to fit in triple-pane windows. Fourth surface low-e coatings over double pane can support the lower U-factor but may lead to condensation issues.

Along with many specialized window manufacturers, many major and minor window manufacturers have facilities in California. Milgard Windows and Doors, a company that produces its own components, including glass and frames, owns several facilities in California with locations in Sacramento, Simi Valley, and Temecula. Pella Corporation, one of North America's largest window manufacturers, operates ten separate branches in California. Andersen Windows, also a major national window manufacturer, operates many supplier locations throughout northern and southern California.[44] These and other manufacturers provide California with a wide variety of fenestration products that meet the requirements proposed here. Just these manufacturers alone provide over 4,700 products that achieve a U-factor of 0.27 or less while having a wide range of SHGC.[45] Even though the product database suggests enough products to meet the proposed U-factor less than 0.28 and SHGC greater than 0.35, the manufacturers have suggested that mid to high gain SHGC fenestration products, specifically above 0.35, are less likely to be stocked in California. The regional suppliers stock the more commonly required windows with current prescriptive performance values. This code change could potentially encourage transferring the product supply of mid to high gain SHGC windows from northern climates to California.

Windows that meet the proposed increase in performance have been in use in northern climates for many years. To qualify as an ENERGY STAR 6.0 product, windows in the northern climate zones have been required to have a U-factor at or below 0.27 since January 2015. Canadian ENERGY STAR ratings have required a U-factor of 0.28 to 0.21 depending on climate zone to qualify since 2015. These products would have been the market standard in these northern markets for ten years when the 2025 iteration of Title 24 building codes goes into effect. Many of the same manufacturers that dominate the California market, including Milgard, Pella, and Andersen, currently produce thousands of product lines for these markets. It should also be noted that version 5.0 of the Canadian ENERGY STAR requirements, which took effect in January of 2020, requires windows to have a maximum U-factor of 0.21 regardless of the climate zone.

While the supply chain impacts of the pandemic were significant and overall market prices remain higher than they were pre-pandemic, the manufacturers and industry stakeholders interviewed suggested that these issues have been resolved for window manufacturing components apart from krypton gas. Krypton, which is used between glass panes to achieve lower U-factors than argon, allows the spacing between panes to be reduced without negatively affecting the U-factor. According to stakeholders, the war in Ukraine has increased the cost of krypton significantly, therefore the technical feasibility and product availability in this study does not rely on krypton technology. This has had significant impacts on the development of “thin” triple-pane windows that have the same mounting requirements as traditional double-pane windows and may have stalled triple-pane windows from wider adoption for the time being.

High performing windows do not require higher maintenance; however, they may have condensation impacts for windows with very low U-factors. Lower SHGC/U-factor windows may have darker colors/tints to the glazing material. The proposed changes do

[44] More information on California window manufacturers available here: www.california.com

[45] Searchable database for high SHGC low U-factor products can be found at: Natural Resources Canada: Searchable Product List

not entail a fourth surface low-e coating. Hence, the team can conclude that there are no adverse impacts related to building maintenance, occupant comfort and/or aesthetics. Because there is a variety of product specifications in market, the verification process allows for a narrow difference of +/- 0.01 between modeled and installed values.

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 2025 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California’s construction industry comprises approximately 93,000 business establishments and 943,000 employees as shown in Table 38. For 2022, total estimated payroll would be about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees are engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction roles (the industrial sector).

Table 38: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establish-ments	Employ-ment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, & Building Exterior	7,891	83,575	5.0
Residential	Building Equipment Contractors	18,108	125,559	8.5
Residential	Building Finishing Contractors	17,942	133,260	8.0
Commercial	**All**	**17,621**	**368,810**	**35.0**
Commercial	Building Construction Contractors	4,919	83,028	9.0
Commercial	Foundation, Structure, & Building Exterior	2,194	59,110	5.0
Commercial	Building Equipment Contractors	6,039	139,442	13.5
Commercial	Building Finishing Contractors	4,469	87,230	7.4
Industrial, Utilities, Infrastructure, & Other (Industrial+)	**All**	**4,206**	**101,002**	**11.4**
Industrial+	Building Construction	288	3,995	0.4
Industrial+	Utility System Construction	1,761	50,126	5.5
Industrial+	Land Subdivision	907	6,550	1.0
Industrial+	Highway, Street, and Bridge Construction	799	28,726	3.1
Industrial+	Other Heavy Construction	451	11,605	1.4

Source: (State of California, n.d.)

The proposed change to multifamily high-performance windows would likely affect residential 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 39 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report.

Builders sometimes cover both the design and construction of a multifamily building. This section covers the impacts on the construction portion. The next section discusses the impacts for the design portion. Builders are responsible for understanding the design requirements and ensuring all subcontractors are aware of these requirements for proper installation. Builders and contractors would need to decide on the appropriate window glass and glazing materials as well as the window placement optimized for the building's space and climate zone if a proposed design alternate is being considered. They would need to be familiar with the proposed measure requirements and ensure all proposed window standards, such as the U-factor and SHGC, are met by the installers. Since the installation method would not likely change and follow the manufacturer's installation guidelines, the proposed measure would not significantly impact the labor time. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 5.2.4 Economic Impacts.

Table 39: Specific Subsectors of the California Residential Building Industry by Subsector in 2022 (Estimated)

Residential Building Subsector	Establishments	Employment	Annual Payroll (Billions $)
New multifamily general contractors	421	6,344	0.7
Residential Framing Contractors	741	25,028	1.3
Residential glass and glazing contractors	722	5,026	0.3
Other Residential Exterior Contractors	628	2,875	0.2

Source: (State of California, 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 in order to remain up to date with changes to design practices and building codes.

Building designers and energy consultants would need to identify the best strategies for implementing the proposed measure for multifamily projects in the climate zones in which the requirements apply. They would need to consider the details of the project, such as the window type (i.e., fixed, casement, or slider), frame (i.e., wood or metal), and location, in order to decide on the appropriate window glass and/or glazing that would meet the minimum required U-factor and SHGC while improving energy performance and being cost effective.

The comfort of the residents also needs to be taken into consideration. This can be affected by the orientation of the windows, where west facing windows and the minimum SHGC may cause discomfort in the summer. Building designers may need to install lower SHGC products depending on the orientation. HVAC designers also need to take higher SHGC products into account when doing their load calculations. Building designers should work with energy consultants to ensure the proposed window requirements are met. They would also need to understand the regulations and industry standards to ensure safety and compliance. Further, building designers would need to review alternate products as proposed by the contractors to ensure compliance with the original specification and the code.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (NAICS 541310). Table 40 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 multifamily high-performance windows to affect firms that focus on multifamily construction.

There is not a NAICS[46] code specific to energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[47] 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 40 provides an upper bound indication of the size of this sector in California.

Table 40: California Building Designer and Energy Consultant Sectors in 2022 (Estimated)

Sector	Establishments	Employment	Annual Payroll (Millions $)
Architectural Services[48]	4,134	31,478	3,623.3
Building Inspection Services[49]	1,035	3,567	280.7

Source: (State of California, n.d.)

5.2.3.3 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 DOSH. 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

[46] 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.

[47] 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.

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

[49] 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.

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 (Including Homeowners and Potential First-Time Homeowners)

Residential Buildings

According to data from the U.S. Census, American Community Survey (ACS), there were more than 14.5 million housing units in California in 2021 and nearly 13.3 million were occupied as shown in Table 41. Most housing units (nearly 9.42 million) were single family homes (either detached or attached), approximately 2 million homes were in buildings containing two to nine units, and 2.5 million homes were in multifamily buildings containing 10 or more units. The California Department of Revenue estimated that building permits for 67,300 single family and 54,900 multifamily homes would be issued in 2022, up from 66,000 single family and 53,500 multifamily permits issued in 2021.

Table 41: California Housing Characteristics in 2021[50]

Housing Measure	Estimate
Total housing units	14,512,281
Occupied housing units	13,291,541
Vacant housing units	1,220,740
Homeowner vacancy rate	0.7%
Rental vacancy rate	4.3%
Number of 1-unit, detached structures	8,388,099
Number of 1-unit, attached structures	1,030,372
Number of 2-unit structures	348,295
Number of 3- or 4-unit structures	783,663
Number of 5- to 9-unit structures	856,225
Number of 10- to 19-unit structures	740,126
Number of 20+ unit structures	1,828,547
Mobile home, RV, etc.	522,442

Sources: (United States Census Bureau, n.d.), (Federal Reserve Economic Data (FRED), n.d.)

Table 42 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59 percent of the total) were built between 1950 and 1989, a period of rapid population and economic growth in California. Finally, about 2.1 million homes in California were built before 1950. According to Kenney et al, 2019, more than half of California's existing

[50] Total housing units as reported for 2021; all other housing measures estimated based on historical relationships.

multifamily buildings (those with five or more units) were constructed before 1978 when there was no California Energy Code (Kenney, 2019).

Table 42: Distribution of California Housing by Vintage in 2021 (Estimated)

Home Vintage	Units	Percent	Cumulative Percent
Built 2014 or later	348,296	2.4	2.4
Built 2010 to 2013	261,221	1.8	4.2
Built 2000 to 2009	1,581,839	10.9	15.1
Built 1990 to 1999	1,596,351	11.0	26.1
Built 1980 to 1989	2,191,354	15.1	41.2
Built 1970 to 1979	2,539,649	17.5	58.7
Built 1960 to 1969	1,915,621	13.2	71.9
Built 1950 to 1959	1,930,133	13.3	85.2
Built 1940 to 1949	841,712	5.8	91.0
Built 1939 or earlier	1,306,105	9.0	100.0
Total housing units	**14,512,281**	**100.0**	**–**

Sources: (United States Census Bureau, n.d.), (Federal Reserve Economic Data (FRED), n.d.)

Table 43 shows the distribution of owner- and renter-occupied housing by household income. Overall, about 55 percent of California housing is owner-occupied and the rate of owner-occupancy generally increases with household income. The owner-occupancy rate for households with an income below $50,000 is only 37 percent, whereas the owner occupancy rate is 71 percent for households earning $100,000 or more.

Table 43: Owner- and Renter-Occupied Housing Units in California by Income in 2021 (Estimated)

Household Income	Total	Owner Occupied	Renter Occupied
Less than $5,000	353,493	113,315	240,178
$5,000 to $9,999	254,304	74,939	179,366
$10,000 to $14,999	495,287	134,633	360,654
$15,000 to $19,999	412,498	144,064	268,435
$20,000 to $24,999	467,694	169,431	298,264
$25,000 to $34,999	906,996	355,968	551,028
$35,000 to $49,999	1,319,892	560,453	759,438
$50,000 to $74,999	2,036,560	990,769	1,045,791
$75,000 to $99,999	1,662,032	920,607	741,425
$100,000 to $149,999	2,307,889	1,490,247	817,642
$150,000 or more	3,074,895	2,337,651	737,244
Total Housing Units	**13,291,541**	**7,292,076**	**5,999,465**

Source: (United States Census Bureau, n.d.), (Federal Reserve Economic Data (FRED), n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 41 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 42 and Table 43.

Estimating Impacts

For California residents, the proposed code changes would result in lower energy bills. The Statewide CASE Team estimates that on average the proposed change to Title 24, Part 6 would increase construction cost by about $35 per multifamily residence. There would be a very minimal increased construction cost per month in payments for a 30-year mortgage (assuming a 5 percent interest rate). The measure would also result in an average energy and maintenance cost savings of about $3 per year, depending on climate zone, or less than $1 per month reduction in energy costs. Overall, the Statewide CASE Team expects these proposed 2025 Title 24, Part 6 Standards changes to save homeowners about $3 per year relative to homeowners whose multifamily residences are minimally compliant with the 2022 Title 24, Part 6 requirements.

When homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low-income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors, 2011).

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

The proposed change would not have a significant impact on manufacturers, distributors, and retailers. The demand for installing high performance windows would increase slightly as the market already includes multifamily buildings using windows with the proposed U-factor and SHGC requirements. As the demand for the new compliant windows increases, there would be less demand for windows that no longer meet the updated performance standards. High performance windows with lower U-factors would have a higher cost but the cost may be partially offset by the lower cost of higher SHGC glazed windows. However, since high performance windows have a higher cost than standard windows, manufacturers, distributors, and retailers would likely have higher sales revenues.

5.2.3.6 Impact on Building Inspectors

Table 44 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing education and training to stay current on all aspects of building regulations, including energy efficiency. This includes understanding how the characteristics, such as the rated RSHGC, of windows affect different climate zones. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 44: Employment in California State and Government Agencies with Building Inspectors in 2022 (Estimated)

Sector	Govt.	Establishments	Employment	Annual Payroll (Million $)
Administration of Housing Programs[51]	State	18	265	29.0
	Local	38	3,060	248.6
Urban and Rural Development Admin[52]	State	38	764	71.3
	Local	52	2,481	211.5

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

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 individual 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 estimated the proposed change for this measure would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in multifamily high-performance windows 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 2025 code cycle, the Statewide CASE Team used the IMPLAN model software[53], 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. Conceptually, IMPLAN estimates jobs created as a function of incoming cash flow in different sectors of the economy, due to implementing a code or a standard. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment (jobs created in the manufacturing plant), indirect employment (jobs created in the sectors that provide raw materials to the manufacturing plant) and

[51] 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.

[52] 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.

[53] IMPLAN employs economic data and advanced economic impact modeling to estimate economic impacts for interventions like changes to the California Title 24, Part 6 code. For more information on the IMPLAN modeling process, see www.IMPLAN.com.

induced employment (jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant). Eventually, IMPLAN computes the total number of jobs created due to a code. The assumptions of IMPLAN include constant returns to scale, fixed input structure, industry homogeneity, no supply constraints, fixed technology, and constant byproduct coefficients. The model is also static in nature and is a simplification of how jobs are created in the macro-economy.

The economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. The IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that the 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 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 economic impacts presented below represent lower bound estimates of the actual benefits 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 residential building and remodeling industry, architects, energy consultants, and building inspectors, as well as indirectly as residents spend all or some of the money saved through lower utility bills on other economic activities.[54] There may also be some nonresidential customers that are impacted by this proposed code change; however, the Statewide CASE Team does not anticipate such impacts to be materially important to the building owner and would have measurable economic impacts.

The estimated impact is based on the relative incremental cost and the estimated proportion of new multifamily units that would be impacted by the proposed change in 2026. The incremental cost is weighted by the applicable climate zones and building prototypes. Also, the Statewide CASE Team does not expect additional labor hours for building designers, energy consultants, and/or building inspectors for the proposed change. The estimated economic impacts for the proposed high performance window measure are shown in Table 45 through Table 47.

[54] For example, for the lowest income group, the Statewide CASE Team assumes 100 percent of money saved through lower energy bills will be spent, while for the highest income group, they assume only 64 percent of additional income will be spent.

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

Type of Economic Impact	Employment (Jobs)	Labor Income (Million $)	Total Value Added (Million $)	Output (Million $)
Direct Effects (Additional spending by Residential Builders)	8.20	0.65	0.86	1.10
Indirect Effect (Additional spending by firms supporting Residential Builders)	1.00	0.07	0.12	0.21
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	3.00	0.21	0.37	0.59
Total Economic Impacts	**12.2**	**0.93**	**1.40**	**1.90**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[55]

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

Type of Economic Impact	Employment (Jobs)	Labor Income (Million $)	Total Value Added (Million $)	Output (Million $)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	0.00	0.00	0.00	0.00
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	0.00	0.00	0.00	0.00
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	0.00	0.00	0.00	0.00
Total Economic Impacts	**0.00**	**0.00**	**0.00**	**0.00**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

Table 47: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

Type of Economic Impact	Employment (Jobs)	Labor Income (Million $)	Total Value Added (Million $)	Output (Million $)
Direct Effects (Additional spending by Building Inspectors)	0.00	0.00	0.00	0.00
Indirect Effect (Additional spending by firms supporting Building Inspectors)	0.00	0.00	0.00	0.00
Induced Effect (Spending by employees of Building Inspection Bureaus and Departments)	0.00	0.00	0.00	0.00
Total Economic Impacts	**0.00**	**0.00**	**0.00**	**0.00**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.

[55] IMPLAN® model, 2020 Data, IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

5.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2025 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 5.2.4 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 the use of specific products, 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.

5.2.4.3 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.[56] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2025 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.

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 net private domestic investment, or NPDI).[57] As Table 48 shows, between 2017 and 2021, NPDI as a percentage of corporate profits ranged from a low of 18 in 2020 due to the worldwide economic slowdowns associated with the COVID 19 pandemic to a high of 35 percent in 2019, with an average of 26 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it

[56] 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.

[57] 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.

provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 48: 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 (Percent)
2017	518.473	1882.460	28
2018	636.846	1977.478	32
2019	690.865	1952.432	35
2020	343.620	1908.433	18
2021	506.331	2619.977	19
5-Year Average	**539.227**	**2068.156**	**26**

Source: (Federal Reserve Economic Data (FRED), 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, directly or indirectly, in any 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 based on the estimated change in economic activity associated with the proposed measure and its expected effect on proprietor income, which the Statewide CASE Teams use a conservative estimate of corporate profits, a portion of which they assume would be allocated to net business investment.[58]

5.2.4.5 Incentives for Innovation in Products, Materials, or Processes

The Statewide CASE Team does not anticipate the proposed code change would impact innovation. The market is already using high performance windows in multifamily buildings.

5.2.4.6 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 California's General Fund, any state special funds, or local government funds.

[58] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 48.

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 measure would not impact state buildings since it is a residential measure.

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 2025 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 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 of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences.

The proposed code changes are likely to impact the DIPs. Refer to Section 2 for more details regarding DIPs as well as energy equity and environmental justice.

5.2.5 Fiscal Impacts

5.2.5.1 Mandates on Local Agencies or School Districts

There are no mandates to local agencies because the measure requirements would be specified at the Statewide level through Title 24, Part 6. There also are no relevant mandates to school districts since this measure impacts multifamily buildings.

5.2.5.2 Costs to Local Agencies or School Districts

There would be minor cost increases for local agencies employing building inspectors who would enforce the measure. Inspectors would need to ensure the windows of multifamily buildings meet the minimum U-value and SHGC requirements, but this is already being done by local inspectors. There are no costs to school districts since this measure only impacts multifamily buildings.

5.2.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies because they would not be involved in the enforcement of the measure.

5.2.5.4 Other Non-Discretionary Cost or Savings Imposed on Local Agencies

There are no added non-discretionary costs or savings to local agencies.

5.2.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state. The proposed measure would have a relatively small impact on the incremental cost. California would not require federal funding to implement the measure.

5.3 Energy Savings

The Statewide CASE Team gathered stakeholder input to inform the energy savings analysis. See Appendix F for a summary of stakeholder engagement.

Energy savings benefits may have potential to disproportionately impact DIPs. Refer to Section 2 for more details addressing energy equity and environmental justice.

5.3.1 Energy Savings Methodology

5.3.1.1 Key Assumptions for Energy Savings Analysis

The final 2026 LSC factors were used in the analysis presented here. The Statewide CASE Team sourced prototypical building models used for energy modeling from the CBECC software for multifamily buildings (CBECC). The models were modified to create baseline and proposal models. The baseline model is based on the 2022 Title 24, Part 6 mandatory and prescriptive requirements. The proposal model is based on the proposed changes to these energy standards. CBECC prototypical models Low-Rise Garden, Loaded Corridor, Mid-Rise Mixed Use and High-Rise Mixed Use, were used for analysis.

The Statewide CASE Team evaluated current Title 24, Part 6 new construction and alterations fenestration U-factor and RSHGC code requirements for multifamily buildings, single family residential, and nonresidential buildings for code alignment opportunities. Applicable current ENERGY STAR and ASHRAE 90.1 fenestration standards were also analyzed during the measure development process.

Based on stakeholder feedback and market research, the Statewide CASE Team determined the three multifamily fenestration categories represented in Title 24, Part 6, Section 170.2 – Prescriptive Approach should each be modeled for cost and energy. The current code uses three categories of window requirements for multifamily buildings: (1) Curtainwall/Storefront, (2) NAFS 2017 Performance NAFS Class AW, and (3) All Other Fenestration. High variation in cost, application, impact, and current Title 24, Part 6 efficiency standards between these fenestration types dictated that they be modeled separately for the building prototypes these products impact. Energy and cost impacts for Curtainwall/Storefront, and NAFS 2017 Performance NAFS Class AW proposed measure changes were modeled for High-Rise Mixed Use and Mid-Rise Mixed Use building models. Energy and cost impacts for All Other Fenestration proposed measure changes were modeled for High-Rise Mixed Use, Mid-Rise Mixed Use, Loaded Corridor, and Low-Rise Garden building models. This choice was based on market research and feedback from stakeholders, and precedent established by the 2022 Multifamily Envelope CASE Team. The prevalence of these fenestration categories in multifamily building construction established for the 2022 CASE Multifamily High Performance Envelope report is discussed in greater detail in Appendix A.

The Statewide CASE Team simulated the energy impacts across all climate zones and applied the climate-zone specific LSC hourly factors when calculating energy and energy cost impacts for All Other Fenestration measure proposals. For Curtainwall/Storefront and NAFS 2017 Performance NAFS Class AW measure proposals, the Statewide CASE Team simulated the energy impacts in Climate Zones 3, 5, and 16 and applied the climate-zone specific LSC hourly factors. The climate zones chosen for proposal modeling was based on those climate zones that would be impacted by these proposals.

For alterations analysis, existing building models for the Low-rise Garden and High-rise Mixed Use prototypes were developed based on 1990s vintage assumptions. The existing building stock is assumed to be divided in the following proportion across the four prototypes selected for analysis, see Table 49 below. The two building types analyzed here represents 64 percent of the existing Multifamily building stock provided by the CEC.

Table 49: Building Prototype Percent of Existing Building Stock

Prototype	Existing Building Stock (Dwelling Units)	Percent of Total Existing Building Stock
Low-Rise Garden	1,787,965	40
Loaded Corridor	804,584	18
Mid-rise Mixed Use	804,584	18
High-rise Mixed Use	1,072,779	24

The per-unit impacts in Section 5.3.2 are calculated by scaling 2-story LowRiseGarden prototype results to the 3-story Low-rise Loaded Corridor prototype and scaling 10-story High-rise Mixed Use prototype results to 5-story Mid-Rise Mixed Use prototype, see scaling ratios in Table 50 below. This is based on the similarity of dwelling unit size, window specifications, system type and some prototype characteristics but may have some architectural differences. The individual prototype results are then used to calculated weighted average savings per dwelling unit in Section 5.4.2 and statewide impacts in Section 5.5. Please note that the Mid-rise Mixed Use prototype assumes a different proportion of Curtainwall, Performance Class AW, and All-Other window types than the one used in High-rise Mixed Use. Further details on existing building construction impacted across climate zones is included in Appendix A.

Table 50: Dwelling Unit Ratio Used to Estimate Impacts for Window Alterations Analysis

Prototype	Dwelling units per building	Ratio applied to model output
Low-Rise Garden	8	1.00
Loaded Corridor	36	4.50
Prototype	Dwelling units per building	Ratio applied to model output
High-rise Mixed Use	117	1.00
Mid-rise Mixed Use	88	0.75

5.3.1.2 Energy Savings Methodology per Prototypical Building

The Statewide CASE Team measured per-unit energy savings expected from the proposed code changes in several ways to quantify key impacts. First, savings are calculated by fuel type. Electricity savings are measured in terms of both energy usage and peak demand reduction. Natural gas savings are quantified in terms of energy usage. Second, the Statewide CASE Team calculated source energy savings. Source Energy represents the total amount of raw fuel required to operate a building. In addition to all energy used from on-site production, source energy incorporates all transmission, delivery, and production losses. The hourly Source Energy values provided by CEC are strongly correlated with GHG emissions.[59] Finally, the Statewide CASE Team calculated LSC Savings, formerly known as TDV LSC Savings. LSC Savings are calculated using hourly LSC factors for both electricity and natural gas provided by the CEC. These LSC hourly factors are projected over the 30-year life of the building and incorporate the hourly cost of marginal generation, transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO2 emissions.

[59] See Hourly Factors for Source Energy, Long-term Systemwide Cost, and GHG Emissions at https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

The CEC 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. More information on CBECC Title 24, Part 6 compliance software and full list of building prototypes are available at [CBECC Title-24 Compliance Software](#).

The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 51.

Table 51: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
Low-Rise Garden	2	7,320	2-story, 8-unit apartment building. Average dwelling unit size: 960 ft^2. Individual gas instantaneous DHW.
Loaded Corridor	3	39,264	3-story, 36-unit apartment building. Average dwelling unit size: 960 ft^2. Individual gas instantaneous DHW.
Mid-rise Mixed Use	5	112,641	4-story (4-story residential, 1-story commercial), 88-unit building. Avg dwelling unit size: 870 ft^2. Central gas storage DHW.
High-rise Mixed Use	10	125,400	10-story (9-story residential, 1-story commercial), 117-unit building. Avg dwelling unit size: 850 ft^2. Central gas storage DHW.

The Statewide CASE Team estimated LSC, Source Energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in EnergyPlus using prototypical buildings and rulesets from the 2025 Research Version of the CBECC software.

CBECC generates two models based on user inputs: the Standard Design and the Proposed Design.[60] The Standard Design represents the geometry of the prototypical building and a design that uses a set of features that result in a LSC budget and Source Energy budget that is minimally compliant with 2022 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2022 Nonresidential and Multifamily 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 their inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design

[60] CBECC-Res creates a third model, the Reference Design, that represents a building similar to the Proposed Design, but with construction and equipment parameters that are minimally compliant with the 2006 IECC. The Statewide CASE Team did not use the Reference Design for energy impacts evaluations.

for each prototypical building with the Standard Design representing compliance with 2022 code and the Proposed Design representing compliance with the proposed 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 2022 Title 24, Part 6. For alterations savings analysis, the standard design is not relative to a building that is minimally compliant with the 2022 Title 24, Part 6, but to a building assumed to represent the average performance of statewide existing multifamily buildings.

The current Title 24 Part 6, prescriptive requirements for fenestration are divided into three categories: (1) Curtainwall/Storefront, (2) NAFS 2017 Performance NAFS Class AW, and (3) All Other Fenestration. These standards feature maximum U-factor, Maximum RSHGC for three or fewer habitable stories, and Maximum RSHGC for four or more habitable stories as described below,

- Curtainwall/Storefront fenestration prescriptive requirements are as follows:
    - Maximum U-factor 0.38 in Climate Zones 1 and 16 and 0.41 in Climate Zones 2-15
    - Maximum RSHGC for three or fewer habitable stories 0.26 in Climate Zones 2, 4, 6-13, and 0.25 in Climate Zone 14
    - Maximum RSHGC for four or more habitable stories 0.35 in Climate Zone 1, 0.26 in Climate Zones 2-13, and 15 and 0.25 in Climate Zones 14 and 16.
- NAFS 2017 Performance NAFS Class AW fenestration prescriptive requirements are as follows:
    - Maximum U-factor 0.38 in Climate Zones 1 and 16, 0.40 in Climate Zones 2-15.
    - Maximum RSHGC for three or fewer habitable stories 0.24 in Climate Zones 2, 4, and 6-15.
    - Maximum RSHGC for four or more habitable stories 0.35 in Climate Zone 1, 0.24 in Climate Zones 2-16.
- All Other fenestration prescriptive requirements are as follows:
    - Maximum U-factor 0.30 in Climate Zones 1-6, and 9-16, and 0.34 in Climate Zones 7 and 8.
    - Maximum RSHGC for three or fewer habitable stories 0.23 in Climate Zones 2, 4, and 6-15.
    - Maximum RSHGC for four or more habitable stories 0.35 in Climate Zone 1, 0.23 in Climate Zones 2-16.

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 52 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. The proposed measure of removing RSHGC requirement applies to four habitable stories or more and modeled for MidRiseMixedUse and HighRiseMixedUse prototypes only in Climate Zones 3, 5, and 16. This increase in RSHGC is supported by the energy modeling that shows these climate zones as benefitting from increased heat gain throughout the year.

The corresponding Standard Design assumption is the maximum prescriptive RSHGC requirement, while the Proposed Design assumes 0.35 RSHGC that would be the 2025 Standard Design ACM threshold to compare against in performance approach. In Climate Zone 1, the current code standard is already 0.35 RSHGC, hence no change was modeled. The same assumptions for Standard Design and Proposed Design window specifications applies to both new construction and alterations savings analysis.

Table 52: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Objects Modified	Parameter Name	Climate Zone	Standard Design Parameter Value	Proposed Design Parameter Value
Low-Rise Garden, All other fenestration	Window	U-factor	1-5,8-16	0.30	0.28
			6,7	0.34	0.28
Low-Rise Garden, All other fenestration	Window	RSHGC	3, 5, 16	0.35	0.35
			1,2,4,6-15	0.23	0.23
Loaded Corridor, All other fenestration	Window	U-factor	1-5,8-16	0.30	0.28
			6,7	0.34	0.28
Loaded Corridor, All other fenestration	Window	RSHGC	3, 5, 16	0.35	0.35
			1,2,4,6-15	0.23	0.23
Mid-rise Mixed Use, Curtainwall/Storefront	Window	RSHGC	3, 5	0.26	0.35
			16	0.25	0.35
Mid-rise Mixed Use, NAFS Class AW	Window	RSHGC	3, 5, 16	0.24	0.35
Mid-rise Mixed Use, All other fenestration	Window	U-factor	1-5,8-16	0.30	0.28
			6,7	0.34	0.28
Mid-rise Mixed Use, All other fenestration	Window	RSHGC	3, 5, 16	0.23	0.35
High-rise Mixed Use, Curtainwall/Storefront	Window	RSHGC	3, 5	0.26	0.35
			16	0.25	0.35
High-rise Mixed Use, NAFS Class AW	Window	RSHGC	3, 5, 16	0.24	0.35
High-rise Mixed Use, All other fenestration	Window	U-factor	1-5,8-16	0.30	0.28
			6,7	0.34	0.28
High-rise Mixed Use, All other fenestration	Window	RSHGC	3, 5, 16	0.23	0.35

CBECC calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/y) and therms per year (therms/y). It then applies the 2025 LSC hourly factors to calculate LSC in 2026 present value dollars (2026 PV$), Source Energy factors to calculate source energy use in kilo British thermal units per year (kBtu/y), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent per year (MT or “tonnes” CO2e/y). CBECC also calculates annual peak electricity demand measured in kilowatts (kW). A recording of the CEC’s [Final Staff Workshop on Energy Accounting for the 2025 Building Energy Efficiency Standards] that took place on November 10, 2022 is available at the embedded link.

The energy impacts of the proposed code change do vary by climate zone. The Statewide CASE Team simulated the energy impacts in applicable climate zones and applied the climate-zone specific LSC hourly factors when calculating energy and energy cost impacts. Per-unit energy impacts for multifamily buildings are presented in savings per dwelling unit. Annual energy and peak demand impacts for each prototype building were translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building. This step enables a calculation of statewide savings using the construction forecast that is published in terms of number of multifamily dwelling units by climate zone.

5.3.1.3 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the statewide construction forecasts that the CEC provided. The statewide construction forecasts estimate new construction/additions that would occur in 2026, the first year that the 2025 Title 24, Part 6 requirements are in effect. They also estimate the amount of total existing building stock in 2026, which the Statewide CASE Team used to approximate savings from building alterations (California Energy Commission, 2022). The construction forecast provides construction (new construction/additions and existing building stock) by building type and climate zone, as shown in Appendix A.

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

5.3.2 Per-unit Energy Impacts Results

Multifamily new construction energy savings and peak demand reductions per dwelling unit are presented in Table 53 through Table 56. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Modeled per-unit savings for the first year range from -72.29 to 22.19 kWh/y, 20.34 to 29.83 therms/y and -18.82 to 247.82 source energy kBtu/y depending upon climate zone and building type. Per-unit demand reductions are expected to range between -0.85 W and 12.44 W depending on climate zone and building type. Modeled alterations, shown in Table 57 through Table 60, per-unit savings for the first year range from -6.20 to 2.13 kWh/y, 12.81 to 284 therms/y and 10.61 to 255.01 source energy kBtu/y, depending upon climate zone.

Multifamily alterations energy savings and peak demand reductions per dwelling unit are also presented. The values presented for the Loaded Corridor and Mid-rise Mixed use building prototypes are estimated based on the results of the Low-rise Garden Style and High-rise Mixed use models. More information on how the estimates were made can be found in Section 5.3.1 Energy Savings Methodology.

As described in Section 5.3.1, the Statewide CASE Team simulated energy impacts of proposed varying stringency levels for NAFS Class AW, curtainwall, and all other window types based on climate zone. These proposals were selected based on both cost effectiveness and modeled energy savings, across all models. Energy models were run across all climate zones using the prototypical buildings identified in above Table 51. Results are presented for all climate zones including those where no changes are currently recommended.

Energy impacts per dwelling unit of a building are presented in the tables below. Electricity savings are shown in kWh/unit. Peak demand reduction is shown in Watts/unit. Natural gas savings and Source energy savings are shown in kBtu/unit.

In climate zones where the proposed code change would increase energy use, the negative energy savings are depicted in red font. The Statewide CASE Team evaluated energy savings of all prototypical buildings in all climate zones and reviewed results to inform recommended code changes.

The proposed measure would lead to modest peak electrical demand reductions in all affected climate zones, given the assumed distribution of forecasted construction building types.

Table 53: First-Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	16.3	12.1	11.4	16.5	13.3	4.78	1.06	-0.43	1.86	9.77	17.8	13.8	15.9	18.3	18.6	-2.45
LoadedCorridor	14.3	10.6	10.5	17.4	11.4	-1.01	-6.2	-2.93	3.93	6.48	14.7	7.54	12.4	16.9	11.6	-5.65
MidRiseMixedUse	4.88	1.24	10.7	10.8	12.3	-9.88	-15.8	-5.53	1.48	3.09	8.39	1.61	7.01	11.0	8.73	-72.3
HighRiseMixedUse	7.34	5.38	22.9	18.6	16.3	-3.51	-8.81	-7.46	-0.88	0.69	11.2	5.65	7.44	14.0	6.63	-50.3

Table 54: First-Year Peak Demand Reduction (W) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	3.09	3.86	3.71	5.10	4.22	2.20	0.82	1.27	2.04	1.84	3.98	3.71	3.18	4.74	0.48	-0.03
LoadedCorridor	3.10	4.22	3.93	5.78	4.14	1.86	0.54	0.97	1.83	2.49	4.52	4.23	3.42	5.36	0.71	-0.17
MidRiseMixedUse	1.76	2.43	11.11	4.84	11.67	0.85	-0.85	0.44	1.42	1.82	3.19	3.04	2.44	4.04	0.50	1.14
HighRiseMixedUse	2.75	4.23	12.56	7.45	12.61	1.86	-0.31	0.80	2.39	3.18	5.65	5.48	4.30	6.27	0.72	-0.14

Table 55: First-Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	28.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	255
LoadedCorridor	29.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	265
MidRiseMixedUse	20.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	342
HighRiseMixedUse	29.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	162

Table 56: First-Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	66.3	38.7	35.7	51.2	38.6	30.9	19.7	11.99	18.3	19.3	42.8	36.7	34.1	47.1	14.2	228
LoadedCorridor	65.0	41.3	36.3	57.4	37.3	22.6	9.71	8.73	19.0	22.1	44.6	37.9	34.3	50.8	11.6	235
MidRiseMixedUse	36.5	20.4	86.2	43.9	90.5	-1.15	-18.8	-2.43	12.7	14.3	29.8	20.1	21.3	37.0	9.7	248
HighRiseMixedUse	53.3	35.4	110	70.1	97.2	14.6	-6.97	-0.54	16.8	20.0	49.3	38.1	31.2	57.5	5.1	91.5

Table 57: First-Year Electricity Savings (kWh) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows – Alterations

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	1.31	-0.66	-0.29	-2.17	-0.21	-2.89	-4.39	-6.20	-4.88	-4.3	-1.28	-2.79	-0.90	-0.87	2.13	-1.93
LoadedCorridor	1.31	-0.66	-0.29	-2.17	-0.21	-2.89	-4.39	-6.20	-4.88	-4.3	-1.28	-2.79	-0.90	-0.87	2.13	-1.93
MidRiseMixedUse	-1.77	-4.40	-24.3	-2.68	-36.0	-3.4	-12.3	-9.26	-6.61	-5.34	-1.72	-5.52	-1.32	-1.09	6.57	-95.4
HighRiseMixedUse	-1.77	-4.40	-15.8	-2.68	-22.4	-3.4	-12.3	-9.26	-6.61	-5.34	-1.72	-5.52	-1.32	-1.09	6.57	-68.6

Table 58: First-Year Peak Demand Reduction (W) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows – Alterations

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	0.13	0.07	0.04	-0.04	0.06	-0.19	-0.32	-0.4	-0.25	-0.33	-0.17	-0.11	-0.16	-0.06	-0.1	-0.05
LoadedCorridor	0.13	0.07	0.04	-0.04	0.06	-0.19	-0.32	-0.4	-0.25	-0.33	-0.17	-0.11	-0.16	-0.06	-0.1	-0.05
MidRiseMixedUse	-0.06	0.03	-0.45	0.17	-0.53	-0.17	-0.88	-0.24	-0.11	-0.13	-0.18	-0.11	-0.21	-0.08	0.09	-1.35
HighRiseMixedUse	-0.06	0.03	-0.3	0.17	-0.35	-0.17	-0.88	-0.24	-0.11	-0.13	-0.18	-0.11	-0.21	-0.08	0.09	-0.91

Table 59: First-Year Natural Gas Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows – Alterations

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	268	163	110	158	111	19.6	20.0	26.6	54.4	54.8	142	144	110	163	12.8	284
LoadedCorridor	268	163	110	158	111	19.6	20.0	26.6	54.4	54.8	142	144	110	163	12.8	284
MidRiseMixedUse	257	199	914	279	916	56.4	133	70.9	102	103	211	202	160	232	29.3	1500
HighRiseMixedUse	257	199	673	279	708	56.4	133	70.9	102	103	211	202	160	232	29.3	1100

Table 60: First-Year Source Energy Savings (kBtu) Per Dwelling Unit by Climate Zone (CZ) - High Performance Windows – Alterations

Prototype	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
LowRiseGarden	246	148	100	141	101	14.5	12.8	17.0	43.8	44.7	128	129	100	147	10.6	255
LoadedCorridor	293	177	119	169	120	17.2	15.3	20.3	52.2	53.3	152	153	120	175	12.7	304
MidRiseMixedUse	277	213	969	302	958	57.0	126	67.6	104	107	229	216	174	250	36.4	1530
HighRiseMixedUse	232	178	598	253	625	47.7	105	56.6	87.4	89.2	192	181	146	209	30.4	937

5.4 Cost and Cost Effectiveness

5.4.1 LSC Savings Methodology

LSC Savings were calculated by applying the LSC hourly factors to the energy savings estimates that were derived using the methodology described in Section 5.3.1. LSC hourly factors are a normalized metric to calculate LSC 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 30-year period of analysis.

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost-effectiveness analysis uses LSC values in 2026 PV$. Costs and cost effectiveness using and 2026 PV$ are presented in Section 5.4 of this report. The CEC uses results in nominal dollars to complete the Economic and Fiscal Impacts Statement (From 399) for the entire package of proposed change to Title 24, Part 6. Appendix G presents LSC savings results in nominal dollars.

These proposed changes to fenestration products apply to new construction and alterations. LSC savings methodology is informed with input of designer, builder, supplier, and manufacturer stakeholder interviews.

5.4.2 LSC Savings Results

Per-unit LSC Savings for newly constructed buildings, and additions in terms of LSC savings realized over the 30-year period of analysis are presented 2026 present value dollars (2026 PV$) in Table 61 and Table 62 for new construction and alterations respectively. The savings results presented include all modeled climate zones including those where the measure is not cost effective.

The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Any time code changes impact cost, there is potential to disproportionately impact DIPs. Refer to Section 2 for more details addressing energy equity and environmental justice.

Table 61: 2026 PV LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – New Construction and Additions – High Performance Windows – All Prototypes

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	68.6	30.6	99.2
2	54.2	0.00	54.2
3	113	0.00	113
4	111	0.00	111
5	118	0.00	118
6	-30.9	0.00	-30.9
7	-84.2	0.00	-84.2
8	-24.2	0.00	-24.2
9	25.3	0.00	25.3
10	38.9	0.00	38.9
11	92.4	0.00	92.4
12	44.0	0.00	44.0
13	78.4	0.00	78.4
14	108	0.00	108
15	67.9	0.00	67.9
16	-263	379	116

Table 62: 2026 PV LSC Savings Per Dwelling Unit Over 30-Year Period of Analysis – Alterations – High Performance Windows – All Prototypes

Climate Zone	30-Year LSC Electricity Savings (2026 PV$)	30-Year LSC Natural Gas Savings (2026 PV$)	Total 30-Year LSC Savings (2026 PV$)
1	1.49	347	349
2	-11.5	239	228
3	-52.7	533	480
4	-15.6	281	266
5	-75.6	541	465
6	-21.5	47.9	26.4
7	-58.1	93.1	35.0
8	-49.2	61.8	12.6
9	-35.4	101	65.9
10	-30.3	102	71.7
11	-6.19	231	225
12	-25.4	228	202
13	-0.07	178	178
14	-5.43	261	256
15	29.9	27.0	56.9
16	-214	941	727

5.4.3 Incremental First Cost

The incremental first cost for high performance windows includes material impacts only. The labor cost is not impacted and hence not included in incremental cost estimate. The incremental cost is based on the 2022 Title 24, Part 6 prescriptive requirements as baseline including a proposed correction of interchanging Climate Zone 6 and 8 U-factor requirements.

The incremental cost is determined by the product cost collection done by EPA for ENERGY STAR Specification V7 development. It is based on costs collected from manufacturers and distributors for a wide base of qualifying products across the country. The product cost database contains costs for a 5x3 window for U-factors ranging from 0.20 to 0.35 and varied SHGCs across the qualifying products. The Statewide CASE Team used this database and created a non-linear cost function to estimate costs for a given U-factor and SHGC combination. The prototype model has varying sizes of windows across the building to meet the window-to-wall area requirements. The cost per window from EPA database is translated to cost per sqft. of window and applied to the windows impacted in the proposed model. The window material costs have increased due to supply chain challenges in the last two years, but the incremental cost is assumed to be minimally impacted. The cost estimates and assumptions were vetted by industry experts and stakeholders.

Table 63 below summarizes the incremental cost estimates for high performance windows of All Other category that applies to the four prototypes evaluated including LowRiseGarden, LoadedCorridor, MidRiseMixedUse and HighRiseMixedUse. The improvement in U-factor alone from 0.30 to 0.28 costs an additional $0.50 per sqft. of window area. However, the increase in cost due to U-factor improvement from 0.30 to 0.28 is almost offset by the decrease in cost due to SHGC requirement change from a 0.23 maximum to no requirement that assumes a standard design of 0.35 in performance approach in Climate Zones 3, 5, and 16. The same costs apply to alterations scenario as well, shown in Table 64 below.

Table 63: Incremental Cost Estimate for High Performance Window Proposal (All Other)

Climate Zones	Prototype	Measure	Baseline	Proposed	Incremental Cost ($/sqft)
1	All	Specification	0.30/0.35	0.28/0.35	U-factor decrease only
		Cost ($/sqft)	17.43	17.93	0.50
2,4,5, 8-15	All	Specification	0.30/0.23	0.28/0.23	U-factor decrease only
		Cost ($/sqft)	17.93	18.43	0.50
6,7	All	Specification	0.34/0.23	0.28/0.23	U-factor decrease only
		Cost ($/sqft)	17.39	18.43	1.04
3,5,16	LowRiseGarden, LoadedCorridor	Specification	0.30/0.35	0.28/0.35	U-factor decrease only
		Cost ($/sqft)	17.43	17.93	0.50
	MidRiseMixedUse, HighRiseMixedUse	Specification	0.30/0.23	0.28/0.35	U-factor decrease, SHGC increase
		Cost ($/sqft)	17.93	17.93	0.00

Table 64: Incremental Cost Estimate for High Performance Window Proposal (All Other) – Alterations

Climate Zones	Prototype	Measure	Baseline	Proposed	Incremental Cost ($/sqft)
1,3,5,16	LowRiseGarden	Specification	0.30/0.35	0.28/0.35	U-factor decrease only
		Cost ($/sqft)	17.43	17.93	0.50
6,7	LowRiseGarden	Specification	0.34/0.23	0.28/0.23	U-factor decrease only
		Cost ($/sqft)	17.39	18.43	1.04
2,4,8-15	LowRiseGarden	Specification	0.30/0.23	0.28/0.23	U-factor decrease only
		Cost ($/sqft)	17.93	18.43	0.50

MidRiseMixedUse and HighRiseMixedUse prototype assumes a certain percentage of curtainwall/storefront or NAFS Class AW windows in the multifamily buildings. The incremental cost for proposed RSHGC requirement removal is evaluated corresponding to an increase in SHGC in Climate Zones 3, 5, and 16, as shown in Table 65 below.

Table 65: Incremental Cost Estimate for High Performance Window Proposal (Curtainwall/Storefront, NAFS Class AW)

Climate Zones	Window Category	Measure	Baseline	Proposed	Incremental Cost ($/sqft)
3,5,16	Curtainwall /Storefront	Specification	0.41/0.26	0.41/0.35	SHGC increase only
		Cost ($/sqft)	-	-	-0.45
		Specification	0.41/0.25	0.41/0.35	SHGC increase only
		Cost ($/sqft)	-	-	-0.45
	NAFS Class AW	Specification	0.40/0.24	0.4/0.35	SHGC increase only
		Cost ($/sqft)	-	-	-0.45

The percentage distribution of window category across prototypes is determined by reviewing an Evergreen Economics survey representing 805 multifamily buildings and 14,673 dwelling units in California. From the data, the Statewide CASE Team estimated that 7 percent of mid-rise and 70 percent of high-rise multifamily dwelling units are in buildings with curtainwall/storefront glazing methods (Evergreen Economics, 2020). The remainder are in buildings that use a combination of fixed and operable punched windows. Data is not available to determine the percentage of buildings that use Performance Class AW windows. The Statewide CASE Team therefore estimated their prominence based on subject matter expert opinion as applicable to the prototype buildings. Of the 93 percent of 5-story mixed-use buildings that use non-curtainwall glazing, experts estimated that 10 percent would use Performance Class AW windows. Of the 30 percent of 10-story mixed-use buildings that use non-curtainwall glazing, experts estimated 75 percent would also use Performance Class AW windows (Evergreen Economics, 2020).

Performance Class AW windows are not required for low-rise construction and are seldom specified due to their significantly higher cost. Therefore, 100 percent of 2-story and 3-story multifamily buildings fall under the proposed All Other window category. Table 66 shows these breakdowns accordingly.

Table 66: Estimated Ratio of Dwelling Units by Prototype and Prescriptive Window Category

Prototype	Curtainwall and Storefront	Performance Class AW	All Others
LowRiseGarden	0%	0%	100%
LoadedCorridor	0%	0%	100%
MidRiseMixedUse	7%	9.3%	83.7%
HighRiseMixedUse	70%	22.5%	7.5%

The weighted average incremental costs using weights and prices from tables above were further adjusted for material price differences between climate zone regions. The Statewide CASE Team calculated the factors in Table 67 based on the representative cities in each climate zone, the different trades that are involved, and the climate zone that they received costs for, which is assumed as Climate Zone 12. The incremental costs of the high performance windows measure are the same for both new construction and alterations applications.

Table 67: Incremental Climate Zone Material Cost Adjustment Factors

Climate Zone	Material Cost Adjustment Factor
1	0.92
2	0.93
3	0.96
4	0.96
5	1
6	0.97
7	1
8	0.95
9	0.94
10	0.96
11	0.96
12	1
13	1
14	0.92
15	0.92
16	0.92

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 (or savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2025 LSC hourly factors. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

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

The expected useful life of the measure is around 30 years. High performance windows do not require any additional maintenance or replacement within 30-year period. Hence no incremental maintenance or replacement costs were considered since it would be the same for baseline and proposed windows measure.

5.4.5 Cost Effectiveness

This measure proposes a primary prescriptive requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

The CEC establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with CEC 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 LSC savings from electricity and natural gas were also included in the evaluation. Design costs were not included nor were the incremental costs of code compliance verification.

According to the CEC'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 2026 PV costs and cost savings.

Results of the per unit cost-effectiveness analyses are presented in Table 68 and Table 69 as a weighted average across the four new construction multifamily prototypes.

The proposed measure saves money over the 30-year period of analysis relative to the assumed 2022 Title 24, Part 6 new construction baseline conditions. The proposed code change to remove RSHGC requirements for Curtainwall/storefront and NAFS 2017 Performance Class AW fenestration is cost effective in Climate Zones 3, 5, and 16. For All Other windows, the proposed code change of 0.28 U-factor and RSHGC update in MidRise and HighRise prototypes is proposed and cost effective in Climate Zones 1, 3-5, 11, and 13-16.

Table 68: 30-Year Cost Effectiveness Summary Per Dwelling Unit - New Construction – High Performance Windows – All Prototypes

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings [a] (2026 PV$/dwelling unit)	Costs Total Incremental PV Costs [b] (2026 PV$/dwelling unit)	B/C Ratio
1	99.2	56.3	1.76
2	54.2	57.0	0.95
3	121	22.2	5.44
4	111	58.8	1.88
5	127	23.2	5.47
6	-30.9	122	-0.25
7	-84.2	126	-0.67
8	-24.2	58.2	-0.42
9	25.3	57.6	0.44
10	38.9	58.8	0.66
11	92.4	58.8	1.57
12	44.0	61.2	0.72
13	78.4	61.2	1.28
14	108	56.3	1.91
15	67.9	56.3	1.21
16	124	21.3	5.81

Table 69: 30-Year Cost Effectiveness Summary Per Dwelling Unit - Alterations – High Performance Windows – All Prototypes

Climate Zone	Benefits: LSC Savings + Other PV Cost Savings [a] (2026 PV$/dwelling unit)	Costs Total Incremental PV Costs [b] (2026 PV$/dwelling unit)	B/C Ratio
1	349	59.8	5.83
2	228	60.4	3.76
3	500	30.9	16.2
4	266	62.4	4.26
5	485	32.2	15.1
6	26.4	130	-0.20
7	35.0	134	-0.26
8	12.6	61.8	-0.20
9	65.9	61.1	1.08
10	71.7	62.4	1.15
11	225	62.4	3.60
12	202	65.0	3.11
13	178	65.0	2.74
14	256	59.8	4.27
15	56.9	59.8	-0.95
16	745	29.6	25.2

5.5 First-Year Statewide Impacts

5.5.1 Statewide Energy and LSC Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction and additions by multiplying the per-unit savings, which are presented in Section 5.3.2, by assumptions about the percentage of newly constructed buildings and building alterations that would be impacted by the proposed code. The statewide new construction forecast for 2026 is presented in Appendix A, as are the existing multifamily building stock values provided by the CEC and the Statewide CASE Team's assumptions about the percentage of new construction and 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 completed in 2026. The 30-year LSC Savings represent the LSC Savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

The tables below present the first-year statewide energy and LSC Savings from newly constructed buildings and additions by climate zone. Table 70 and Table 71 presents first-year statewide savings from new construction/additions and alterations respectively and Table 72 presents the results rolled up to the statewide level.

The statewide impacts results do not include Climate Zones 2, 6-10, and 12 where the measure is not cost effective and hence not proposed as code change. The weighted average results are predominantly determined by All Other window category analysis since the construction forecast is dominated by LoadedCorridor and MidRiseMixedUse prototypes.

While a statewide analysis is crucial to understanding broader effects of code change proposals, there is potential to disproportionately impact DIPs that needs to be considered. Refer to Section 2 for more details addressing energy equity and environmental justice.

Table 70: Statewide Energy and Energy Cost Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Dwelling Units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	144	0.00	0.00	0.00	0.01	0.01
2	-	-	-	-	-	-
3	7,700	0.09	0.07	0.00	0.53	0.87
4	3,420	0.05	0.02	0.00	0.17	0.38
5	285	0.00	0.00	0.00	0.02	0.03
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	1,170	0.01	0.00	0.00	0.04	0.11
12	-	-	-	-	-	-
13	1,010	0.01	0.00	0.00	0.03	0.08
14	1,450	0.02	0.01	0.00	0.06	0.16
15	373	0.00	0.00	0.00	0.00	0.03
16	187	-0.01	0.00	0.00	0.04	0.02
Total	15,700	0.17	0.10	0.00	0.91	1.68

a. First-year savings from all buildings completed statewide in 2026.

Table 71: Statewide Energy and Energy Cost Impacts – Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Dwelling Units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	585	0.00	0.00	0.00	0.15	0.20
2	-	-	-	-	-	-
3	18,400	-0.15	0.00	0.07	6.99	8.85
4	9,620	-0.02	0.00	0.02	1.95	2.55
5	1,520	-0.02	0.00	0.01	0.58	0.71
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-
11	2,840	0.00	0.00	0.00	0.47	0.64
12	-	-	-	-	-	-
13	5,230	-0.01	0.00	0.01	0.67	0.93
14	2,780	0.00	0.00	0.01	0.52	0.71
15	-	-	-	-	-	-
16	935	-0.03	0.00	0.01	0.61	0.68
Total	41,900	-0.24	0.00	0.12	11.9	15.3

a. First-year savings from all alterations completed statewide in 2026.

Table 72: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (PV$ Million)
New Construction & Additions	0.17	0.10	0.00	0.91	1.68
Alterations	-0.24	0.00	0.12	11.9	15.3
Total	-0.07	0.10	0.12	12.9	17.0

5.5.2 Statewide GHG Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions associated with energy consumption using the hourly GHG emissions factors that the CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric tons of carbon dioxide equivalent emissions (metric tons CO2e).

The monetary value of avoided GHG emissions is based on a proxy for permit costs, not social costs.[61] The cost-effectiveness analysis presented in Section 5.4 of this report does not include the cost savings from avoided GHG emissions. To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from other economic impacts. Table 73 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 49 metric tons CO_2e would be avoided.

[61] The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

Table 73: First-Year Statewide GHG Emissions Impacts - High Performance Windows

Construction Type	Electricity Savings[a] (GWh/y)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/y)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
New Construction	0.17	45.0	0.00	3.61	48.6	5,980
Alterations	-0.24	-8.11	0.12	738	730	89,900
TOTAL	-0.07	36.9	0.12	742	779	95,800

a. First-year savings from all applicable newly constructed buildings, additions, and alterations completed statewide in 2026.

b. GHG emissions savings were calculated using GHG emissions factors alongside the LSC hourly factors and Source Energy hourly factors by the CEC here: https://www.energy.ca.gov/files/2025-energy-code-hourly-factors

c. The monetary value of avoided GHG emissions is based on a proxy for permit costs, not social costs, derived from the 2022 TDV Update Model published by CEC here: https://www.energy.ca.gov/files/tdv-2022-update-model

5.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

5.5.4 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 availability of krypton and argon to fill windows to meet the code requirements. However, manufacturers interviewed have reported that the proposed code changes would not require significant changes in window construction materials over the current Title 24, Part 6 multifamily code requirements. Thus, the material impact would be minimal. Popular construction materials such as mercury, lead, copper, steel, plastic, and others would not be impacted by the proposed measure.

5.5.5 Other Non-Energy Impacts

Based on stakeholder feedback, the proposed measure would not affect the installation, operation, or maintenance of fenestration at the site, so additional environmental impacts on site should be nonexistent. Any environmental impact would be associated with the manufacture of the products related to the material increase required with added higher-performing fenestration components, not construction or operation.

The proposed measure would have a positive impact on occupancy comfort, as well as providing aesthetic benefits through daylighting. On-site air quality, health, and safety would likely not be impacted.

5.6 Addressing Energy Equity and Environmental Justice

The Statewide CASE Team assessed the potential impacts of the proposed measure, and based on a preliminary review, the measure should have a positive impact on DIPs. The proposed change improves window performance which has a positive impact on energy consumption. Since DIPs pay disproportionately higher percentage of their income towards energy costs, this would result in a slight reduction in these bills.

There is an additional benefit of higher performance windows; the windows would improve the thermal comfort properties of the space by making sun lighting less impactful inside (in cooling-dominated climate zones) and this would reduce the need to turn on the air conditioner.

Lower U-factor windows would also produce an additional benefit in heating situations by reducing the heat loss out of the building and this impact can be felt by people sitting near a window. Since thermal comfort is a state of mind, the better performing windows can have a positive impact on a person’s well-being and sense of satisfaction with their environment, which can have a positive, but indirect, impact on their stress levels and other human health factors.

6. Proposed Revisions to Code Language

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 2022 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

6.2 Standards

6.2.1 Cool Roof

Section 170.2 – Prescriptive Approach.

Section 170.2 (a) 1.

1. Exterior roofs and ceilings.

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

   A. Roofing Products. All roofing products shall meet the requirements of Section 110.8 and the applicable minimum aged solar reflectance and thermal emittance requirements of TABLE 170.2-A.
   EXCEPTION 1 to Section 170.2(a)1A: Roof area covered with ~~B~~building integrated photovoltaic panels and building integrated solar thermal panels are exempt from the minimum requirements for solar reflectance and thermal emittance or SRI.

TABLE 170.2-A:

TABLE 170.2-A ENVELOPE COMPONENT PACKAGE – Multifamily Standard Building Design																			
Multifamily				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roof/Ceiling	Option B (meets §170.2(a)1Bii)	Below Roof Deck Insulation [1,2] (With Air Space)		NR	NR	NR	R19	NR	NR	NR	R19	R19	R13	R19	R19	R19	R19	R19	R13
		Ceiling Insulation		R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38
		Radiant Barrier		NR	REQ	REQ	NR	REQ	REQ	REQ	NR	NR	NR	NR	NR	NR	NR	NR	NR
		Low-sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.63	NR	0.63	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	NR	0.75	NR
			Solar Reflectance Index (SRI)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	75	NR	75	NR
		Steep-sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	~~0.2~~ 0.25	~~0.2~~ 0.25	0.2	~~0.2~~ 0.25	0.2	~~0.2~~ 0.25	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	~~0.75~~ 0.8	~~0.75~~ 0.8	0.75	~~0.75~~ 0.8	0.75	~~0.75~~ 0.8	NR
			Solar Reflectance Index (SRI)	NR	NR	NR	NR	NR	NR	NR	NR	NR	~~16~~ 23	~~16~~ 23	16	~~16~~ 23	16	~~16~~ 23	NR
	Option C (meets §170.2(a)1Biii)	Ceiling Insulation		R 38	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38
		Radiant Barrier		NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
		Low-sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.63	NR	0.63	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	NR	0.75	NR
			Solar Reflectance Index (SRI)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	75	NR	75	NR
		Steep-sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.2	0.2	0.2	0.2	0.2	0.2	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0. 75	0.75	0.75	0.75	0.75	0.75	NR
			Solar Reflectance Index (SRI)	NR	NR	NR	NR	NR	NR	NR	NR	NR	16	16	16	16	16	16	NR
	Option D (Non Attic Roof)	Metal Building U-factor		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 U-factor		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
		Low-sloped	Aged Solar Reflectance	NR	~~NR~~ 0.63	NR	~~NR~~ 0.63	NR	~~NR~~ 0.63	~~NR~~ 0.63	~~NR~~ 0.63	0.63	0.63	0.63	~~NR~~ 0.63	0.63	0.63	0.63	NR
			Thermal Emittance	NR	~~NR~~ 0.75	NR	~~NR~~ 0.75	NR	~~NR~~-0.75	~~NR~~ 0.75	~~NR~~ 0.75	0.75	0.75	0.75	~~NR~~ 0.75	0.75	0.75	0.75	NR
			Solar Reflectance Index (SRI)	NR	~~NR~~ 75	NR	~~NR~~ 75	NR	~~NR~~ 75	~~NR~~ 75	~~NR~~ 75	75	75	75	~~NR~~ 75	75	75	75	NR
		Steep-sloped	Aged Solar Reflectance	NR	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	NR
			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
			Solar Reflectance Index (SRI)	NR	16	16	16	16	16	16	16	16	16	16	16	16	16	16	NR

6.2.2 Improved Minimum Wall Insulation

Section 160.1—Mandatory Requirements for Building Envelopes

Section 160.1 (b) Wall Insulation.

1. Metal Building—The area-weighted average U-factor of the wall assembly shall not exceed 0.113.
2. Metal Framed—The area-weighted average U-factor of the wall assembly shall not exceed~~0.151~~ 0.148.
3. Wood Framed and Others:

   A. Nominal 2x4 inch framing shall have an area-weighted average U-factor of the wall assembly not exceeding ~~0.102~~ 0.095.

   B. Nominal 2x6 inch framing shall have an area-weighted average U-factor of the wall assembly not exceeding~~0.071~~ 0.069.

   C. Other wall assemblies shall have an area-weighted average U-factor of the wall assembly not exceeding 0.102.

6.2.3 High Performance Windows

Section 170.2—Prescriptive Approach.

Section 170.2 (a) 1. TABLE 170.2-A:

TABLE 170.2-A ENVELOPE COMPONENT PACKAGE – Multifamily Standard Building Design

Multifamily		Climate Zone 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Curtain Wall/ Storefront[5]	Maximum U-factor	0.38	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.38
	Maximum RSHGC ~~three or less habitable stories~~	NR	0.26	NR	0.26	NR	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.26	NR
	~~Maximum RSHGC, four or more habitable stories~~	~~0.35~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.26~~	~~0.25~~	~~0.26~~	~~0.25~~
	Minimum VT, four or more habitable stories	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
NAFS 2017 Performance Class AW[~~5~~6]	Maximum U-factor	0.38	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.38
	Maximum RSHGC ~~three or less habitable stories~~	NR	0.24	NR	0.24	NR	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	NR
	~~Maximum RSHGC, four or more habitable stories~~	~~0.35~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~	~~0.24~~
	Minimum VT, four or more habitable stories	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
All Other Fenestration	Maximum U-factor	~~0.3~~ 0.28	0.3	~~0.3~~ 0.28	~~0.3~~ 0.28	~~0.3~~ 0.28	0.34	0.34	0.3	0.3	0.3	~~0.3~~ 0.28	0.3	~~0.3~~ 0.28	~~0.3~~ 0.28	~~0.3~~ 0.28	~~0.3~~ 0.28
	Maximum RSHGC ~~three or less habitable stories~~	NR	0.23	NR	0.23	NR	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	NR
	~~Maximum RSHGC, four or more habitable stories~~	~~0.35~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~	~~0.23~~
Maximum Window to Floor Ratio		20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Maximum Window to Wall Ratio		40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Maximum Skylight Roof Ratio		5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

Footnotes to TABLE 170.2-A

5: Requirements apply to doors included in the Curtainwall/Storefront construction assembly

~~5~~6: Product must be certified to meet the North American Fenestration Standard/Specification for an Architectural Window (AW).

Section 180.2 1. TABLE 180.2-B:

Table 180.2-B Altered 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**
Curtainwall / Storefront / Window Wall ~~and Glazed Doors~~[1]	U-factor	0.38	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.38
Curtainwall / Storefront / Window Wall ~~and Glazed Doors~~[1]	RSHGC	~~0.35~~ NR	0.26	~~0.26~~ NR	0.26	~~0.26~~ NR	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	~~0.25~~ NR
Curtainwall / Storefront / Window Wall ~~and Glazed Doors~~[1]	VT[2]	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
NAFS 2017 Performance Class AW Window – Fixed~~[1]~~	U-factor	0.38	0.38	0.38	0.38	0.38	0.47	0.47	0.41	0.41	0.38	0.38	0.38	0.38	0.38	0.38	0.38
NAFS 2017 Performance Class AW Window – Fixed~~[1]~~	RSHGC	~~0.35~~ NR	0.25	~~0.25~~ NR	0.25	~~0.25~~ NR	0.31	0.31	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	~~0.25~~ NR
NAFS 2017 Performance Class AW Window – Fixed~~[1]~~	VT[2]	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
NAFS 2017 Performance Class AW Window – Operable~~[1]~~	U-factor	0.43	0.43	0.43	0.43	0.43	0.47	0.47	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
NAFS 2017 Performance Class AW Window – Operable~~[1]~~	RSHGC	~~0.35~~ NR	0.24	~~0.24~~ NR	0.24	~~0.24~~ NR	0.31	0.31	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	~~0.24~~ NR
NAFS 2017 Performance Class AW Window – Operable~~[1]~~	VT[2]	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
All Other Windows and Glazed Doors~~[1]~~	U-factor	~~0.3~~ 0.28	0.3	~~0.3~~ 0.28	~~0.3~~ 0.28	~~0.3~~ 0.28	0.3	0.34	0.3	0.3	0.3	~~0.3~~ 0.28	0.3	~~0.3~~ 0.28	~~0.3~~ 0.28	~~0.3~~ 0.28	~~0.3~~ 0.28
All Other Windows and Glazed Doors~~[1]~~	RSHGC	~~0.35~~ NR	0.23	~~0.23~~ NR	0.23	~~0.23~~ NR	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	~~0.23~~ NR
Skylights, 3 habitable stories and fewer	U-factor	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Skylights, 3 habitable stories and fewer	RSHGC	NA	0.23	NA	0.23	NA	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	NA
Skylights, 4 habitable stories and greater	U-factor	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Skylights, 4 habitable stories and greater	RSHGC	0.35	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	0.25	0.25
Skylights, 4 habitable stories and greater	VT[2]	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49

Footnotes to TABLE 180.2-B

~~**1. For fenestration installed in buildings with three or fewer habitable stories, there is no SHGC requirement in Climate Zones 1, 3, 5, and 16.**~~

1: Requirements apply to doors included in the Curtainwall/Storefront construction assembly

2. Minimum VT requirements to not apply to multifamily buildings 3 habitable stories or less

6.3 Reference Appendices

No proposed changes to the Reference Appendices.

6.4 ACM Reference Manual

No proposed changes to the ACM Reference Manual except changes to prescriptive or mandatory standards used in standard design.

6.5 Compliance Documents

Prescriptive method documents would have to be updated to match new prescriptive proposed requirements of cool roof and vertical fenestration measure. For vertical fenestration, an additional verifications step is required to ensure the modeled and installed specifications do not vary by more than +/- 0.01.

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Appendix A: Statewide Savings Methodology

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts that the CEC provided (California Energy Commission, 2022; California Energy Commission, 2022). The CEC provided the construction estimates on February 15, 2023.

For Multifamily

The Statewide CASE Team followed guidance provided in the CEC's New Measure Proposal Template, developed by the CEC, to calculate statewide energy savings using the CEC's construction forecasts, including a request to assume a statewide weighting as follows: Low-Rise Garden (four percent), Low-Rise Loaded Corridor (33 percent), Mid-Rise Multifamily (58 percent) and High-Rise Multifamily (five percent). See Section 3.3.2 of the CEC's New Measure Proposal Template.

The Statewide CASE Team did not make any changes to the CEC's construction estimates.

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by the CEC's statewide construction forecasts. The Statewide CASE Team made assumptions about the percentage of buildings in each climate zone that would be impacted by the proposed code change. The number of dwelling units in newly constructed multifamily buildings that the Statewide CASE Team assumed would be impacted by the proposed code change during the first year the 2025 code is in effect are presented in Table 74 through Table 76.

Table 74: Estimated New Construction Building Stock for Multifamily Buildings by Climate Zone- Cool Roof

Building Climate Zone	Total Dwelling Units Completed in 2026 (New Construction) [A]	Percent of New Dwelling Units Impacted by Proposal [B]	New Dwelling Units Impacted by Proposal in 2026 C = A x B
1	144	0%	0
2	1391	96%	1335
3	7699	0%	0
4	3417	96%	3280
5	285	0%	0
6	2243	96%	2153
7	5156	96%	4950
8	8600	96%	8256
9	10302	0%	0
10	4306	4%	172
11	1173	4%	47
12	5537	96%	5316
13	1009	4%	40
14	1446	0%	0
15	373	4%	15
16	187	0%	0
TOTAL	**53268**	**48%**	**25565**

Source: https://www.energy.ca.gov/media/3538

Table 75: Estimated New Construction Building Stock for Multifamily Buildings by Climate Zone- Minimum Wall Insulation

Building Climate Zone	Total Dwelling Units Completed in 2026 (New Construction) [A]	Percent of New Dwelling Units Impacted by Proposal [B]	New Dwelling Units Impacted by Proposal in 2026 C = A x B
1	144	100%	144
2	1391	100%	1391
3	7699	100%	7699
4	3417	100%	3417
5	285	100%	285
6	2243	100%	2243
7	5156	100%	5156
8	8600	100%	8600
9	10302	100%	10302
10	4306	100%	4306
11	1173	100%	1173
12	5537	100%	5537
13	1009	100%	1009
14	1446	100%	1446
15	373	100%	373
16	187	100%	187
TOTAL	**53268**	**100%**	**53268**

Table 76: Estimated New Construction Building Stock for Multifamily Buildings by Climate Zone- Improved High Performance Windows

Building Climate Zone	Total Dwelling Units Completed in 2026 (New Construction) [A]	Percent of New Dwelling Units Impacted by Proposal [B]	New Dwelling Units Impacted by Proposal in 2026 C = A x B
1	144	100%	144
2	1391	0%	0
3	7699	100%	7699
4	3417	100%	3417
5	285	100%	285
6	2243	0%	0
7	5156	0%	0
8	8600	0%	0
9	10302	0%	0
10	4306	0%	0
11	1173	100%	1173
12	5537	0%	0
13	1009	100%	1009
14	1446	100%	1446
15	373	100%	373
16	187	100%	187
TOTAL	**53268**	**30%**	**15733**

For alterations analysis of high-performance windows measure, it is assumed that windows have a life expectancy of 30 years and hence the total dwelling units are multiplied to 1/30th of the existing building stock in each climate zone for All Other window category. The percentage of new dwelling units impacted by the alterations proposal is approximately three percent of total existing dwelling units in each of the relevant climate zones. Table 77 provides the estimated affected alterations building stock by climate zone.

Table 77: Estimated Alterations Building Stock for Multifamily Buildings by Climate Zone- Improved High Performance Windows

Building Climate Zone	Total Existing Dwelling Units in 2026 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	17,558	3.3%	585
2	105,894	0%	0
3	553,186	3.3%	18,421
4	288,786	3.3%	9,617
5	45,671	3.3%	1,521
6	322,513	0%	0
7	307,272	0%	0
8	515,137	0%	0
9	1,117,605	0%	0
10	329,302	0%	0
11	85,339	3.3%	2,842
12	471,876	0%	0
13	157,075	3.3%	5,231
14	83,480	3.3%	2,780
15	41,152	0%	0
16	28,066	3.3%	935
TOTAL	**4,310,108**	**0.9%**	**41,930**

The CEC Building Standards Office provided the multifamily residential construction forecast, which is available for public review on the CEC's website: https://www.energy.ca.gov/media/3538

The construction forecast presents total 53,268 of newly constructed multifamily dwelling units in 2026 by building type and climate zone. The building types included in the CECs' forecast are summarized in Appendix A of the California Energy Commission Measure Proposal Template linked here: https://www.energy.ca.gov/media/3538.

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

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

Introduction

The purpose of this appendix is to present proposed revisions to CBECC for multifamily buildings along with the supporting documentation that the CEC staff and the technical support contractors would need to approve and implement the software revisions.

Technical Basis for Software Change

The envelope measures have been a part of Title24 code and CBECC software already. The change in prescriptive requirements affects the Standard Design against which a proposed model is being compared. The energy budget of Standard Design is improved correspondingly and hence the software is required to make a change in Standard Design to update according to the change in prescriptive requirements. The change in mandatory requirement threshold do not necessarily affect the Standard Design energy budget, but changes the flexibility allowed to make trade-offs in Performance approach. The software incorporates these backstops as checks in CBECC ruleset.

Description of Software Change

Background Information for Software Change

The change in Standard Design outlined in ACM Reference Manual is required for both cool roof and high-performance window measure related code updates. It applies to multifamily buildings in climate zones where the code change is proposed as described in Section 6.2.

This CASE study also proposed change in mandatory requirements for exterior wall insulation to reduce the maximum U-factor for metal framed, wood framed, and other walls to align with a similar measure proposal done by a 2025 CASE study for single family buildings. The proposed update to the mandatory requirements for wall insulation referred in Section 4.1.5 is required to be included in software ruleset checks to disallow wall insulation that has a higher U-factor than the new maximum mandatory requirement.

Existing CBECC Building Energy Modeling Capabilities

Existing inputs for roof and window construction are adequate in CBECC, no change is required. Existing ACM Reference Manuals provide a comprehensive set of modeling rules for wall construction. Input restrictions consists of construction assembly U-factors to be equal or more efficient than the current mandatory requirements.

Summary of Proposed Revisions to CBECC

There are no recommended revisions to the compliance software as a result of this code change proposal except updating the ruleset to check for updated mandatory wall insulation requirement and compare Proposed Design to updated Standard Design informed by the cool roof and high-performance window measure.

User Inputs to CBECC

No user inputs need to be added or modified in the user interface for this proposed software change. All relevant inputs are already existing in current software capabilities.

Simulation Engine Inputs

EnergyPlus California Simulation Engine Inputs

No change in EnergyPlus California simulation engine inputs is required as a result of the proposed change.

Calculated Values, Fixed Values, and Limitations

For vertical fenestration, the CBECC software calculates a weighted average of U-factor and RSHGC of all windows modeled, if they vary by orientation and location. The RSHGC further accounts for exterior shading elements like overhang or slats in addition to SHGC of the window products being modeled. The calculations are same as 2022 Title24 code and do not require any changes in software.

Simulation Engine Output Variables

No change expected in simulation output variables as a result of the proposed code changes.

Compliance Report

CBECC generates a Title 24 Compliance Report that presents the results of the building's compliance analysis. For high performance window measure, the compliance report should include detailed schedule of all windows being modeled to support the verification process that uses a weighted average of input specifications.

Compliance Verification

The Cool Roof measure would increase the stringency for steep sloped roofs and extend the measure for low sloped roofs to additional climate zones. Building department officials are used to verifying cool roof measures, and this change would not add to building departments' burden of verifying compliance. There would need to be some training on the climate zones which previously do not now have low-sloped roof requirements but would under this proposal. This training can be accomplished through the Energy Code Ace team.

Description of Changes to ACM Reference Manual

This section summarizes changes to the ACM Reference Manual and how this ties back to the software change described in the sections above. Refer to Section 6 of the CASE Report for marked up language.

Appendix D: Environmental Analysis

Potential Significant Environmental Effect of Proposal

The CEC is the lead agency under the California Environmental Quality Act (CEQA) for the 2025 Energy Code and must evaluate any potential significant environmental effects resulting from the proposed standards. A "significant effect on the environment" is "a substantial adverse change in the physical conditions which exist in the area affected by the proposed project." (Cal. Code Regs., tit. 14, § 15002(g).)

The Statewide CASE Team has considered the environmental benefits and adverse impacts of its proposal including, but not limited to, an evaluation of factors contained in the California Code of Regulations, Title 14, section 15064 and determined that the proposal would not result in a significant effect on the environment.

Mitigation Measures

The Statewide CASE Team has considered opportunities to minimize the environmental impact of the proposal, including an evaluation of "specific economic, environmental, legal, social, and technological factors." (Cal. Code Regs., tit. 14, § 15021.) The Statewide CASE Team did not determine this measure would result in significant direct or indirect adverse environmental impacts and therefore, did not develop any mitigation measures.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Embodied Carbon in Materials

Accounting for embodied carbon emissions is important for understanding the full picture of a proposed code change's environmental impacts. The embodied carbon in materials analysis accounts specifically for emissions produced during the "cradle-to-gate" phase: emissions produced from material extraction, manufacturing, and transportation. Understanding these emissions ensures the proposed measure considers these early stages of materials production and manufacturing instead of emissions reductions from energy efficiency alone.

The Statewide CASE Team calculated emissions impacts associated with embodied carbon from the change in materials because of the proposed measures. The calculation builds off the materials impacts outlined in Section 5.5.3, see that section for more details on the materials impact analysis.

After calculating the materials impacts, the Statewide CASE Team applied average embodied carbon emissions for each material. The embodied carbon emissions are based on industry-wide environmental product declarations (EPDs).[62, 63] These industry-wide EPDs provide global warming potential (GWP) values per weight of specific materials.[64] The Statewide CASE Team chose the industry-wide average for GWP values in the EPDs because the materials accounted for in the statewide calculation will have a range of embodied carbon; i.e. some materials like concrete have a wide range of embodied carbon depending on the manufacturer's processes, source of the materials, etc. The Statewide CASE Team assumes that most building projects would not specify low embodied carbon products. Therefore, an average is appropriate for a statewide estimate.

First-year statewide impacts per material in pounds were multiplied by the GWP impacts for each material. This provides the total statewide embodied carbon impact for each material. If a material's use is increased, then there is an increase in embodied carbon impacts causing additional emissions. If a material's use is decreased, then there is a decrease in embodied carbon impacts and emissions are reduced. The total emissions reductions from this measure are the total GHG emissions reductions from Section 5.5.2 combined with emissions reductions or additions from embodied carbon in Section 5.5.4.

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[62] EPDs are documents that disclose a variety of environmental impacts, including embodied carbon emissions. These documents are based on lifecycle assessments on specific products and materials. Industry-wide EPDs disclose environmental impacts for one product for most or all manufacturers in a specified area and are often developed through the coordination of multiple manufacturers or associations. A manufacturer specific EPD only examines one product from one manufacturer. Therefore, an industry-wide EPD discloses all the environmental impacts from the entire industry for a specific product/material, but a manufacturer EPD only factors one manufacturer.

[63] An industry-wide EPD was not used for mercury, lead, copper, plastics, and refrigerants. Global warming potential values for mercury, lead, and copper are based on data provided in a Lifecycle Assessment (LCA) conducted by Yale University in 2014. The GWP value for plastic is based on a LCA conducted by Franklin Associates, which captures roughly 59 percent of the total U.S. production of PVC and HDPE. The GWP values for refrigerants are based on data provided by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.

[64] GWP values for concrete and wood were in units of kg CO_2 equivalent by volume of the material rather than by weight. An average density of each material was used to convert volume to weight.

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

This appendix discusses how the recommended compliance process, which is described in Section 3.1.5, Section 4.1.5 and Section 5.1.5, could impact various market actors. Table 78 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they are responsible, how the proposed code change could impact their existing workflow, and the ways negative impacts could be mitigated. The information contained is a summary of the 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 78: Roles of Market Actors in the Proposed Compliance Process—Multifamily Envelope Measures

Market Actor	Task(s) in current compliance process relating to the CASE measure	How would the proposed measure impact the current task(s) or workflow?	How would the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
Architect or Designer	• Ensure compliance with mandatory Title 24, Part 6 requirements, including fire safety. • Design and specify materials in construction assembly that meet the requirements. • Primary coordinator with other entities. • Document energy efficiency specifications and related details on building plans and schedules such as use of roofing, wall insulation, window NFRC rating, Performance NAFS Class AW windows, exterior wall fire ratings. • Color designers inform color choices for exterior aesthetics such as roofs.	• Improved mandatory and prescriptive thresholds would dictate alternative construction assemblies to meet the energy code. • Specify the roofing performance values in climate zones, adding a new cool roof in climate zones with no requirement previously. • Color designers would have slightly reduced color options for steep-sloped roofs.	Added detail to communicate to construction team including builders, contractors.	• N/A (Minor addition for few climate zones) • Manufacturers should release a list of cool roof compliance materials, especially for steep-sloped roofs, specifying color options (For example, Eagle Roofing).
Energy Consultant	• Determine compliance path and applicable energy code requirements. • Coordinate with other team members to support energy code compliance. • Complete compliance documents for permit application.	Slight increase in stringency, no significant workflow change.	Slight increase in compliance process to meet additional efficiency criteria, nothing out of ordinary for code cycle change.	EnergyCodeAce's Training
Contractors	• Follow plans and install per specifications. • Ensure procurement of compliant materials	N/A	Same materials just higher density for wall insulation.	N/A

Market Actor	Task(s) in current compliance process relating to the CASE measure	How would the proposed measure impact the current task(s) or workflow?	How would the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
HERS Rater	Follow protocol for on-site verification of wall insulation installation, when QII required for compliance.	N/A	N/A	N/A
Plans Examiner or Building Inspector (PEBI)	• Review installation of envelope components to align with plans and energy code compliance documents. • Review Performance NAFS Class AW and exterior wall fire ratings on plans and compliance documentation. • Check if plans and specifications match the documents. • Check if compliance documents match the requirements.	• Added check for cool roof requirement in climate zones with no requirement currently. • Check for added or improved envelope requirements. • Would require windows field inspection to check if the modeled and installed U-factor and RSHGC do not differ by more than +/- 0.01.	Added stringency to examine.	Not required, regular EnergyCodeAce training would cover it.
Distributors	• Stock the appropriate materials to meet compliance.	• May have to adjust the stock to increase the supply of materials meeting new demand for window products with SHGCs around 0.35 and steep-sloped cool roof requirement.	N/A.	Covered in EnergyCodeAce training.
Manufacturers	Produce enough quantity of suitable range of products.	• Potentially adjust product line. • May need more production accessible for cool roof steep-sloped products with ASR 0.25.	N/A.	Manufacturers should release a list of cool roof compliance materials, especially for steep-sloped roofs, specifying color options (For example, Eagle Roofing).

Appendix F: Summary of Stakeholder Engagement

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

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2025 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
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for High Performance Envelope via webinar described in Table 79. 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 79: Utility-Sponsored Stakeholder Meetings

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round Nonresidential, Multifamily, Single family Envelope Utility-Sponsored Stakeholder Meeting	Tuesday, February 14, 2023	Nonresidential, Multifamily, Single Family Envelope Utility-Sponsored Stakeholder Meeting | Title 24 Stakeholders
Second Round of Multifamily HVAC and Envelope Utility-Sponsored Stakeholder Meeting	Wednesday, May 17, 2023	Single Family Buried Ducts & High Performance Windows, Multifamily Envelope, and Indoor Air Quality Utility-Sponsored Stakeholder Meeting | Title 24 Stakeholders

The first round of utility-sponsored stakeholder meetings occurred in February 2023 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 2025 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 is scheduled for May 2023 and will provide updated details on proposed code changes; 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 3,000 individuals, and a second email was sent to a targeted list of individuals on the listserv based on their subscription preferences. The Title 24 Stakeholders website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders LinkedIn page and cross-promoted on the CEC's LinkedIn page two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted into the listserv. Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report.

In October 2022 through January 2023, the Statewide CASE Team conducted an outreach campaign to engage stakeholders in the multifamily design, consultation, construction, roofing, fenestration, and insulation industries. This outreach was designed to engage stakeholders with a history of engagement in the Title 24 development process, or a significant professional interest in the outcome of multifamily envelope measure development.

The goal of this outreach campaign was to gather expertise and professional input on the current products, markets, costs, standards, and practices that would be impacted by changes to California Title 24, Part 6 multifamily envelope code. To this end, the Statewide CASE Team focused on engaging in long-form one-on-one interviews with industry experts. Table 80 provides a summary of industry experts the Statewide CASE Team was able to engage during the measure development process. This list represents both stakeholders that were interviewed and those whom the Statewide CASE Team engaged in written exchanges that provided crucial industry knowledge and feedback. Table 81 provides a list of the engaged stakeholders for this effort.

Table 80: Summary of Stakeholder Engagement

Stakeholder Type	Number of Individuals Contacted	Number of Individuals Engaged	Number of Organizations Engaged
Developer	1	1	1
Designers	2	2	2
Energy Consultants	3	3	3
HERS Raters or ATTs	2	1	1
Industry Associations	5	6	6
Manufacturer	8	6	6
Regulatory Agency	3	2	1
Distributor	1	1	1
Total	**25**	**22**	**21**

Table 81: Engaged Stakeholders

Organization/Individual Name	Market Role	Do they serve majority Affordable Housing Properties?
Andersen Windows	Manufacturers	N/A
Asphalt Roofing Manufacturers Association (ARMA) / Aaron R. Phillips	Industry Associations	N/A
Beyond Efficiency	Designers; Energy Consultants	N/A
Birch Point Consulting / Thomas Culp	Energy Consultants	N/A
CalCERTS	HERS Raters or ATTs	Market Rate
Cool Roof Rating Council	Industry Associations	N/A
Eagle Roofing	Manufacturers	N/A
Enercomp, Inc. / Ken Nittler	Energy Consultants	N/A
Environmental Protection Agency / Doug Anderson	Regulatory Agency	N/A
Environmental Protection Agency / Rebecca Hudson	Regulatory Agency	N/A
Guttmann & Blaevoet Consulting Engineers / Ted Tiffany	Designers	Primarily Affordable
International Institute of Building Enclosure Consultant / Emily Lorenz	Industry Associations	N/A
Jel-Wen Windows / Steve Strawn	Manufacturers	N/A
Malarkey Roofing / John Kouba	Manufacturers	N/A
National Coil Coating Association / David A. Cocuzzi	Industry Associations	N/A
National Core / Tim Kohut	Developer	Affordable
Pella	Manufacturers	N/A
Service Partners / Josh Boone	Distributor	N/A
Sika / Steve Dublin	Manufacturers	N/A
Simpson Gumpert & Heger / Kenneth Klein	Energy Consultants	N/A
Single Ply Roofing Industry / Mike Ennis	Industry Associations	N/A
Tile Roofing Industry Alliance / Rick Olson	Industry Associations	N/A

Appendix G: LSC Savings in Nominal Dollars

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost-effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost effectiveness using 2026 PV$ are presented in Sections 3.4 and 5.4 of this report. This appendix presents LSC Savings in nominal dollars. Table 82 through Table 85 provide LSC savings over a 30 year period for the analysis conducted in this report.

Table 82: Nominal LSC Savings Over 30-Year Period of Analysis—Per Dwelling Unit, Steep-Sloped New Construction, Cool Roof

Climate Zone	30-Year Lifecycle Electricity Cost Savings (Nominal $)	30-Year Lifecycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Lifecycle LSC Savings (Nominal $)
1	-105	-40.0	-145
2	-49.7	0.00	-49.7
3	-104	0.00	-104
4	91.5	0.00	91.5
5	-153	0.00	-153
6	72.4	0.00	72.4
7	166	0.00	166
8	346	0.00	346
9	294	0.00	294
10	142	0.00	142
11	161	0.00	161
12	110	0.00	110
13	183	0.00	183
14	72.3	0.00	72.3
15	339	0.00	339
16	177	-413	-236

Table 83: Nominal LSC Savings Over 30-Year Period of Analysis—Per Dwelling Unit, Low-Sloped New Construction, Cool Roof

Climate Zone	30-Year Lifecycle Electricity Cost Savings (Nominal $)	30-Year Lifecycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Lifecycle LSC Savings (Nominal $)
1	-42.9	-38.5	-81.4
2	366	0.00	366
3	-64.2	0.00	-64.2
4	495	0.00	495
5	-106	0.00	-106
6	372	0.00	372
7	760	0.00	760
8	850	0.01	850
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	786	0.00	786
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	458	-395	63.3

Table 84: Nominal LSC Savings Over 30-Year Period of Analysis—Per Dwelling Unit, New Construction, High Performance Windows

Climate Zone	30-Year Lifecycle Electricity Cost Savings (Nominal $)	30-Year Lifecycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Lifecycle LSC Savings (Nominal $)
1	155	81.7	237
2	123	0	123
3	255	0	255
4	250	0	250
5	267	0	267
6	-69.9	0	-69.9
7	-191	0	-191
8	-54.8	0	-54.8
9	57.3	0	57.3
10	88.1	0	88.1
11	209	0	209
12	99.6	0	99.6
13	177	0	177
14	244	0	244
15	154	0	154
16	-594	1010	414

Table 85: Nominal LSC Savings Over 30-Year Period of Analysis—Per Dwelling Unit, Alterations, High Performance Windows

Climate Zone	30-Year Lifecycle Electricity Cost Savings (Nominal $)	30-Year Lifecycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Lifecycle LSC Savings (Nominal $)
1	3.38	925	929
2	-25.9	637	611
3	-119	1420	1300
4	-35.2	750	714
5	-171	1440	1270
6	-48.7	128	78.9
7	-131	248	117
8	-111	165	53.2
9	-80.1	270	190
10	-68.7	272	203
11	-14.0	615	601
12	-57.6	607	549
13	-0.17	476	476
14	-12.3	695	683
15	67.7	71.9	140
16	-485	2510	2020

Appendix H: Parametric Analysis: LSC Energy vs SHGC Trends

This section demonstrates the results of parametric energy simulations conducted for the four multifamily prototypes and how the LSC energy varies with SHGC for different U-factor levels of windows.

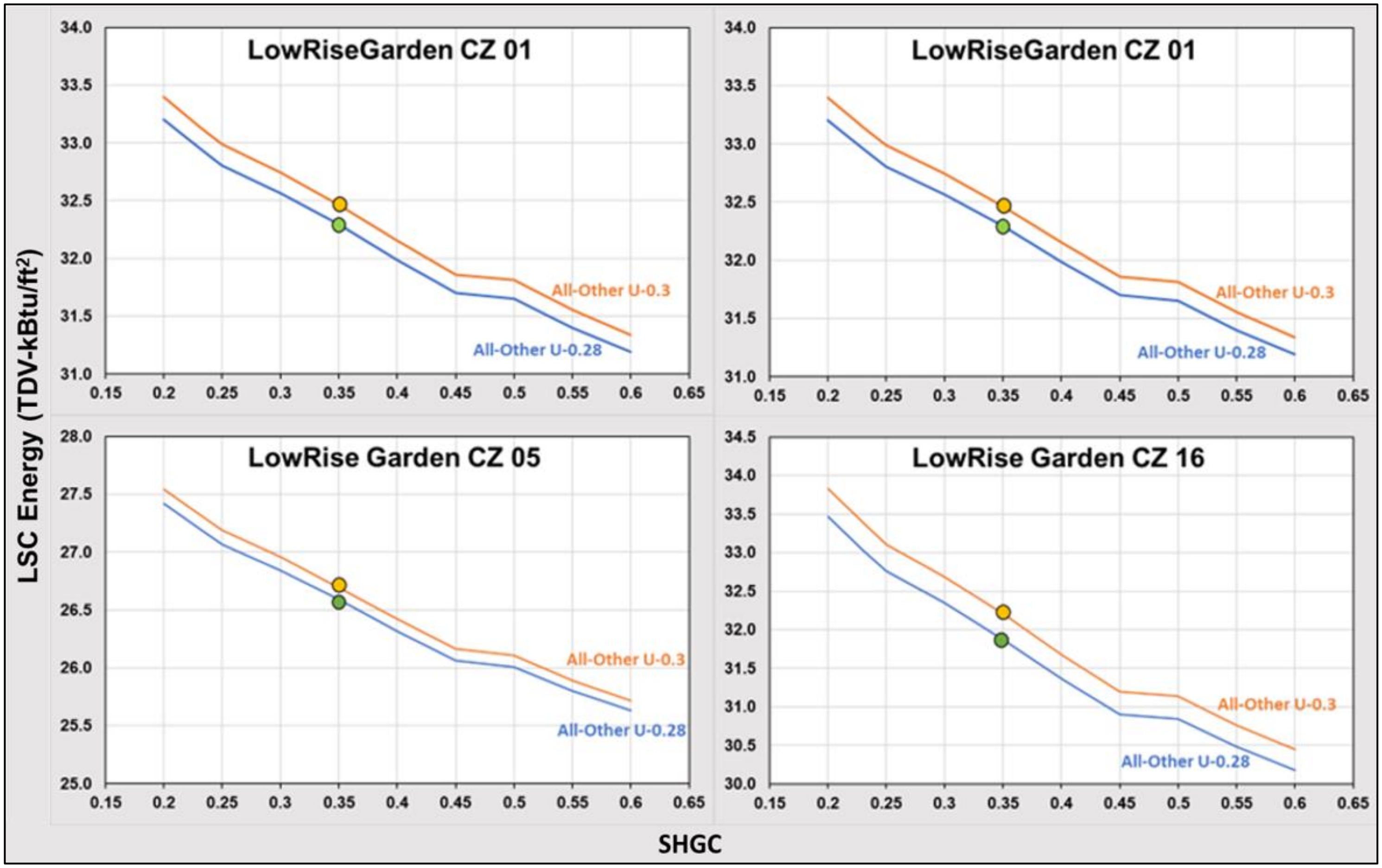

Figure 5: Parametric analysis: LSC energy vs. SHGC trends – LowRiseGarden

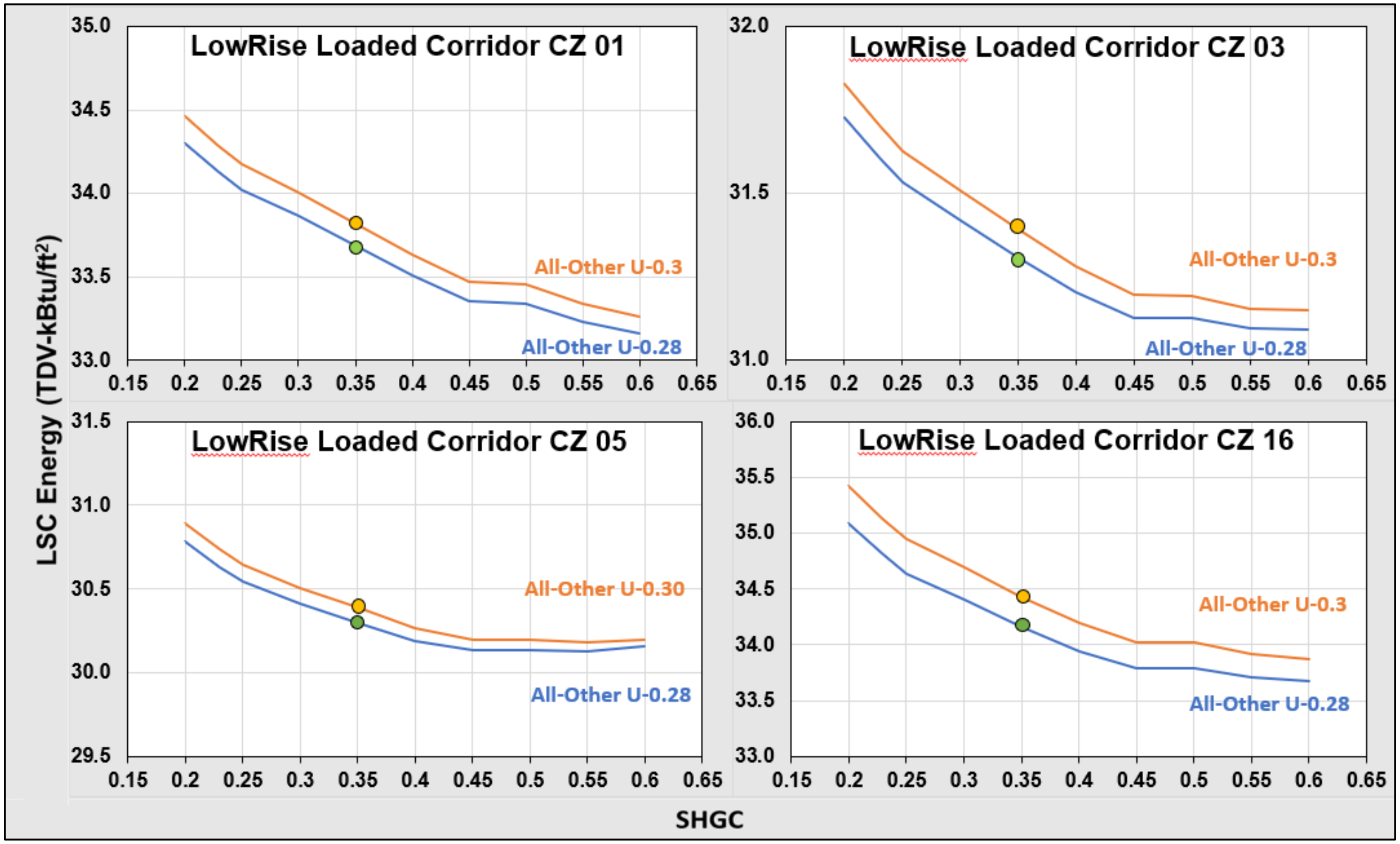

Figure 6: Parametric analysis: LSC energy vs. SHGC trends – LowRiseLoadedCorridor

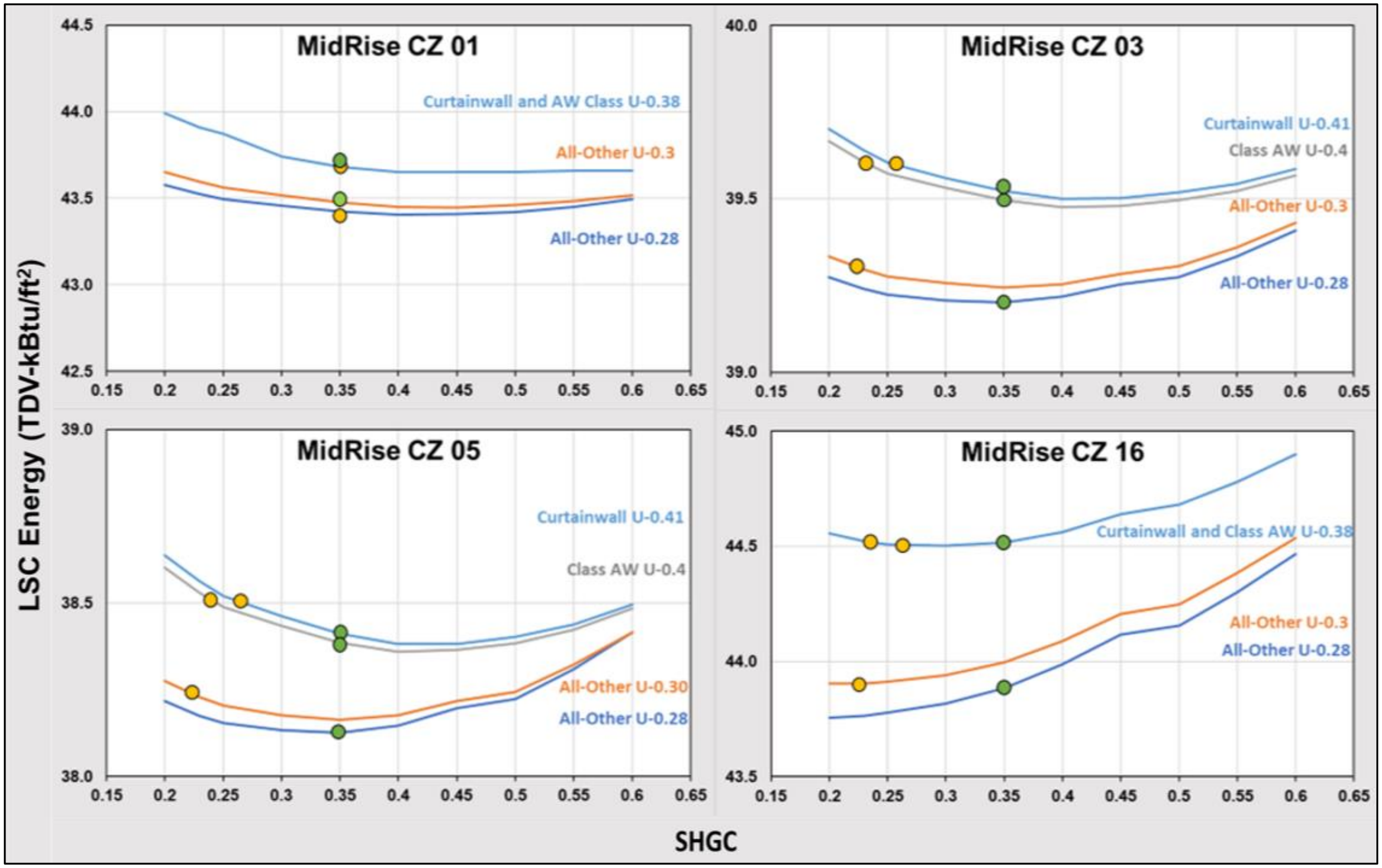

Figure 7: Parametric analysis: LSC energy vs. SHGC trends - MidRiseMixedUse

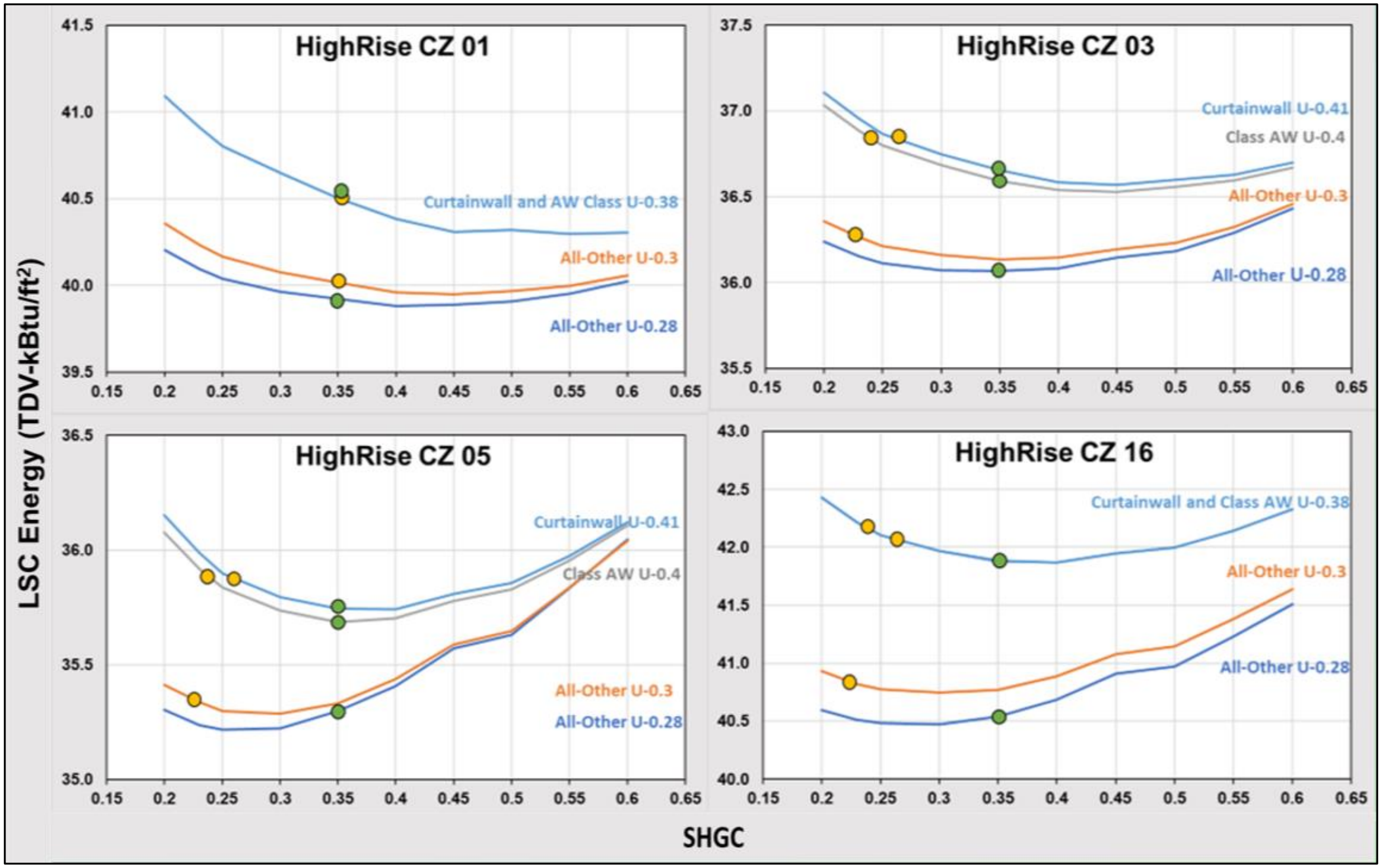

Figure 8: Parametric analysis: LSC energy vs. SHGC trends - HighRiseMixedUse