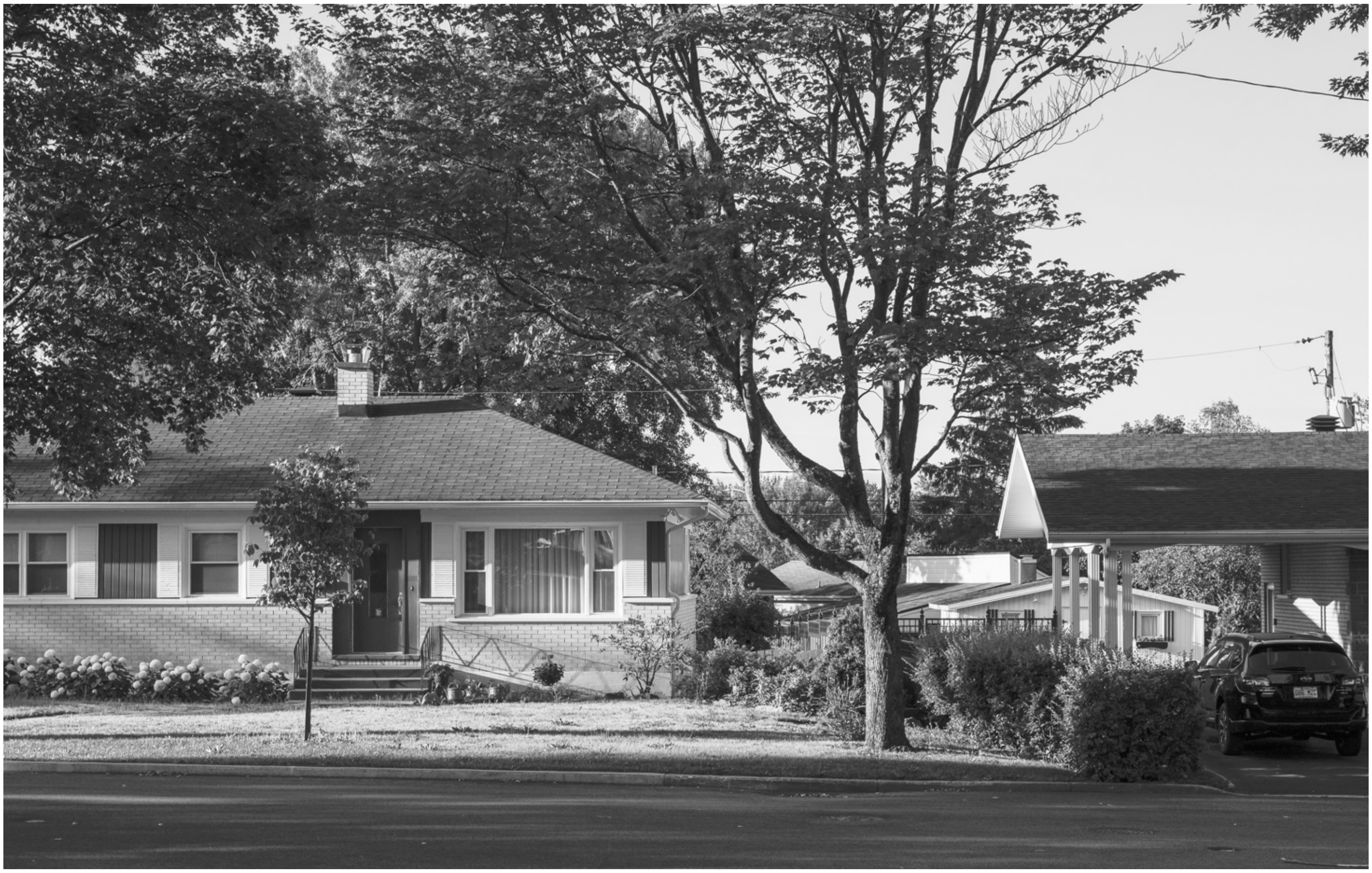
Codes and Standards Enhancement (CASE) Initiative

2025 California Energy Code

Single Family High-Performance Windows and Walls



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Simon Pallin, Frontier Energy, Inc.

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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

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Authors:	Simon Pallin, Claudia Pingatore, Alea German (Frontier Energy)
Prime Contractor	Frontier Energy
Project Management:	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Sacramento Municipal Utility District, and Los Angeles Department of Water and Power.
Revisions as of 10/16/2023	This document contains the following revisions: 1. Moved references to embodied carbon from executive summary and material impacts sections to Appendix D. 2. Updated Appendix I, and added a full suite of per-unit and statewide energy savings for window prescriptive U-factors, which use heat pump space heaters as a baseline in newly constructed homes (and as presented by the CEC at the August 2023 workshop). 3. Added language in the Executive Summary and the Measure Description sections stating that the CEC is moving forward with the proposal as reflected in Appendix I. 4. Corrected units & figures in Table 3 in the Executive Summary. 5. Corrected values in Table 14 and 15 by removing the word "Millions" in column headings (to denote units).

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Executive Summary

Understanding the California Energy Commission's (CEC) priority for statewide energy savings, simplifying code structure and requirements, and streamlining compliance and enforcement, this CASE Report presents a cost-effective code change proposal for high performance windows and updated mandatory R-value requirements for framed walls.

The proposed window measure would:

- Reduce statewide peak demand energy use by 0.5 MW in the first year.
- Provide a return on investment in as low as five years or less.
- Provide a return on the investment in as few as five years or less.
- Save 1.48 GWh of electricity and 0.40 Million Therms of natural gas in the first year statewide, in newly constructed homes.
- Save 62.55 kBtu of energy over the lifetime of the measure in new homes.

The code change proposals in this report would:

- Reduce the prescriptive maximum U-factor requirement of window assemblies in most homes to 0.27 in California Climate Zones 1 through 6 and 8 through 16 and to 0.28 in Climate Zone 7. Reduce the prescriptive U-factor requirement in homes 500 square feet or less to 0.27 in Climate Zones 1 through 4, 11 through 14, and 16.
    - Note: The CEC is moving forward with a U-factor proposal that differs from what is stated and evaluated in this CASE report. The description, energy savings, and cost-effectiveness of the revised proposal are presented in Appendix I.
- Require that installed windows match modeled solar heat gain coefficient (SHGC) values with a margin of ±0.01 in all climate zones.
- Reduce the mandatory U-factor requirement to 0.40 for all climate zones.
- Increase required minimum cavity insulation from R-13 to R-15 for 2 x 4 wood framed wall assemblies, and R-20 to R-21 for 2 x 6 assemblies.

Windows and walls can be a significant source of heat gain or loss within a home, which can lead to wasted Heating, Ventilation, and Air Conditioning (HVAC) system energy use. Therefore, these envelope components have been the subject of building energy code revision through many code cycles, including this current proposal. The two measures in this proposal call for a change in material and assembly thermal performance characteristics whose relationship to energy use is understood and modeled. In both cases, the performance characteristic is the assembly U-factor.

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

The Statewide CASE Team submits code change proposals to the CEC, the state agency that has authority to adopt revisions to Title 24, Part 6. The CEC will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The CEC may revise or reject proposals. See the CEC's 2025 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency.

High-Performance Windows

Proposed Code Change

This proposed measure has three components:

- Reduce the prescriptive maximum U-factor requirement of window assemblies in most homes from 0.30 to 0.27 for all California climate zones except for 7, for which the proposed U-factor is 0.28. Small homes 500 square feet or less would lower the prescriptive U-factor requirement to 0.27 in Climate Zones 1 through 4 , 11 through 14, and 16.
    - Note: The CEC is moving forward with a proposal that differs from what is presented in this report and bases cost-effectiveness results on new homes with a heat pump space heater in alignment with the CEC's heat pump baseline proposal for the 2025 Energy Code. The revised proposal is to reduce the prescriptive maximum U-factor requirement of window assemblies from 0.30 to 0.27 in Climate Zones 1 through 5, 11 through 14, and 16. All other Climate Zones are not affected by the proposed change. For small homes, the proposal includes to lower the maximum U-factor from 0.30 to 0.27 in Climate Zones 1 through 4, 11 through 14, and 16.

For alterations, the revised proposal would require a maximum U-factor of 0.27 in all Climate Zones. The description, energy savings, and cost-effectiveness of the revised proposal are presented in Appendix I.

- Require that installed windows match modeled solar heat gain coefficient (SHGC) values with a margin of ±0.01 in all climate zones.
- Reduce the mandatory U-factor requirement for all climate zones.

For windows, products with the proposed characteristics are readily available, using either double-paned or triple-pane glazing with additional features such as low-e films or use of argon or krypton gas between the panes. Therefore, the Environmental Protection Agency (EPA) is enacting similar U-factor changes in the latest updates to ENERGY STAR® window criteria (Version 7). Such national changes would promote code compliance within California given increased product availability, lower cost, and ease of design specifications resulting from increased consistency. All window manufacturers engaged for stakeholder feedback confirmed that windows compliant with ENERGY STAR requirements are already part of their production line.

Table 1: Scope of Mandatory Code Change Proposal: High Performance Windows

Type of Requirement	Mandatory
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	150.0(q)
Modified Title 24, Part 6 Appendices	N/A
Compliance Software Would Be Modified	N/A
Modified Compliance Document(s)	N/A

Table 2: Scope of Prescriptive Code Change Proposal: High Performance Windows

Type of Requirement	Prescriptive
Applicable Climate Zones	All
Modified Sections of Title 24, Part 6	150.1(c)3; Table 150.1-A
Modified Title 24, Part 6 Appendices	N/A
Compliance Software Would Be Modified	Yes: ACM Reference Manual section 2.5.6.6
Modified Compliance Documents	• CF1R-NCB-01-E, Section I. Fenestration/Glazing Allowed Areas and Efficiencies • CF2R-ENV-01-E, Section B.02. Fenestration Installation

According to manufacturers, the proposed U-factors of 0.27 and 0.28 are reasonable for double-paned windows. Both costs and the range of product styles would improve as manufacturers adjust to both the new building code and the new ENERGY STAR criteria. Based on Cal CERTS data, windows with a U-factor of 0.28 or less are installed in 19.6 percent of all new construction single family homes, and 17.8 percent for alterations. For U-factors 0.27 or less, the number of new constructions is 4.4 percent, and 5.3 percent for alterations.

Market impacts reported for this measure include:

- While builders and building designers/energy consultants would be impacted, it would not affect employment of building inspectors or regulations applicable to builders regarding occupational safety and health.
- While minor material impacts regarding glass, krypton and argon are possible, there would be no significant material impacts on California component retailers, manufacturers, and distributors.
- Aside from the modest impacts listed here, the Statewide CASE Team does not anticipate significant employment or financial impacts to any other sector of the California construction industry, including building owners and occupants.

Economic impacts reported for this measure include a net statewide private investment estimated at $869,528, considered minor as it is less than $1,000,000 (as discussed in section 3.2.4.4), promotion of product and material innovations, and newly developed ENERGY STAR window criteria. The Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy, and it would not affect competitiveness for California businesses.

Cost Effectiveness

The proposed prescriptive U-factor requirements of the high-performance window code change would be cost effective. The benefit-to-cost (B/C) ratio over the 30-year period of analysis ranged, by climate zone, between 1.09 and 6.29 for the 2,100/2,700 Weighted New Construction prototype and 1.19 and 4.64 for the Small Homes New Construction prototype in applicable climate zones (Climate Zones five through 10 and 15 are proposed to be excluded because of B/C ratios less than one). See sections 3.4 and 4.4 for additional details.

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

Table 3 presents the estimated impacts of the proposed code change that would be realized statewide during the first 12 months that proposed requirements are in effect.

Table 3: Summary of Impacts for High Performance Windows

Category	Metric	New Construction and Additions	Alterations
Cost Effectiveness	Benefit-to-Cost Ratio Range (Factor of money saved compared to money spent. Any value of “1” or higher is expected to generate a positive net present value over 30 years.)	0 - 6.55	1.95 - 11.73
Statewide Impacts During First Year	Electricity Savings (GWh)	1.48	-0.14
	Peak Electrical Demand Reduction (MW)	0.50	0.01
	Natural Gas Savings (Million Therms)	0.40	0.11
	Source Energy Savings (kBtu)	40.83	9.71
	Life Cycle Electricity Savings (million 2026 PV$)	12.79	-0.56
	Life Cycle Gas Savings (million 2026 PV$)	49.77	13.30
	Total Life Cycle Energy Savings (million 2026 PV$)	62.55	12.74
	Avoided GHG Emissions (Metric Tons CO_2e)	2,608	624
	Monetary Value of Avoided GHG Emissions ($2026)	321,108	76,785
	On-site Indoor Water Savings (Gallons)	0	0
	On-site Outdoor Water Savings (Gallons)	0	0
	Embedded Electricity in Water Savings (kWh)	0	0
Per home Impacts During First Year	Electricity Savings (kWh)	23.02	-9.90
	Peak Electrical Demand Reduction (W)	7.79	0.77
	Natural Gas Savings (kBtu)	620	733
	Source Energy Savings (kBtu)	636	672
	Life Cycle Energy Savings (2026 PV$)	974	882
	Avoided GHG Emissions (kg CO_2e)	40.62	43.19
	On-site Indoor Water Savings (Gallons)	0	0
	On-site Outdoor Water Savings (Gallons)	0	0
	Embedded Electricity in Water Savings (kWh)	0	0

Mandatory R-Value Requirements for Framed Walls

Proposed Code Change

This proposed measure would increase the required minimum cavity insulation from R-13 to R-15 for 2 x 4 wall assemblies, and R-20 to R-21 for 2 x 6 assemblies.

The wall insulation market, like windows, boasts readily available products with the proposed R-values and is in fact already used in half of new construction projects (CalCERTS, 2023). Therefore, current design, construction, and code compliance processes would remain unchanged. While this can raise up-front costs for minimally compliant homes, home occupants would enjoy greater thermal comfort. In addition, wall insulation typically remains untouched over the building lifetime, therefore it is essential to install levels of insulation that would meet the future needs of thermal performance.

Table 4: Scope of Code Change Proposal: Mandatory R-Value Requirements for Framed Walls

Type of Requirement	Mandatory
Applicable Climate Zones	All
Modified Sections of Title 24, Part 6	150.0(c); Table 150.1-A
Modified Title 24, Part 6 Appendices	N/A
Would Compliance Software Be Modified	N/A
Modified Compliance Document(s)	N/A

Table 5: Estimated Impacts for Key Sectors: Prescriptive High Performance Window Proposal

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
California Residential Construction Sector	35.6	$2,665,044	$12,109,510	$20,283,156
California Building Designers and Energy Consultants Sectors	6.2	$563,281	$698,510	$1,110,624
Discretionary Spending by California Residents	34.3	$2,339,498	$4,224,802	$6,718,985
Total Economic Impacts	**76.1**	**$5,567,822**	**$17,032,821**	**$28,112,765**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[1]

The mandatory framed wall U-factor proposes mandatory requirements that are less stringent than the existing prescriptive requirements, which sets the energy budget for a given building project. Therefore, there would be no significant net changes in economic impact due to the proposed code change. See Section 3.2 for an overview of the current market structure, as well as technical feasibility and market availability.

CalCERTS data for single family homes constructed under Title 24 code in 2019 reveals that most exterior walls were constructed with either 2 x 4-inch or 2 x 6-inch wall framing. Since all these products are readily available on the market, there would be no barriers to technical feasibility or market availability.

Cost Effectiveness

A parallel analysis was conducted to evaluate cost-effectiveness for homes with heat pump space heaters instead of the 2022 prescriptive fuel choice, which is a gas furnace

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

in most climate zones. This analysis showed the proposal to not be as cost-effective when heat pumps provide space heating, and the measure would not be cost-effective in all climate zones where the measure is proposed. Details on this analysis are in Appendix I.

Addressing Energy Equity and Environmental Justice

These proposed code changes are unlikely to have significant impacts on energy equity or environmental justice. Renters include disproportionately impacted populations (DIPs), who are subject to the split incentive. The individual who invests in energy efficiency upgrades (i.e., the owner) is different from the individual who pays the energy bills (i.e., the renter). Therefore, the owner would be less motivated to invest in energy upgrades. These proposals ensure a minimum level of energy savings as a code requirement, which alleviates concerns related to split incentives. Full details addressing energy equity and environmental justice are available in Section 2 of this report.

1. Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (CEC's) 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 & Electric, and Southern California Edison—and two publicly owned utilities—Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author)—sponsored this effort. The program goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The 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. CEC will evaluate proposals the Statewide CASE Team and other stakeholders submit 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.

This CASE Report presents code change proposals for prescriptive window U-factor requirements, mandatory window U-factor requirements, and mandatory wall insulation requirements, along with pertinent information supporting the proposed code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with many industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, general contractors, HERS Raters, national laboratories, trade associations, 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 contents of this report:

Section 2 – Addressing Energy Equity and Environmental Justice describes the potential impacts of this code change measure package on DIPs.

Section 3 – High Performance Windows

- **Section 3.1 – Measure Description** of this CASE Report provides an overview 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.
- **Section 3.2 – Market Analysis** includes a review of the current market structure. Section 3.2.2 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, or other safety standards, and whether technical, compliance, or enforceability challenges exist.
- **Section 3.3 – 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.
- **Section 3.4 – 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 3.5 – 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 and associated greenhouse gas emissions that would be saved by California building owners and tenants, as well as impacts (increases or reductions) on material use. Statewide water consumption impacts are also reported in this section.

Section 4 – Mandatory U-Factor Requirements for Framed Walls

- **Section 4.1 – Measure Description** of this CASE Report provides an overview of the measure and its background. This section also presents details of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- **Section 4.2 – Market Analysis** includes a review of the current market structure. Section 4.2.2 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, and whether technical, compliance, or enforceability challenges exist.
- **Section 4.3 – Energy Savings** presents the per unit energy, demand reduction, and 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.

- **Section 4.4 – 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 4.5 – 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 and associated greenhouse gas emissions that would be saved by California building owners and tenants, as well as impacts (increases or reductions) on material use. Statewide water consumption impacts are also reported in this section.

The following is a brief summary of Sections and Appendices that are included in the report and apply to all measures.

- **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.
- **Section 5 – Proposed Revisions to Code Language** concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (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 forms.
- **Section 6 – Bibliography** lists 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 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: Energy Cost Savings in Nominal Dollars** presents LSC savings over the period of analysis in nominal dollars.
- **Appendix H: Description of Existing Building Prototype** presents details on the prototype used for modeling alteration savings.
- **Appendix I: Cost-Effectiveness Results with Heat Pump Space Heating** presents cost-effectiveness analysis using a heat pump space heater baseline.

The California IOUs offer free energy code training, tools, and resources for those who need to understand and meet the requirements of Title 24, Part 6. The program recognizes that building codes are one of the most effective pathways to achieve energy savings and GHG reductions from buildings—and that well-informed industry professionals and consumers are key to making codes effective. With that in mind, the available resources can help both those who enforce the code, as well as those who must follow it. Visit EnergyCodeAce.com to learn more and to access content, including a glossary of terms.

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). DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.[2]

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 Simon Pallin (spallin@frontierenergy.com) and Marissa Lerner (mlerner@energy-solution.com) for further 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

[2] 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 (Goldsmith & Bell, 2021). Socioeconomic inequities, climate, energy, and other inequities are inextricably linked and often mutually reinforcing.

beyond.[3] 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 community-based organizations 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 community-based organizations and inviting feedback on proposed code changes with a goal of engagement with these organizations representing DIPs

[3] The CEC defines energy equity as "the quality of being fair or just in the availability and distribution of energy programs" (CEC, 2018). 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" (ACEEE). 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" (State of California).

throughout the code cycle. Several strategies for future code cycles are being considered, including:

- Creating an advisory board of trusted community-based organizations that may provide consistent feedback on code change proposals throughout the development process
- Establishing a robust compensation structure that enables participation from community-based organizations 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 Single Family and 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. For example, residents in market rate apartments will have different air quality concerns than those in single family homes, or even those in subsidized multifamily housing (where smoking and other potential contaminants are closely regulated and monitored).

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, SO_2, and $PM_{2.5}$. 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 Section 3.4.2 for an estimate of energy cost 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.

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. 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.[4]

2.1.2.4 Cost Impacts for Renters

Renters within DIPs can also benefit from home energy efficiency improvements. Whether market rate or affordable housing, utility bills will be lower to the degree their homes are more energy efficient. However, the utility bill impacts of energy efficiency in subsidized affordable housing is less clear, since CTCAC staff regularly review tax credit properties, to assure that renters pay utility bills that match initial utility cost estimates (Internal Revenue Service, Treasury, 2011). Renters of market-rate housing

[4] Examples include Yardi-Matrix **Invalid source specified.**, HCA **Invalid source specified.**, and Foley & Puls **Invalid source specified.**, which all conduct market studies.

seldom ask about energy efficiency and utility bills,[5] 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 Proposal

These proposed code changes are unlikely to have significant impacts on energy equity or environmental justice other than as mentioned above. DIPs likely include many renters, a group that is subject to the split incentive: whereby the individual investing in energy efficiency upgrades (i.e., the owner) is not the same individual that pays the energy bills, which reduces the motivation for the owner to invest in energy upgrades. These proposals ensure a minimum level of energy savings as a code requirement, which alleviates concerns related to split incentives. See Section 3.5.5 for a discussion of potential impacts to health, cost, resiliency, and comfort.

[5] 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. High Performance Windows

3.1 Measure Description

3.1.1 Proposed Code Change

The single-family high-performance window proposal has two code change components:

- Reduce the prescriptive maximum U-factor requirement of window assemblies for all California climate zones.
- Reduce the mandatory U-factor requirement for all climate zones.

The current (2022) prescriptive fenestration (window) requirements are outlined in Title 24, Part 6, Section 150.1(c)3A and include a maximum U-factor of 0.30 in all climate zones. The proposed code change would lower the maximum U-factor to 0.27 for all California Climate Zones except 7, for which the proposed value is 0.28. For new homes 500 square feet and less, an exception is proposed for Climate Zones 5 through 10, and 15 and the current U-factor requirement of 0.30 would remain.

Note: The CEC is moving forward with a proposal that differs from what is presented in this report and bases cost-effectiveness results on new homes with a heat pump space heater in alignment with the CEC's heat pump baseline proposal for the 2025 Energy Code. The revised proposal is to reduce the prescriptive maximum U-factor requirement of window assemblies from 0.30 to 0.27 in Climate Zones 1 through 5, 11 through 14, and 16. All other Climate Zones are not affected by the proposed change. For small homes, the proposal includes to lower the maximum U-factor from 0.30 to 0.27 in Climate Zones 1 through 4, 11 through 14, and 16. For alterations, the revised proposal would require a maximum U-factor of 0.27 in all Climate Zones. The description, energy savings, and cost-effectiveness of the revised proposal are presented in Appendix I.

These changes would apply to new construction and additions as well as to added and replacement fenestration in alterations. The existing exceptions for alterations would remain.

For mandatory U-factor requirements, 2022 Code Section 150.0(q)1 mandates a maximum window U-factor of 0.45. This measure proposes to lower the maximum U-factor to 0.40 for all construction types. The current exceptions as defined under Section 150.0(q)1 would remain.

The Statewide CASE Team also evaluated the impact of solar heat gain coefficient (SHGC) for all California Climate Zones. Results of energy modeling showed that the compliance impacts of higher or lower SHGC are not always intuitive, as energy use may increase or decrease depending on the climate zone, size of the home, orientation of the window, building characteristics, and other factors. As a result, the Statewide CASE Team proposes to require that the performance path compliance documents report SHGC as an acceptable range based on the modeled value, rather than a fixed minimum or maximum value. A range of plus or minus 0.01 modelled area weighted average SHGC would allow for some flexibility between the design and construction phases of a project but would not allow for large discrepancies between the modeled and installed values.

The Statewide CASE Team also proposes minor revisions to Appendix A4, the residential voluntary measures section of the California Green Building Standards Code, Title 24, Part 11. These changes will align the voluntary SHGC requirements by climate zone with the current requirements in Part 6.

3.1.2 Justification and Background Information

3.1.2.1 Justification

Windows can be a significant source of heat gain or loss within a home and have been the subject of code revision through many code cycles, including a reduction to 0.30 from 0.32 in U-factor during the 2019 code cycle (Nittler, 2018). A code proposal for multifamily buildings with similar U-factor requirements is also being proposed during this code cycle. [6]

Products with U-factors lower than 0.30 are readily available in the marketplace, and typically include either double-panes (double glazing) with low-e films, argon or krypton gas between the panes, or feature triple-paned construction.

As a reflection of the current window market and expected energy savings, the Environmental Protection Agency (EPA) is enacting similar 0.28 U-factor reductions in the latest updates to ENERGY STAR® window criteria (Version 7). Such changes at the national level will support code compliance within California in terms of product availability, cost, and ease of design specifications as manufacturing scales up to meet a higher demand for these products. All window manufacturers engaged for stakeholder feedback on this proposal confirmed that windows compliant with ENERGY STAR requirements are already part of their production line (EPA, ENERGY STAR Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report, 2021).

3.1.2.2 Background Information

Windows are a critical aspect in the energy efficiency of a building envelope. Unlike other building envelope components, windows typically act as a thermal bridge because energy transfers more easily through windows than through walls and roofs. Weaknesses in the building envelope result in energy losses that the HVAC system to

[6] https://title24stakeholders.com/measures/cycle-2025/multifamily-envelope/

run more frequently and thus require more source energy, such as natural gas or electricity.

The ability for a window to transfer energy is defined as a U-factor in British thermal units per hour per square foot per degree Fahrenheit [Btu/(h·ft^2·°F)]. The U-factor is seen as an indicator of conductance—or how effectively a material or component can transfer heat. Thus, a window with a higher U-factor will “lose” energy to the outside more effectively than a window with a lower U-factor.

Solar radiation in the form of sunlight entering a house typically provides light. Solar radiation also includes heat, making sunlight a contributor to heat gain into the house. During the heating season, such heat gain can be beneficial and reduce the home’s overall heating demand. During the cooling season, the same phenomenon typically increases the overall cooling demand and may result in perceived discomfort. Solar heat gain is typically very localized to specific rooms of a building. Therefore, high-temperature discomfort may even be perceived during heating season if the solar heat gain is larger than what is needed to keep a space (room) heated.

For windows, the amount of heat gain from solar radiation is measured as SHGC, expressed as a fraction between 0 and 1. This value is directly related to heat gain: the higher the value, the larger the relative heat gain. Whether a lower or higher SHGC is beneficial on the overall energy demand and cost of energy depend on the balance between heating and cooling demands as well as the cost of source energy. Though this report does not propose any change to existing SHGC requirements, it does propose that the installed window SHGC as reported on the CF2R match (within ±0.01 units) the value using in the performance model. This ensures that impacts of solar heat gains are properly accounted for in the compliance calculation and that this is representative of what is installed.

Optimizing the thermal characteristics of windows needed to manage this heat exchange along with other window features has been the focus of product development for decades, leading to advents such as multiple panes or glass sheets, use of insulating gases between panes, and low-e coatings that today are readily available to consumers. Building code changes such as this proposal and others described in the previous section have likely accelerated such energy saving developments. Perhaps more impactful is the national, voluntary product standards set by the Environmental Protection Agency’s ENERGY STAR program, which identifies and promotes top tier energy efficient models within numerous product types, including windows. In the recently updated window criteria (version 7.0), new U-factor and SHGC requirements are given by EPA-defined climate zones as shown in Figure 1.

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.22	≥ 0.17	Prescriptive
	= 0.23	≥ 0.35	Equivalent Energy Performance
	= 0.24		
	= 0.25	≥ 0.40	
	= 0.26		
North-Central	≤ 0.25	≤ 0.40	
South-Central	≤ 0.28	≤ 0.23	
Southern	≤ 0.32	≤ 0.23	

Air Leakage for windows ≤ 0.3 cfm/ft^2

[1] Btu/h ft^2·˚F

[2] Solar Heat Gain Coefficient

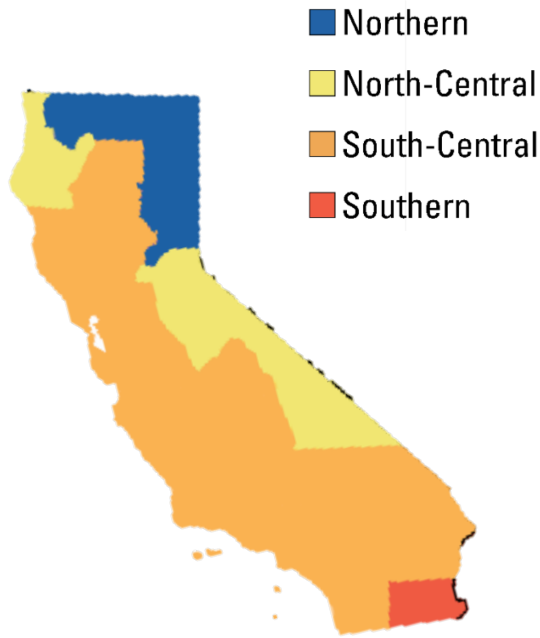
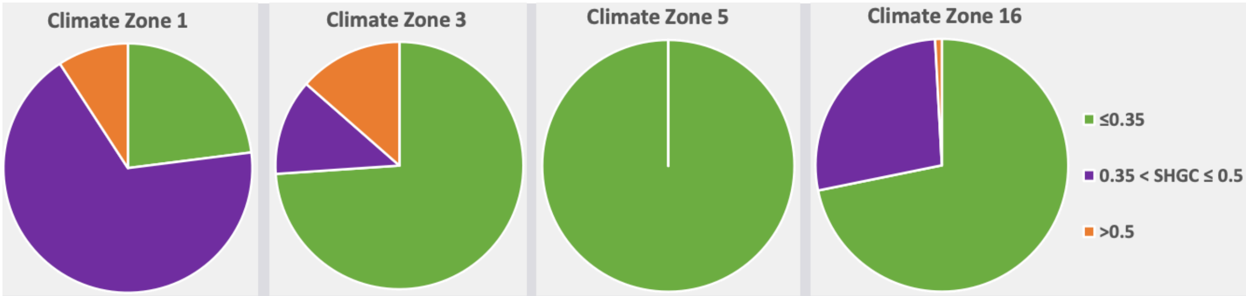


Figure 1: ENERGY STAR Version 7.0 program requirements for windows.

Source: (EPA, ENERGY STAR Residential Windows, Doors, and Skylights Version 7.0, 2022)

The U-factor and SHGC requirements of ENERGY STAR Version 7 are based on a highly researched and collaborative work between EPA and key window and glass manufacturers and other industry stakeholders. Therefore, the Statewide CASE Team aimed for alignment between California's energy code and the standards set by an influential program such as ENERGY STAR (EPA, 2022). The Statewide CASE Team did, however, deviate from ENERGY STAR standards in that this proposal does not have different window requirements for EPA-defined Northern and Southern climate zones with maximum U-factors of 0.22 and 0.32, respectively. Since these climate zones represent a small portion of the state, simplification of requirements across California climate zones was deemed worth the deviation from ENERGY STAR. In addition, a lower U-factor than 0.28 was found cost-effective in all California Climate Zones except for 7. Smaller homes than 500 square feet in Climate Zones 5 through 10, and 15 are proposed fully exempt from any change to existing requirements. Meaning, these Climate Zones will not follow the proposed code change for larger homes.

During the development of this CASE Report, two proposals were considered involving a minimum SHGC requirement. Either as a definite minimum, or as part of a range of a maximum and a minimum requirement. Figure 2 depicts CalCERTS data of typical SHGC values installed in Climate Zones 1, 3, 5, and 16. A SHGC of 0.35 or lower is predominantly installed in Climate Zones 3, 5, and 16. While, data for Climate Zone 1 reveals that a SHGC between 0.35 and 0.5 is typically installed.



SHGC	Climate Zone 1	3	5	16
≤0.35	23%	74%	100%	72%
0.35 < SHGC ≤ 0.5	68%	13%	0%	27%
>0.5	9%	14%	0%	1%

Figure 2: Percentage of windows installed in Climate Zones 1, 3, 5, and 16 with a solar heat gain coefficient of less or equal to 0.35, larger than 0.35 but less or equal to 0.5, or larger than 0.5.

The data size for which the pie charts represent is not revealed in Figure 2. Climate Zone 1 is based on 87 new constructions, Climate Zone 3 has 813, Climate Zone 5 has 61, and Climate Zone 16 has 1,156. Thus, the distributions for Climate zone 1 and 5 may or may not be as reliable and representative because of smaller data sets.

Many window manufacturers and a trade association expressed disapproval towards the introduction of a minimum SHGC requirement in Climate Zones 1, 3, 5, and 16. The main points stated against a minimum requirement are the issue with obtaining a SHGC minimum for glazed doors, and that a minimum SHGC in Climate Zones 1, 3, 5, and 16 would send the signal that it is critically important to have a high SHGC on one side of the border and critically important to be low on the other. Based on the feedback, the Statewide CASE Team concluded to not further evaluate revisions to current SHGC requirements.

3.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the Energy Code, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change.[7] See Section 5 of this report for detailed proposed revisions to code language.

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

3.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 6 and Part 11 are described below. See Section 5.2 of this report for marked-up code language.

Part 6, Subchapter 7, Section 150.0(q)1

Specific Purpose: The specific purpose of the change to Subchapter 7, Section 150.0(q)1 is to update maximum U-factor requirements for fenestrations, including skylight products.

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

Part 6, Subchapter 8, Table 150.1-A

Specific Purpose: The specific purpose of the change to this table is to update the maximum prescriptive U-factors requirements.

Necessity: These changes are necessary to increase energy efficiency via cost effective building design standards, as directed by California Public Resources Code Sections 25213 and 25402.

Part 11, Appendix A4, Division A4.2

Specific Purpose: The specific purpose of the change to Appendix A4, Division A4.2 is to clarify that SHGC requirements are a maximum, for which Climate Zones SHGC requirements apply, and remove an erroneous Section reference.

Necessity: These changes are necessary for clarification.

3.1.3.2 Summary of Changes to the Residential ACM Reference Manual

The Fenestration subsection of Section 2.5.6 of the Single-Family Residential ACM Reference Manual would be revised. The Standard Design U-factor references would be revised to reflect the proposed requirements. For the Proposed Design, an error message would be provided to the user and the simulation would not proceed if a project does not meet the mandatory U-factor requirements. For reporting of the Proposed Design SHGC, the CF1R would report the SHGC for each window as represented by the modeled SHGC (within the range of plus or minus 0.01). The narrow range would allow for flexibility between the planning and construction stages of a project.

See Section 5.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

3.1.3.3 Summary of Changes to the Single-Family Residential Compliance Manual

Section 3.3.5 of the Single-Family Residential Compliance Manual would need to be revised. This would mirror the changes to Subchapter 8, Section 150.1(c)3A explained in above Section 3.1.1, where the changes would reflect the updated code requirements for mandatory and prescriptive U-factors.

3.1.3.4 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below, as noted in Section 5.5. The primary change would be to update any numeric references to U-factor requirements from 0.30 to 0.27 in Climate Zones 1 through 6, and 8 through 16, and 0.28 in Climate Zone 7 as a reflection of this proposal. Homes with less than or equal to 500 square feet of conditioned space in Climate Zone 5 through 10 and 15 would remain at 0.30. Other changes are to clarify the proposed requirement that the installed window SHGC match that from the performance model for projects that comply via the performance path.

- CF1R-PRF-01E Performance Newly Constructed Building
    - See Appendix C for details.
- CF1R-ADD-01-E Prescriptive Residential Additions 1,000 ft^2 or Less
- CF1R-ALT-01-E Prescriptive Alterations Building
- CF1R-ADD-02-E Prescriptive Residential Additions That Do Not Requires HERS Field Verification
- CF1R-NCB-01-E Prescriptive Newly Constructed Building
- CF1R-ALT-05-E Prescriptive Alterations – Simple Non-HERS
- CF2R-ADD-02-E Prescriptive Residential Additions That Do Not Requires HERS Field Verification
- CF2R-ENV-01-E Fenestration Installation

3.1.4 Regulatory Context

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

This proposal is not relevant to other parts of the California Building Standards Code. Changes outside of Title 24, Part 6 are not needed.

3.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal or local laws or regulations.

3.1.4.3 Difference From Existing Model Codes and Industry Standards

There is overlap between this code change proposal and EPA's voluntary ENERGY STAR program. This is detailed in section 3.1.2.2.

According to IECC 2021 International Energy Conservation Code, Table R402.1.3, a U-factor of 0.30 is prescriptively required for climates equivalent to the 16 California Climate Zone regions. The most southern and inland area of California is categorized as Zone 2 in IECC and has a U-factor requirement of 0.40. In California, Zone 2 of the IECC climate zone map overlaps with California Climate Zone 15.

For mandatory window U-factor requirements, the 2021 IECC code requires a maximum of 0.48 for IECC Climate Zones 4 and 5. For IECC Climate Zones 6 through 8, the mandatory fenestration U-factor is 0.4.

3.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors that 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. Section 5 shows specific changes to existing code language and 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:** The design professional works with the property owner to specify fenestration products meeting all applicable requirements for the project's climate zone. In remodel projects, this may simply be a general contractor working directly with a homeowner.
- **Permit Application Phase:** The design professional, contractor, or homeowner applies for a permit with the applicable jurisdiction and completes, signs, and submits the necessary CF1R documents to a HERS Registry. The building department plans examiner reviews the plans for code compliance. For projects in Climate Zones 1, 3, 5, and 16 where SHGC is not regulated, addressing SHGC in this form will be a new step.
- **Construction Phase:** The contractor installs the windows.
- **Inspection Phase:** The contractor completes the necessary CF2R documents and submits them to a HERS Registry, and a building inspector conducts a final inspection. As proposed in this CASE Report, the SHGC as specified on the CF2R should match entries on the CF1R withing a margin of ±0.01.

Though the compliance process described above does not differ from the existing compliance process for the high-performance windows code change proposal, the SHGC verification process will be a new addition. All windows are provided with a label that specifies the U-factor and SHGC of the installed unit (see Figure 3). The label must be left on the window until performance requirements are validated by a building inspector, or any other third-party inspector. This inspection would occur at the same time as the final inspection and would not add complexity to the compliance process, nor add any incremental time for inspection.

If the windows are not selected at the time of permit application when the energy model is completed, there may be a need to update the model and re-submit it to the HERS Registry later in the compliance process. This can add cost and additional time for coordination with the energy consultant. To alleviate the burden for these projects, the energy consultant should advise the project team of this during the design phase. Once the windows are selected and the energy model revised, re-submitting to the HERS Registry is fairly straightforward as long as there are no CF2R documents that have been associated with the project. The Statewide CASE Team expects that in most cases the windows will be selected before CF2R documents are completed.

Figure 3: Window label for energy performance rating and proof of NFRC certification

Source: National Fenestration Rating Council via Energy Code Ace.

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. 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.

In developing the latest version of ENERGY STAR window criteria, the EPA performed extensive market analysis, and that data informs this report.

3.2.2 Technical Feasibility and Market Availability

The window market is well-established and mature, with general predictability in product availability, producer stability, and field performance. In addition, numerous products currently on the market meet the proposed U-factor requirement (EPA, ENERGY STAR Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report, 2021). Thus, the proposed code change would likely only impact the material specification for a project, not the construction or compliance portions. With this constraint in mind, the key question becomes: what other technical and market barriers exist for high performance window? This information was gathered largely through stakeholder engagement (see Appendix F for details) and is summarized below.

Currently, required U-factors of 0.30 are easily met through double-paned windows. According to a window manufacturer, as maximum U-factors decrease, the market becomes increasingly limited to triple-paned windows, particularly when approaching a 0.25 U-factor. This tipping point overlaps with select climate zone requirements proposed by California and ENERGY STAR. The aesthetic of triple-paned windows can be undesirable in buildings seeking a modern look as they tend to be relatively bulky. While there is an option for “thin-triple” windows, one stakeholder noted that product options are currently limited, have increased in price due to their use of krypton, and have no tempering option to meet safety glazing code.

In addition, the stakeholder cited concerns about the costs and payback times for triple paned windows relative to dual-paned, potential aesthetic mismatches during remodels, and the technical difficulty in reducing the U-factor of certain product types such as double-hung and aluminum windows. However, according to several window manufacturers the proposed U-factor of 0.27 or 0.28 (depending on Climate Zone) can easily be met using double glazing only. Thus, the Statewide CASE Team estimates the need for triple paned windows to be minor.

CalCERTS data reveals that 19.6 percent of all new constructions install windows with a U-factor of 0.28 or less, and 4.4 percent install 0.27 or less. For alterations, the same ratios are 17.8 percent and 5.3 percent respectively.

This collective feedback contributed to the moderate proposal of either 0.27 or 0.28 prescriptive maximum U-factor depending on Climate Zone. This helps alleviate concerns associated with more stringent requirements such as ENERGY STAR's Northern Zone and with product options and prices currently offered on the market. In addition, both costs and the range of product styles are expected to improve as manufacturers adjust to both new building codes and ENERGY STAR criteria. The price of krypton may also settle over the next few years as regional tensions causing the price hike will hopefully wane.

The Statewide CASE Team evaluated lowering current SHGC requirements for Climate Zone 2, 4, and 6 through 15 which was met with concerns by some window manufacturers regarding the implications to meet a window SHGC of less than 0.23. SHGC values lower than 0.23 typically require either colored glass or darker coatings, which are both unpopular among customers and may interfere with visual transmittance preferences and requirements for windows.

3.2.3 Market Impacts and Economic Assessments

This section of the CASE Report applies to the window prescriptive U-factor code change proposal, which would modify the stringency of the existing California Energy Code. Impacts are not reported for the reduction in mandatory U-factor requirements. While such would increase the stringency of the code, this will not change the compliance baseline, which reflects the prescriptive code requirements.

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 within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training to remain updated on and compliant with changes in design practices and building codes.

California's construction industry comprises approximately 93,000 business establishments and 943,000 employees (see). For 2022, total estimated payroll was about $78 billion. Nearly 72,000 of these business establishments and 473,000 employees were engaged in the residential building sector, while another 17,600 establishments and 369,000 employees focused on the commercial sector. Remaining establishments and employees worked in industrial, utility, infrastructure, and other heavy construction roles (the industrial sector).

Table 6: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)

Building Type	Construction Sectors	Establishments	Employment	Annual Payroll (Billions $)
Residential	**All**	**71,889**	**472,974**	**31.2**
Residential	Building Construction Contractors	27,948	130,580	9.8
Residential	Foundation, Structure, and 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, and 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, and 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 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 industry subsectors. Table 7 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.2.4 Economic Impacts.

Table 7: Estimated Subsectors of the California Residential Building Industry in 2022

Residential Building Subsector	Establishments	Employment	Annual Payroll (Billions $)
New single family general contractors	12,671	58,367	4.4
New multifamily general contractors	421	6,344	0.7
New housing for-sale builders	189	3,969	0.5
Residential remodelers	14,667	61,900	4.2
Residential glass and glazing contractors	722	5,026	0.3
Residential siding contractors	242	2,081	0.1
Residential drywall contractors	1,901	32,631	2.0
Residential painting contractors	4,869	26,402	1.3

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

3.2.3.2 Impact on Building Designers and Energy Consultants

Complying with changing building codes is within the normal practice 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 updated on and compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 8 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for high performance window to affect firms that focus on single family construction.

There is not a North American Industry Classification System (NAICS)[8] 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

[8] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was 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.

residential and nonresidential buildings.[9] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 8 provides an upper bound indication of the size of this sector in California.

Table 8: Estimated California Building Designer and Energy Consultant Sectors in 2022

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

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

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

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

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 data from the United States (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 (see Table 9). Most housing units, nearly 9.42 million, were either detached or attached single family homes, approximately two million homes were

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

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 9: California Housing Characteristics in 2021[a]

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.)

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

Table 10 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 or 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 were no building energy efficiency standards (Kenney, 2019).

Table 10: 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 11 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 11: Estimated Owner- and Renter-Occupied Housing Units in California by Income in 2021

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, so the counts of housing units by building type shown in Table 9 provide the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, or by household income, as shown in Table 10 and Table 11

Estimating Impacts

For California residents, the proposed code changes would result in lower energy bills for remodels of existing homes. The Statewide CASE Team estimates that on average the proposed change to Title 24, Part 6 would increase construction cost by about $179 per single family home, but the measure would also result in a savings of $185.15 in energy and maintenance cost savings over 30 years. This is roughly equivalent to a $1.07 per month increase in payments for a 30-year mortgage and a $1.12 per month reduction in energy costs. Overall, the Statewide CASE Team expects the 2025 Title 24, Part 6 Standards to save homeowners about $0.58 per year relative to homeowners whose single-family homes are minimally compliant with the 2022 Title 24, Part 6 requirements.

As discussed in Section 3.2.4, 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 Statewide CASE Team anticipates the proposed change would have no significant material impact on California component retailers. Modest impacts, however, in use of materials such as glass, krypton and argon are possible as they are the primary strategies in developing thermally high performing windows (see section 3.5.4). While such material use changes are not expected to significantly impact component retailers, it is possible that an increased demand for krypton may exacerbate lead time delays for products using that material due to current supply chain issues mentioned by several stakeholders.

3.2.3.6 Impact on Building Inspectors

Table 12 shows employment and payroll information for state and local government agencies where 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 anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 12: Estimated Employment in California State and Government Agencies with Building Inspectors in 2022

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

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

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

3.2.3.7 Impact on Statewide Employment

As described in Sections 3.2.3.1 through 3.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.2.4, the Statewide CASE Team estimated the proposed change in high performance windows would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in high performance Windows would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.2.4 Economic Impacts

This section of the CASE Report applies to the prescriptive window U-factor code change proposal that would increase the stringency of the existing California Energy Code.

For the 2025 code cycle, the Statewide CASE Team used the IMPLAN model software,[10] 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 due to code or a standard implementation as a function of incoming cash flow into economic sectors. The jobs created are typically categorized into direct, indirect, and induced employment. For example, cash flow into a manufacturing plant captures direct employment or jobs created in the manufacturing plant, indirect employment or jobs created in the sectors that provide raw materials to the manufacturing plant, and induced employment or jobs created in the larger economy due to purchasing habits of people newly employed in the manufacturing plant. Eventually, IMPLAN aggregates the total number of jobs created due to a code change proposal. 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 macroeconomic job creation.

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 simplifies complex actions and interactions of individual, business, and other entities 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.[11] There may also be some nonresidential customers that are impacted by this proposed code change; however, the Statewide CASE Team does

[10] 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.

[11] For example, for the lowest income group, the Statewide CASE Team assumed 100 percent of money saved through lower energy bills would be spent, while for the highest income group, it was assumed that only 64 percent of additional income would be spent.

not anticipate such impacts to be materially important to the building owner and would have measurable economic impacts.

Table 13: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Residential Builders)	5.61	$422,454	$8,369,797	$13,974,138
Indirect Effect (Additional spending by firms supporting Residential Builders)	27.11	$2,048,233	$3,391,709	$5,755,125
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	2.86	$194,357	$348,004	$553,894
Total Economic Impacts	**35.6**	**$2,665,044**	**$12,109,510**	**$20,283,156**

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.[12]

Table 14: 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	Total Value Added	Output
Direct Effects (Additional spending by Building Designers & Energy Consultants)	3.1	$337,109	$333,734	$527,498
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	1.2	$100,374	$139,500	$224,567
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	1.8	$125,797	$225,275	$358,558
Total Economic Impacts	**6.2**	**$563,281**	**$698,510**	**$1,110,624**

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

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

Table 15: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents

Type of Economic Impact	Employment (Jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by households)	0.0	$0	$0	$0
Indirect Effect (Purchases by businesses to meet additional household spending)	0.0	$0	$0	$0
Induced Effect (Spending by employees of businesses experiencing "indirect" effects)	34.3	$2,339,498	$4,224,802	$6,718,985
Total Effect	**34.3**	**$2,339,498**	**$4,224,802**	**$6,718,985**

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 regulation cycle 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 may represent a modest change to material demands (see section 3.5.4 for more information), however this 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.[13] 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

[13] 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.

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).[14] As Table 16 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 16: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits (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	**-**	**-**	**26**

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

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 were used as a conservative estimate of corporate profits, a portion of which was assumed to be allocated to net business investment.[15] For the prescriptive high performance window proposal, the resulting net private investment is estimated at $869,528. Because this is less than $1,000,000, the Statewide CASE Team determines this is a minor impact relative to California's economy.

[14] 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 capital stock due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

[15] 26 percent of proprietor income was assumed to be allocated to net business investment; see Table 16.

3.2.4.5 Incentives for Innovation in Products, Materials, or Processes

As discussed in Section 3.2.2, there can be technical challenges to producing low-cost, high-performance windows that meet both desired thermal properties and aesthetics such as window color and assembly thickness. However, as noted in Section 3.1.2.2, the newly released ENERGY STAR window criteria as well as the history of changes to window requirements within the Energy Code – including this current proposal – propel the industry to further refine high performance window technology.

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 will 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.

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 ongoing 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) and the CEC's Outreach and Education Unit. As noted in Section 3.1.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.2.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. Refer to Section 2 for more details addressing energy equity and environmental justice.

3.2.5 Fiscal Impacts

This section of the CASE Report applies to the window prescriptive U-factor code change proposal, which would modify the stringency of the existing California Energy Code.

3.2.5.1 Mandates on Local Agencies or School Districts

There are no relevant mandates to local agencies or school districts because this proposal applies to single family construction only.

3.2.5.2 Costs to Local Agencies or School Districts

There are no costs to local agencies except those tasked with the responsibility of managing and enforcing these measures (as noted in Cost to the Local Governments above), nor are the costs to school districts because this proposal applies to single family construction only.

3.2.5.3 Costs or Savings to Any State Agency

There are no costs or savings to any state agencies except those tasked with the responsibility of managing and enforcing these measures (as noted in Cost to the State above).

3.2.5.4 Other Nondiscretionary Cost or Savings Imposed on Local Agencies

There are no added nondiscretionary costs or savings to local agencies because this proposal applies to single family construction only.

3.2.5.5 Costs or Savings in Federal Funding to the State

There are no costs or savings to federal funding to the state that are related to this measure.

3.3 Energy Savings

This section of the CASE Report applies to the window prescriptive U-factor code change proposal, which would increase the stringency of the existing California Energy Code. Impacts are not reported for the change in mandatory U-factor requirement.

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 not reach 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 energy savings analysis relies on results of California Building Energy Code Compliance (CBECC) software simulations, specifically the 2025 research version of CBECC-Res, to estimate energy use for single family prototype buildings. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate zone specific Long-term Systemwide Cost (LSC) hourly factors when calculating energy cost impacts. To arrive at the proposals presented in this report, the Statewide CASE Team evaluated various scenarios comparing different U-factor and SHGC values. For most scenarios, all sixteen climate zones were evaluated to refine the proposals regionally based on energy savings and cost-effectiveness results.

3.3.1.2 Energy Savings Methodology per Prototypical Building

To quantify key impacts, the Statewide CASE Team measured per unit energy savings expected from the proposed code changes in several ways.

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 as energy usage.

Second, the Statewide CASE Team calculated savings in the total amount of raw fuel required to operate a building, called Source Energy Savings. 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.[16] Finally, the Statewide CASE Team calculated 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 CO_2 emissions.[12]

The CEC directed the Statewide CASE Team to model the energy impacts using prototypical building models that represent building geometries for different types of buildings (California Energy Commission, 2022). The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 17.

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

Energy savings are calculated using three new construction prototypes, a 500 square foot small home, a single story 2,100 square foot home, and a two-story 2,700 square foot home. Statewide results are weighted 2 percent for the 500 square foot prototype, 42 percent for the 2,100 square foot prototype and 56 percent for the 2,700 square foot prototype. Energy savings and overall impacts are similar across the 2,100 and 2,700 square foot prototypes. In this report where individual prototype results are presented, results of the 2,100 and 2,700 square foot homes are presented as a weighted average based on the statewide distribution. Results are separately presented for the 500 square foot single family new construction prototype since the impacts in some cases differ significantly for the smaller prototype. See Appendix A for further details on how the weighting was derived. Energy savings for alterations are calculated based on a single 1,665 square foot existing home prototype.

Additional details on the 2,100 and 2,700 square foot single family prototypes can be found in the Single-Family Residential Alternative Calculation Method (ACM) Approval Manual (California Energy Commission, 2022). The 500 square foot single family prototype is a new prototype being evaluated in this code cycle to reflect recent trends in California construction of a greater number of accessory dwelling units and small homes (Bay Area Council Economic Institute, n.d.) (UC Berkeley Center for Community Innovation, 2021). The single family existing building prototype reflects the prototype developed during the 2022 code cycle as part of the Residential Energy Savings and Process Improvements for Additions and Alterations CASE Report (Statewide CASE Team, 2020) and was developed based on the alteration prototypes described in the ACM Approval Manual (California Energy Commission, 2022). Further detail on this can be found in Appendix H.

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

Prototype Name	Number of Stories	Floor Area (Square Feet)	Description
One-Story Single Family	1	2,100	Single story 3-bedroom house with attached garage, 9-ft ceilings, vented attic, and steep-sloped roof.
Two-Story Single Family	2	2,700	Two-story 4-bedroom house with attached garage, 9-ft ceilings, 1-ft between floors, vented attic, and steep-sloped roof.
Small Single Family	1	500	Detached single story 1-bedroom small home, 9-ft ceilings.
Single Family Existing Building	1	1,665	Single story 3-bedroom existing home, no attached garage, 8-ft ceilings, vented attic, and steep-sloped roof.

The Statewide CASE Team estimated LSC, Source Energy, electricity, natural gas, peak demand, and GHG impacts by simulating the proposed code change in prototypical buildings and rulesets from the 2025 Research Version of the California Building Energy Code Compliance (CBECC-Res) software (California Energy Commission, n.d.).

CBECC-Res generates two models based on user inputs: the Standard Design and the Proposed Design.[17] 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 minimal compliance with 2022 code and the Proposed Design representing the same features but in compliance with the proposed requirements. Features used in the Standard Design and Proposed Design are described in the 2022 Single-Family Residential ACM Reference Manual.

Table 18 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume a reduction in U-factor from the prescriptive value of 0.30. There is no change in the proposed conditions for the SHGC proposal.

[17] 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 International Energy Conservation Code (IECC). The Statewide CASE Team did not use the Reference Design for energy impacts evaluations.

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

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
2100, 2700, 1665	1-6, 8-16	Window Properties	U-factor	0.30	0.27
2100, 2700, 1665	7	Window Properties	U-factor	0.30	0.28
500	1-4, 11-14, 16	Window Properties	U-factor	0.30	0.27

CBECC-Res calculates whole building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) 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 are used to calculate Source Energy Use in kilo British thermal units per year (kBtu/yr), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent per year (metric tons or "tonnes" of CO_2e/yr). CBECC-Res also calculates annual peak electricity demand measured in kilowatts (kW).

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 single family buildings are presented in savings per prototype building. As described above, the Statewide CASE Team developed a weighted average savings of the prototypes to calculate statewide savings.

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.

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

3.3.2 Per Unit Energy Impacts Results

Energy savings results are separately presented for three prototypes. Energy savings and peak demand reductions per unit are presented in Table 19 through Table 23. Savings are presented for new construction and alterations.

The per unit energy savings do not account for naturally occurring market adoption or compliance rates.

Per-unit savings for the first year are expected to range from -17 to 120 kWh per year on electricity for the 2100/2700 weighted new construction prototype. For small homes, the electricity savings vary between -5 to 19 kWh per year. Alterations present a range of -27 to 32 kWh per year. Table 19 displays several climates with small negative numbers for savings. The main reason for that is that a higher U-factor can help to release some of the extra heat to which solar radiation contributes to. Meaning, when the beam from the sun radiates through the windows, some of the associated heat gain can be “vented” to the outside more effectively with a higher window U-factor. This effect is stronger for smaller homes which in general have a larger heat gain per square foot. However, the effect is minor compared to heating savings, which vary between 0 to 20.6 therms per year for the 2100/2700 weighted new construction prototype. For small homes, heating energy savings range from 0 to 3.3 therms per year, and from 2.2 to 18.1 for alterations.

As seen in Table 20, the proposed measure reduces peak demand in electricity in most cases with up to 0.04 kW in peak demand reduction.

Table 19: First Year Electricity Savings (kWh) Per Home—Prescriptive Window U-Factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	13	1	11
2	8	-3	5
3	88	10	-6
4	120	14	-6
5	5	N/A	-8
6	-1	N/A	-5
7	-3	N/A	-9
8	-17	N/A	-28
9	-12	N/A	-23
10	-9	N/A	-18
11	3	-2	2
12	-1	-4	-8
13	78	11	9
14	120	19	4
15	26	N/A	32
16	0	-5	-27

Table 20: First Year Peak Demand Reduction (kW) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.001	0.002	0.001
2	0.001	0.000	0.001
3	0.029	0.005	0.001
4	0.032	0.007	0.002
5	0.001	N/A	0.002
6	0.000	N/A	0.001
7	0.000	N/A	0.000
8	0.000	N/A	0.000
9	0.000	N/A	0.001
10	0.000	N/A	0.000
11	0.000	0.000	0.000
12	0.001	0.000	0.001
13	0.022	0.005	0.000
14	0.041	0.009	0.002
15	0.000	N/A	0.000
16	0.002	-0.002	0.002

Table 21: First Year Natural Gas Savings (therms) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	20.3	2.8	15.3
2	13.4	1.8	12.5
3	0.0	0.0	6.9
4	0.0	0.0	12.5
5	10.1	N/A	6.4
6	3.7	N/A	3.6
7	2.2	N/A	2.2
8	4.3	N/A	4.5
9	4.9	N/A	5.2
10	5.1	N/A	5.2
11	11.2	1.6	10.9
12	11.4	1.6	11.2
13	0.0	0.0	8.5
14	0.0	0.0	12.4
15	2.1	N/A	2.4
16	20.6	3.3	18.1

Table 22: First Year Source Energy Savings (kBtu) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	1,892	250	1,399
2	1,242	160	1,166
3	279	45	649
4	366	60	1,149
5	921	N/A	566
6	339	N/A	333
7	195	N/A	216
8	363	N/A	383
9	426	N/A	466
10	464	N/A	483
11	1,016	145	999
12	1,037	150	1,032
13	244	45	783
14	401	70	1,149
15	192	N/A	233
16	1,850	305	1,632

Table 23: First Year LSC Savings (2026 PV$) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$2,576	$365	$1,981
2	$1,742	$220	$1,615
3	$754	$100	$866
4	$918	$125	$1,548
5	$1,323	N/A	$799
6	$461	N/A	$450
7	$279	N/A	$216
8	$450	N/A	$400
9	$583	N/A	$533
10	$597	N/A	$599
11	$1,445	$200	$1,399
12	$1,427	$175	$1,349
13	$639	$110	$1,182
14	$974	$160	$1,615
15	$447	N/A	$533
16	$2,583	$390	$2,148

3.4 Cost and Cost Effectiveness

An analysis of costs and cost effectiveness of the prescriptive U-factor code change proposal is presented in the following sections. For the proposed change in mandatory U-factor requirement, a cost effectiveness analysis is not required because it does not impact the energy baseline against which compliance is evaluated since the mandatory requirement is much less stringent than the prescriptive requirement. Therefore, the Statewide CASE Team is presenting information on the cost implications in lieu of a full cost-effectiveness analysis of a mandatory code change.

In this section results are presented for a weighted average of the 2,100 square foot and 2,700 square foot new construction prototypes (the 2100/2700 weighted prototype) since results for each of these two prototypes are similar. Results are separately presented for the 500 square foot single family new construction prototype. While this code change proposal will impact alterations, incremental costs are estimated to be the same for alterations as for new construction. Estimated energy savings for alterations are greater than that for new construction in all cases due to the higher heating and cooling loads in existing buildings. As such, for this proposal cost effectiveness will also be greater for alterations than for new construction and so cost effectiveness is not presented for alterations.

3.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the LSC hourly 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 energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the 30-year period of analysis.

The CEC requested LSC 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 2026 PV$ are presented in this section of the report. 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.

3.4.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and additions in terms of LSC savings realized over the 30-year period of analysis are presented as 2026 present value dollars (2026 PV$) in Table 24 and Table 25. Savings for alterations are presented in Table 26. 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 Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction – Prescriptive Window U-factor

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	$98	$2,478	$2,576
2	$59	$1,682	$1,742
3	$754	$0	$754
4	$918	$0	$918
5	$49	$1,274	$1,323
6	$10	$450	$461
7	-$14	$293	$279
8	-$98	$548	$450
9	-$49	$632	$583
10	-$49	$646	$597
11	$28	$1,417	$1,445
12	$0	$1,427	$1,427
13	$639	$0	$639
14	$974	$0	$974
15	$185	$262	$447
16	$35	$2,548	$2,583

Table 25: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction – Prescriptive Window U-factor

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	$15	$350	$365
2	$0	$220	$220
3	$100	$0	$100
4	$125	$0	$125
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	-$5	$205	$200
12	-$25	$200	$175
13	$110	$0	$110
14	$160	$0	$160
15	N/A	N/A	N/A
16	-$20	$410	$390

Table 26: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Home – Alterations – 1665 Existing Building – Prescriptive Window U-factor

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	$100	$1,881	$1,981
2	$50	$1,565	$1,615
3	$0	$866	$866
4	-$17	$1,565	$1,548
5	-$17	$816	$799
6	-$17	$466	$450
7	-$50	$266	$216
8	-$166	$566	$400
9	-$117	$649	$533
10	-$67	$666	$599
11	$33	$1,365	$1,399
12	-$50	$1,399	$1,349
13	$100	$1,082	$1,182
14	$50	$1,565	$1,615
15	$216	$316	$533
16	-$100	$2,248	$2,148

3.4.3 Incremental First Cost

Incremental first costs (or incremental costs) reflect the difference in material and labor costs of installing window units with properties meeting the proposed measure as compared to those with properties meeting existing code requirements.

The Statewide CASE Team conducted several interviews and surveys with manufacturers, trade associations, builders, national laboratories, and other stakeholders to gain knowledge on window pricing and installation labor (see Appendix F for information on stakeholder engagement). In addition, the Statewide CASE Team utilized recent work presented by the EPA ENERGY STAR program and the release of its Version 7 criteria for residential windows, doors, and skylights (EPA, ENERGY STAR Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report, 2021) (EPA, ENERGY STAR Residential Windows, Doors, and Skylights Version 7.0, 2022). This work by the EPA to increase stringency involved extensive and highly collaborative research in which over 35 U.S. based window manufacturers and other stakeholders participated. As part of the research, EPA collected individual window costs and developed an incremental cost model based on the window U-factor.

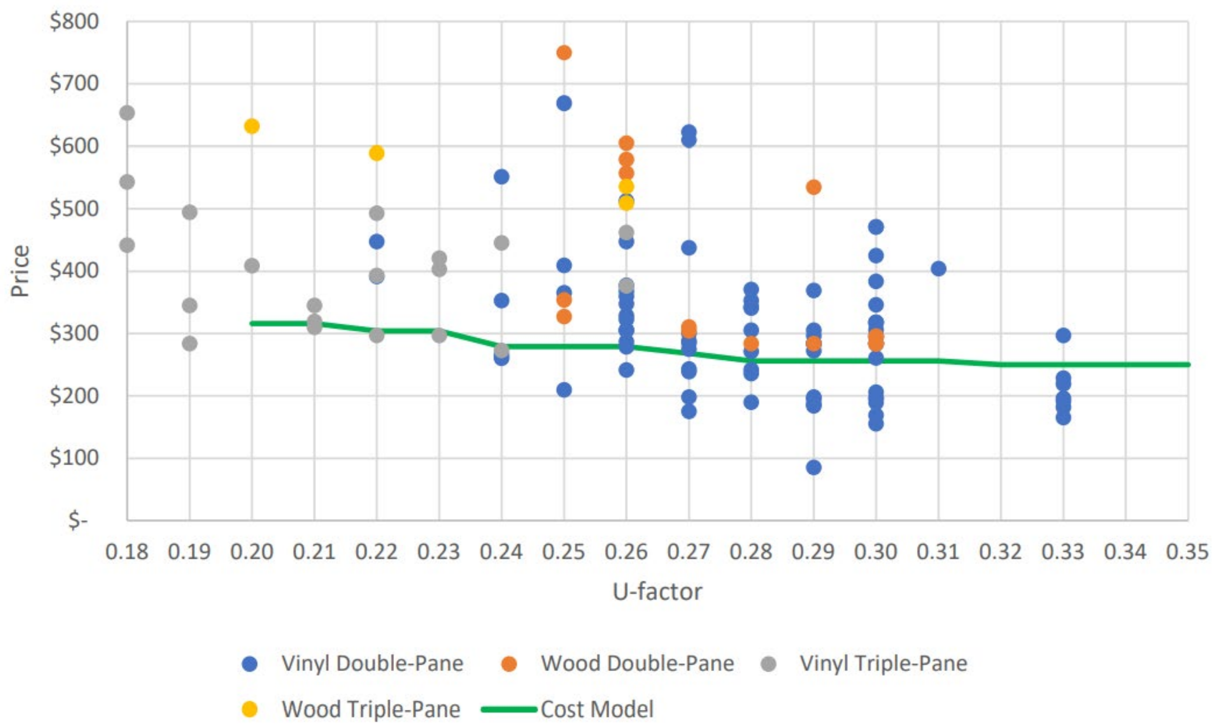


Figure 4: ENERGY STAR incremental consumer cost model (green line) based on window U-factor

Source: (EPA, ENERGY STAR Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report, 2021).

As seen in Figure 4, window costs are highly variable, even among comparable product types. This was a recurring point of feedback from engaged stakeholders as well. The cost variability likely reflects the variety of products offered in this mature and robust marketplace. For the purposes of this cost-effectiveness analysis, however, the Statewide CASE Team sought a single representative incremental cost per proposed U-factor requirement. Using the cost model data from ENERGY STAR, a best-fit regression line equation for incremental cost was developed. From this equation, an incremental cost was found for a specific U-factor. Using the difference in costs, estimated incremental cost for windows with lower U-factor than 0.30 were determined.

The applicability of the incremental cost model presented by ENERGY STAR was verified and validated based on stakeholder feedback. More specifically, one window manufacturer offers window products with a lower incremental cost compared to the cost model, while another manufacturer offers windows with a higher incremental cost. On average, their incremental costs match the cost model provided by ENERGY STAR well. Using the cost model, the Statewide CASE Team estimated incremental material costs at $0.51/ft^2$ going from a U-factor of 0.30 to 0.28, and $0.84/ft^2$ when going from 0.3 to 0.27.

Most labor costs associated with window installation will remain unchanged. One possible impact raised by stakeholders is the additional weight and associated costs if triple-paned windows start to displace double-paned windows (see Section 3.2.2). The Statewide CASE Team, supported by stakeholder input, does not anticipate any increase in labor for windows with either a U-factor of 0.28 or 0.27, which can be readily achieved with double glazing.

In summary, the incremental costs associated with the prescriptive U-factor reduction proposal are shown in Table 28.

Table 27: Window Incremental Costs

Window U-Factor Reduction	Incremental Material Cost, with Multiplier	Incremental Labor Cost	Total Incremental Cost
0.3 → 0.27 (CZs 1-6, 8-14, and 16)	$0.84/ft^2$	N/A	$0.84/ft^2$
0.3 → 0.28 (CZ 2-15)	$0.51/ft^2$	N/A	$0.51/ft^2$

For alterations, the costs are not expected to differ from new construction/additions.

Again, no cost analysis is required to justify the change of mandatory window U-factor requirement, as described at the beginning of section 3.4.

The incremental first costs are not expected to increase over time. The price of windows in general may increase over time, but the impact on incremental cost is assumed negligible. This assumption has also been confirmed by various stakeholders.

3.4.4 Incremental Maintenance and Replacement Costs

Windows are expected to have a useful life greater than the 30-year period of analysis. Therefore, there are no replacement costs included in this analysis. Similarly, there is no incremental maintenance required because of these code change proposals.

3.4.5 Cost Effectiveness

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 B/C ratio was calculated using 2026 PV costs and cost savings.

Results of the per-unit cost effectiveness analyses are presented in Table 28 through Table 29 for the 2100/2700 weighted and small home new construction prototypes, respectively. Table 30 presents results for alterations.

The proposed measure is cost effective in every climate zone for the 2100/2700 weighted new construction prototype and for alterations. For the small home prototype, the measure is cost effective in Climate Zones 1 through 4, 11 through 14, and 16. The measure was not found to be cost-effective in the other climate zones and therefore no change is proposed for small homes with no greater than 500 square feet of conditioned floor area.

These savings reflect a home that meets the 2022 prescriptive fuel requirements which includes a heat pump space heater in Climate Zones 3, 4, 13, and 14 and a gas furnace in the other climate zones. In another proposal for the 2025 code cycle, the CEC is evaluating a heat pump baseline that would prescriptively require heat pump space heaters in all climate zones for single family homes. If the CEC adopts this, they may want to evaluate the impacts of single family envelope upgrades, such as presented in this code change proposal, against a heat pump rather than gas furnace. The LSC factors vary by fuel type, which can impact cost-effectiveness results for envelope measures based on the space heating fuel choice. Appendix I presents cost-effectiveness results for homes with heat pump space heating in all climate zones.

Table 28: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – 2100/2700 Weighted New Construction – Prescriptive Window U-factor

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$2,576	$410	6.28
2	$1,742	$410	4.24
3	$754	$410	1.84
4	$918	$410	2.24
5	$1,323	$410	3.22
6	$461	$410	1.12
7	$279	$249	1.12
8	$450	$410	1.10
9	$583	$410	1.42
10	$597	$410	1.45
11	$1,445	$410	3.52
12	$1,427	$410	3.48
13	$639	$410	1.56
14	$974	$410	2.37
15	$447	$410	1.09
16	$2,583	$410	6.29

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.

Table 29: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Small Home New Construction – Prescriptive Window U-factor

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	$365	$84	4.35
2	$220	$84	2.62
3	$100	$84	1.19
4	$125	$84	1.49
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$200	$84	2.38
12	$175	$84	2.08
13	$110	$84	1.31
14	$160	$84	1.90
15	N/A	N/A	N/A
16	$390	$84	4.64

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.

Table 30: 30-Year Cost-Effectiveness Summary Per Home – Alterations – 1665 Existing Building – Prescriptive Window U-factor

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,981	$183	10.82
2	$1,615	$183	8.82
3	$866	$183	4.73
4	$1,548	$183	8.46
5	$799	$183	4.36
6	$450	$183	2.45
7	$216	$111	1.95
8	$400	$183	2.18
9	$533	$183	2.91
10	$599	$183	3.27
11	$1,399	$183	7.64
12	$1,349	$183	7.36
13	$1,182	$183	6.46
14	$1,615	$183	8.82
15	$533	$183	2.91
16	$2,148	$183	11.73

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

Statewide savings for the prescriptive U-factor code change proposal is presented in the following sections. The proposed change of mandatory U-factor requirement is less stringent than the current prescriptive requirement and therefore there are no savings on a per unit basis, and thus not reported on in this section.

3.5.1 Statewide Energy and Energy Cost 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 in 2026 (see Appendix A) that would be impacted by the proposed code, based on climate zone and building type.

In the case of alterations, the statewide savings associated with this proposal rely heavily on the estimated number of homes completing alterations involving windows.

The first-year energy impacts calculation takes the number of buildings that were completed in 2026 and estimates the total savings realized within their first year of operation. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

The tables below present the first-year statewide energy savings and 30-year cost savings from newly constructed buildings, additions, and alterations by climate zone. Table 33 presents combined savings data across all climate zones for new construction, additions, and alterations.

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.

Both Table 31 and Table 32 show negative electrical savings for some climates. The reasons for this are mentioned in Section 3.3.2 and derive from the phenomenon that a higher U-factor can help to release some of the heat gain inside a building. This effect is stronger for smaller homes which in general have a larger heat gain per square foot and thus more impacted by additional heat gains.

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

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	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	359	0.00	0.00	0.01	0.66	$0.90
2	1,861	0.01	0.00	0.02	2.27	$3.18
3	3,035	0.26	0.09	-	0.83	$2.24
4	2,689	0.32	0.08	-	0.97	$2.43
5	604	0.00	0.00	0.01	0.55	$0.79
6	1,685	0.00	0.00	0.01	0.57	$0.77
7	1,832	-0.01	0.00	0.00	0.36	$0.51
8	4,080	-0.07	0.00	0.02	1.47	$1.83
9	4,200	-0.05	0.00	0.02	1.78	$2.44
10	7,791	-0.07	0.00	0.04	3.62	$4.64
11	5,840	0.02	0.00	0.06	5.84	$8.31
12	14,542	-0.01	0.01	0.16	14.79	$20.37
13	7,257	0.56	0.16	-	1.74	$4.58
14	3,739	0.44	0.15	-	1.47	$3.57
15	3,097	0.08	0.00	0.01	0.62	$1.40
16	1,937	0.00	0.00	0.04	3.51	$4.91
Total	**64,547**	**1.49**	**0.50**	**0.40**	**41.04**	**$62.86**

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

Table 32: Statewide Energy and Energy Cost Impacts—Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	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	72	0.00	0.000	0.00	0.10	$0.14
2	425	0.00	0.001	0.01	0.50	$0.69
3	1,556	-0.01	0.002	0.01	1.01	$1.35
4	796	0.00	0.001	0.01	0.91	$1.23
5	156	0.00	0.000	0.00	0.09	$0.12
6	951	0.00	0.000	0.00	0.32	$0.43
7	791	-0.01	0.000	0.00	0.17	$0.17
8	1,482	-0.04	0.001	0.01	0.57	$0.59
9	2,001	-0.05	0.001	0.01	0.93	$1.07
10	1,708	-0.03	0.001	0.01	0.82	$1.02
11	537	0.00	0.000	0.01	0.54	$0.75
12	2,110	-0.02	0.002	0.02	2.18	$2.85
13	1,016	0.01	0.000	0.01	0.79	$1.20
14	397	0.00	0.001	0.00	0.46	$0.64
15	284	0.01	0.000	0.00	0.07	$0.15
16	157	0.00	0.000	0.00	0.26	$0.34
Total	**14,437**	**-0.14**	**0.011**	**0.11**	**9.71**	**$12.74**

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

Table 33: 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	1.48	0.50	0.40	40.83	62.86
Alterations	-0.14	0.01	0.11	9.71	12.74
Total	**1.34**	**0.51**	**0.50**	**50.54**	**75.60**

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

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 CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric ton of carbon dioxide equivalent emissions (metric tons CO2e). (California Energy Commission, 2020)

The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs).[18] 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 34 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 3,231 (metric tons CO2e) would be avoided.

Table 34: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/yr)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
TOTAL	1	288	0.50	2,943	3,231	$397,892

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

b. GHG emissions savings were calculated using hourly GHG emissions factors published alongside the LSC hourly factors and Source Energy hourly factors by 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

3.5.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

3.5.4 Statewide Material Impacts

The thermal characteristics of high-performance windows are typically achieved through the use of three panes and/or more inert filler gases such as krypton, confirmed through

[18] 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.

stakeholder feedback. As discussed in section 3.2, products utilizing such strategies to meet proposed requirements are readily available, and the general design and construction processes are not expected to change as a result of this proposal. While the high-performance window proposal may impact the number of products on the market that utilize a third pane or added filler gas, this is not necessary to achieve code compliance nor is the impact expected to be considerable on a statewide level. Therefore, the Statewide CASE Team does not expect any material impacts. See Appendix D for more details.

3.5.5 Other Non-Energy Impacts

A primary benefit of high-performance windows is the energy savings and resulting cost savings. However, as with any measure that tightens the building envelope, the occupant may experience increased comfort through better regulated indoor temperatures and reduced drafts from leaky windows. Improvements to the building envelope performance may also relieve strain on HVAC systems and building occupants during significant outdoor temperature swings.

4. Mandatory U-Factor Requirements for Framed Walls

4.1 Measure Description

4.1.1 Proposed Code Change

This measure proposes to reduce the mandatory U-factor of framed walls in single family new construction, additions, and alterations. Current mandatory requirements in the Building Energy Efficiency Standards-Title 24, Part 6, Subchapter 7 Single-Family Residential Buildings, Section 150.0, are expressed in terms of the U-factor of the whole wall assembly, with guidance on corresponding insulation R-values. Specific current and proposed requirements for wood-framed walls, along with corresponding insulation R-values, are summarized in Table 35.

Table 35: Current and proposed U-factor and R-value requirements for exterior walls in new constructions, additions, and alterations.

Wall Stud Assembly	Current Max. U-Factor	Current Corresponding Min. R-Value[a]	Proposed Max. U-Factor	Proposed Corresponding Min. R-Value[a]
2x4	U-0.102	R-13	U-0.095	R-15
2x6	U-0.071	R-20	U-0.069	R-21

a. R-value corresponds to given U-factor for 16 inch-on-center wood framing.

As a mandatory measure, this would prohibit the installation of wall cavity insulation resulting in wall U-factors higher than those proposed. However, it would not prevent the use of R-13 in 2 x 4 inch framing nor R-19 or R-20 in 2 x 6 inch framing as long as the overall wall U-factor requirements are met. For example, R-20 insulation can be used in a 2 x 6 inch wood framed wall if the studs are constructed 24 inch-on-center, resulting in a U-factor of 0.068.

The prescriptive wall insulation requirements used in the Standard Design would remain at a U-factor of 0.048 for Climate Zone 1 through 5 and 8 through 16, and 0.065 in Climate Zone 6 and 7. This means that there would be no change to the baseline against which wall insulation compliance is compared, only a change in the backstop allowed in potential trade-offs with other energy saving measures.

This change would require an update to compliance software to reflect new maximum U-factors.

The proposed code change for mandatory wall insulation applies only to framed above-grade walls. All other types of exterior walls are excluded from the proposal.

4.1.2 Justification and Background Information

4.1.2.1 Justification

Exterior walls are typically the largest building envelope area in contact with the outside. Thus, increased insulation levels in exterior walls will reduce heat transfer between the inside and outside. Many walls are constructed with cavity insulation, which typically remains untouched over the building's lifetime. Therefore, it is essential to install levels of insulation that will meet the future needs of thermal performance. Decreasing mandatory U-factor requirements creates a "backstop" for wall performance and energy efficiency.

Wall insulation of the proposed U-factors is readily available on the market and in fact already used in roughly half of new construction projects (CalCERTS, 2023). Other than specifying more or different cavity insulation material that would meet proposed requirements, current design, construction, and code compliance processes would remain largely unchanged. While this can raise up-front costs for minimally-compliant homes, home occupants will enjoy greater thermal comfort.

Increased mandatory insulation requirements are also proposed for multifamily buildings, which are presented in the Multifamily Envelope report.[19]

4.1.2.2 Background Information

In California, most single-family exterior walls are constructed with 2 x 4 or 2 x 6 inch wood framing, spaced at 16 or 24 inches on center, respectively, with insulation within the space (cavity) between. The most common insulation materials are fiberglass, cellulose, or rockwool. In addition to cavity insulation, many walls are also insulated with continuous rigid insulation, which can be installed either on the inside or outside of the framing.

For materials, both R-values and U-factors are used when describing thermal performance. Though the terms are very much related, there are significant differences between the two. In practice, R-value is material/component-specific, whilst U-factor represents the whole system. For walls, the U-factor includes the thermal performance of all assembled materials, including potential air gaps and surface heat transfer coefficients. In addition, the terms are inverses of each other: R-value defines the resistance of heat transfer whereas U-factor defines the ability to conduct heat. Thus, a higher U-factor means that heat is transferred more effectively, while the opposite is true for a higher R-value. Consequently, R-value is measured in degrees Fahrenheit, square foot of area perpendicular to the direction of heat transfer, and hour per BTU, whereas U-factor is measured as BTU per degree Fahrenheit, area and hour.

[19] https://title24stakeholders.com/measures/cycle-2025/multifamily-envelope/

For exterior walls, the benefit of using U-factor over R-value is that it accounts for thermal bridges. By definition, a thermal bridge is something that allows for higher heat transfer compared to adjacent materials. In walls, the studs will act as a thermal bridge since it has less R-value than insulation. The advantage of continuous rigid insulation, which is placed over the studs, is that it has no significant thermal bridges.

Insulation materials have been the focus of numerous California energy efficiency efforts from building energy code to utility incentive programs. For wall insulation, residential Investor Owned Utility (IOU) incentives have long been retired due to the maturity of the market, but some incentives are still offered by municipal utilities (such as Burbank Water & Power and Plumas-Sierra Rural Electric Co-Op) to help bring existing buildings with no insulation up to the current minimum requirement of R-13. In the case of California's building code, wall insulation proposals were included in both the 2019 and 2016 code cycles. High performance walls were introduced as a residential prescriptive requirement for the 2016 Title 24, Part 6 code cycle as a prescriptive wall U-factor requirement of 0.051 for all Climate Zones except 6 and 7 (Farahmand & Chappell, 2015). For the 2019 code cycle, wall insulation increased from R-19 to R-20 for 2x6 wall assemblies in alterations (Statewide CASE Team, 2018)]. The current proposal to increase R-13 to R-15 was also considered in 2019 as a prescriptive measure, but it was not adopted as it was not shown to be cost effective; this is being re-evaluated in the current proposal. Because the current proposal is a mandatory measure that does not impact the prescriptive-based energy budget used as a baseline for all construction, it does not require a full cost-effective analysis, but rather a display that cost increases, if any, would not be highly significant.

4.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the Energy Code, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change.[20] See Section 5 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 are described below. See Section 5.2 of this report for marked-up code language.

Section: Subchapter 7, Section 150.0(c)

Specific Purpose: The specific purpose of the changes to Subchapter 7, Section 150.0(c) is to reflect the updated U-factor requirements for wall assemblies of U-0.095

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

in 2 x 4 inch assemblies and U-0.069 in 2 x 6 inch assemblies for framed walls. Equivalent wall insulation R values will be displayed in-line with U-factors, rather than separately as is currently structured, for clarification.

Necessity: These changes are necessary to increase energy efficiency via cost effective building design standards, as directed by California Public Resources Code Sections 25213 and 25402.

4.1.3.2 Specific Purpose and Necessity of Changes to the Single-Family Residential ACM Reference Manual

Section 2.5.6.3 Exterior Walls of the Single-Family Residential ACM Reference Manual would be revised to specify that the software provide a warning message if a user enters a wall with a U-factor that does not meet the updated mandatory requirements as well as an error message during ruleset check if the non-compliance persists.

4.1.3.3 Summary of Changes to the Single-Family Residential Compliance Manual

Section 3.5.4.1 of the Single-Family Residential Compliance Manual would need to be revised. This would mirror the changes to Subchapter 7, Section 150.0(c) explained in above section 4.1.3.1, where the changes would reflect the updated code requirements of 0.095 in U-factor (R-15) in 2x4 assemblies and 0.069 (R-21) in 2x6 assemblies for framed walls.

4.1.3.4 Summary of Changes to Compliance Documents

The proposed code change would modify the CF2R-ENV-03-E Insulation Installation compliance document, as noted in Section 5.5. This is to update any numeric references to mandatory maximum U-factor requirements to reflect this proposal—that is, changing from U-0.102 to U-0.095 for 2 x 4 wall assemblies and from U-0.071 to U-0.069 for 2 x 6 wall assemblies.

4.1.4 Regulatory Context

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

There are no relevant state or local laws or regulations.

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

There are no relevant industry standards or model codes.

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. Section 5 shows specific changes to existing code language and 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:** The design professional or general contractor specifies wall cavity insulation of minimum R-value according to the stud depth of the framed walls. Remodel projects follow the same process as new construction.
- **Permit Application Phase:** The design professional, contractor, or homeowner applies for a permit with the applicable jurisdiction and completes, signs, and submits the necessary CF1R documents:
- **Construction Phase:** The contractor installs the wall assembly with insulation. If Quality Insulation Installation (QII) is specified, a HERS Rater comes onsite at rough install and at insulation installation phases to perform verification and complete the relevant CF3R forms.
- **Inspection Phase:** The contractor completes the necessary CF2R documents. If QII is specified, a HERS Rater comes onsite to verify the wall insulation installation and completes the relevant CF3R forms. Lastly, a building inspector conducts a final inspection and verifies the CF2R forms.

The compliance process described above does not differ from the existing compliance process for the proposed code change for wall construction.

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 (see https://title24stakeholders.com/event/nonresidential-multifamily-and-single-family-envelope-utility-sponsored-stakeholder-meeting/).

4.2.1 Current Market Structure

The technologies and markets surrounding wall cavity insulation meeting the proposed requirements of maximum 0.095 (2 x 4 inch framing) or 0.069 (2 x 6 inch or greater) in U-factor using R-15 or R-21 (respectively) are mature and readily available. This was confirmed through engaged stakeholders and is reflected in CalCERTS data for single-family homes constructed under Title 24 2019 Code, which reveals useful information on current construction design and practice (CalCERTS, 2023). The data includes projects that had at least one CF2R form registered as of November 2022 under the 2019 Code. From the data, the following information is given for the construction of single-family homes:

- Exterior walls in single-family homes are mainly constructed with either 2 x 4 inch wall framing (68 percent), or 2 x 6 inch (31.9 percent). Larger dimensions are rarely used and only represent a minuscule portion of new construction exterior walls.
- R-13 cavity insulation is used for 2 x 4 inch framing in 44 percent of the registered projects. R-15 cavity insulation is used in about 53 percent of the projects.

4.2.2 Technical Feasibility and Market Availability

Exterior walls can be insulated with a variety of varied materials and with different designs. Cavity insulation refers to insulation installed between the structural members of the exterior wall (typically, wood framing in single-family homes). Common cavity insulation materials are fiberglass, cellulose, mineral wool, and open or closed-cell spray foam. Exterior walls can also be insulated with rigid continuous insulation, such as expanded polystyrene (EPS), extruded polystyrene (XPS), or polyisocyanurate (Polyiso). Other non-rigid continuous insulation materials exist, such as rockwool.

There are also insulation installation designs where the insulation is embedded between the structural members to avoid thermal bridges (materials or components with less thermal resistance than insulation resulting in increased energy flow). An example of such construction is a panelized solution, typically constructed in a manufacturing environment and installed onsite. Structural insulation panels, or SIPs, consist of an insulated foam core sandwiched between two structural layers, typically oriented strand board (OSB). Other panelized solutions are Covestro's PUReWall and Rmax's Thermasheath®. Another design to reduce thermal bridges is double framing (two separate and parallel frames installed with cavity insulation). For such construction, the studs of the two frames are shifted to not align with each other, thus breaking the thermal bridge for which wood studs typically contribute to.

The prevalence of various insulation materials currently being installed was estimated using the same CalCERTS data mentioned previously (CalCERTS, 2023), and shows:

- R-21 cavity insulation is predominately used for 2 x 6 inch framing, represented by about 55 percent of registered projects. 33.8 percentage of projects installed either R-18 or R-19 cavity insulation. R-20, which aligns which currently mandatory minimum, was installed in 9.8 percent of the projects.
- Regardless of wall framing dimensions, fiberglass was used as cavity insulation in 79 percent of projects. Cellulose accounted for 14.7 percent of the market and spray foam 6.1 percent.

As seen by the CalCERTS data, R-15 and R-21, which both comply with proposed U-factors of 0.095 (2 x 4 inch) and 0.069 (2 x 6 inch) already have the largest market uptake. Because most common current design practices align with the proposed mandatory requirements, no unforeseen barriers on technical feasibility or market availability are expected.

While the proposed mandatory U-factor requirements are equivalent with R-15 and R-21 cavity insulation, lower R-value cavity insulation is not excluded from use. Any combination of insulation materials can be installed as long as the overall U-factor requirement is met. For example, R-13 cavity insulation can be installed in 2 x 6 inch framing if the cavity also includes two inches of additional insulation, such as spray foam, or R-13 cavity insulation can be installed together with the right amount of continuous insulation. However, the mandatory requirement would prevent the exclusive use of cavity insulation R-values below R-15 and R-21 for 2 x 4, and 2 x 6 inch framing respectively.

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 the existing prescriptive requirements. Since the proposal will not change the overall energy budget, nor standard design, no energy savings can be claimed. As such, this section of the CASE Report, which typically presents the methodology, assumptions, and results of the per unit energy impacts, has been truncated for this proposal.

Though no energy savings can be claimed from this proposed change in mandatory wall insulation requirements, it will raise the bar for overall building envelope performance. In the absence of this bar or “backstop”—a maximum/minimum performance value, in this case a wall assembly’s U-factor—the energy savings that would result from wall insulation can be traded off by energy savings in another building characteristic, such as the HVAC system. The backstop, on the other hand, ensures a minimum level of building envelope thermal efficiency.

4.4 Cost and Cost Effectiveness

The code change proposal introduces mandatory requirements that are less stringent than the existing prescriptive requirements, so the CEC does not need a complete cost effectiveness analysis to approve the proposed change. For this proposed change, the Statewide CASE Team is presenting information on the cost implications in lieu of a full cost effectiveness analysis, which is typically presented in this section of the CASE Report and details assumptions, methodologies, and results of a broad analysis regarding costs and savings.

As discussed in Section 4.2.1, wall cavity insulation products meeting the proposed requirements are both widely available and widely used. This indicates that material and labor costs for the proposed measure are already acceptable in much of the building community, which was supported in stakeholder feedback gathered by the Statewide CASE Team. Still, for the roughly half of applicable projects with minimally compliant wall insulation (i.e. R-13 and R-20; see section 4.2.1), this requirement would result in additional costs either for added or for different materials needed to reach compliance. To assess the scale of this additional cost, the Statewide CASE Team collected price data from over twenty wall insulation products on the market representing four manufacturers and several retailers including insulation distributors, shown in Figure 5. Most of the products are fiberglass insulation, representing the industry standard for wall cavity insulation.

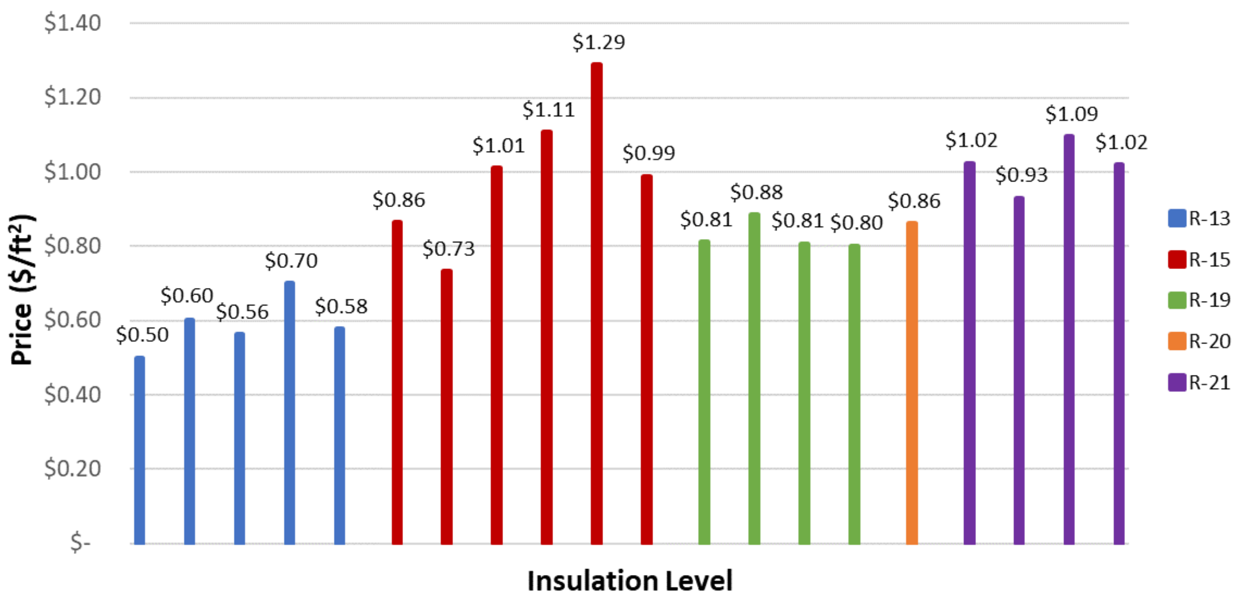


Figure 5: Price of cavity insulation. Products included are on rolls or packaged flat, faced and unfaced.

Source: (HomeDepot, 2023) (Lowe's, 2023).

The data in Figure 5 shows an increase in cost with increasing insulation R-value. Note, however, that there are significant price differences for some products with the same R-value. For example, the price of R-15 is highly variable with cost differences as high as $0.56 per square foot—or 71 percent of the cost range of all products. The price differences are mainly a result of different manufacturers, but also depend on how the insulation is packaged, whether the insulation is faced (has an attached Class II vapor retarder—kraft paper) or not, and possibly transportation costs. The price data in Figure 5 does not include bulk prices, which is typically available for the most commonly used insulation products.

In Figure 5, the price of many R-15 insulation products exceeds that of R-19 products. The main reason for the price increase is that R-15 (like R-21) is a high-density fiberglass product. During the production of high-density insulation, the production line slows down while producing insulation at the same rate, resulting in compressed insulation according to a stakeholder. If this material were not compressed, its R-value would be much higher.

For one specific manufacturer (HomeDepot, 2023), the resulting incremental cost is $0.36/ft^2 when going from R-13 to R-15, and $0.16/ft^2 when going from R-20 to R-21. For the prototype homes typically used in cost effectiveness analyses, this amounts to total incremental costs shown in Table 36.

Table 36: Incremental cost for proposed increased mandatory wall insulation requirements.

Proposed Increase	One Story Single Family New Construction Prototype (2,100 ft^2)	Two Story Single Family New Construction Prototype (2,700 ft^2)
R-13 → R-15	$366	$767
R-20 → R-21	$163	$341

Another aspect to consider when using high-density insulation products is the benefit toward quality insulation installation, or QII. High-density insulation typically expands upon application to better fit within the cavity, thus filling voids more effectively according to an insulation manufacturer.

4.5 First-Year Statewide Impacts

The code change proposal introduces mandatory requirements that are less stringent than the existing prescriptive requirements, so the savings associated with this proposed change are minimal. Typically, the Statewide CASE Team presents a detailed analysis of statewide energy and cost savings associated with the proposed change in this section of the CASE Report. In lieu of such an analysis, an overview of the benefits is provided.

By promoting higher overall wall cavity insulation levels, even small but persistent savings can add up over the product's lifetime. Since cavity insulation inside exterior walls typically remains untouched over the building's lifetime, it is essential to install levels of insulation that will meet the future needs of thermal performance. Through incremental code changes, the mandatory "bottom", or backstop, is moved up in a way that allows the market to adjust with minimal disruption in costs. Associated non-energy benefits include increased occupant comfort, especially when considering the aforementioned low rate of wall insulation replacement, and more overall robust construction that will help with building longevity.

5. Proposed Revisions to Code Language

5.1 Guide to Markup Language

The proposed changes to the Building Energy Efficiency Title 24 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).

5.2 Standards

Title 24, Part 6

SUBCHAPTER 7 SINGLE-FAMILY RESIDENTIAL BUILDINGS—MANDATORY FEATURES AND DEVICES

SECTION 150.0—MANDATORY FEATURES AND DEVICES

(c) **Wall insulation.** Opaque portions of above grade walls separating conditioned spaces from unconditioned spaces or ambient air shall meet the following requirements:

a. 2 × 4 inch framing shall have an overall assembly U-factor not exceeding U-0.095~~102~~. In wood framed assemblies, compliance with this U-factor may be demonstrated by installing R-15 or greater insulation between 16 inch-on-center framing members, or R-14 or greater insulation between 24 inch-on-center framing members.

Exception 1 to Section 150.0(c)1a: Existing walls in additions already insulated to a U-factor not exceeding U-0.110 or already insulated between framing members with insulation having an installed thermal resistance of R-11 or greater.

Exception 2 to Section 150.0(c)1a: Altered wood-framed walls where the existing siding is not being removed or replaced may meet the requirement with insulation between framing members of R-13 or greater.

b. 2 × 6 inch or greater framing shall have an overall assembly U-factor not exceeding U-0.069~~071~~. In wood framed assemblies, compliance with this U-factor may be demonstrated by installing R-21 or greater insulation between 16 inch-on-center framing members, or R-20 or greater insulation between 24 inch-on-center framing members.

Exception to Section 150.0(c)1b: Altered wood-framed walls where the existing siding is not being removed or replaced may meet the requirement with insulation between framing members of R-20 or greater.

c. Opaque non-framed assemblies shall have an overall assembly U-factor not exceeding U-0.102.

d. Bay or bow window roofs and floors shall be insulated to meet the wall insulation requirements of Table 150.1-A.

e. Masonry walls shall be insulated to meet the wall insulation requirements of Table 150.1-A.

~~f. In wood framed assemblies, compliance with U-factors may be demonstrated by installing wall insulation with an R-value of 13 in 2x4 assemblies, and 20 in 2x6 assemblies.~~

(q) **Fenestration products.** Fenestration separating conditioned space from unconditioned space or outdoors shall meet the requirements~~ of either Item 1 or 2~~ below:

1. Fenestration, including skylight products, must have a maximum U-factor of 0.4~~5~~0.

Exception 1 to Section 150.0(q)1: Up to 10 square feet of fenestration area or 0.5 percent of the conditioned floor area, whichever is greater, is exempt from the maximum U-factor requirement.

Exception 2 to Section 150.0(q)1: For dual-glazed greenhouse or garden windows, up to 30 square feet of fenestration area is exempt from the maximum U-factor requirement.

Exception 3 to Section 150.0(q)1: Replacement skylights in an alteration.

~~2. The area-weighted average U-factor of all fenestration, including skylight products shall not exceed 0.45.~~

SUBCHAPTER 8 SINGLE-FAMILY RESIDENTIAL BUILDINGS - PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES

SECTION 150.1—PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR SINGLE-FAMILY RESIDENTIAL BUILDINGS

(c) **Prescriptive standards/component packages.** Buildings that comply with the prescriptive standards shall be designed, constructed and equipped to meet all of the requirements for the appropriate climate zone shown in Table 150.1-A. In Table 150.1-A, NA (not allowed) means that feature is not permitted in a particular climate zone and NR (no requirement) means that there is no prescriptive requirement for that feature in a particular climate zone. Installed components shall meet the following requirements:

3. **Fenestration.**

A. Installed fenestration products, including glazed doors, shall have an area-weighted average U-factor and a Solar Heat Gain Coefficient (SHGC) meeting the applicable fenestration value in Table 150.1-A and shall be determined in accordance with Sections 110.6(a)2 and 110.6(a)3.

Exception 1 to Section 150.1(c)3A: For each dwelling unit, up to 3 square feet of ~~new~~ glazing area installed in doors and up to 3 square feet of ~~new~~ tubular skylights area with dual-pane diffusers shall not be required to meet the U-factor and SHGC requirements of Table 150.1-A.

Exception 2 to Section 150.1(c)3A: In Climate Zone 2, 4, and 6 through 15, fFor each dwelling unit up to 16 square feet of new skylight area with a maximum U-factor of 0.40 and a maximum SHGC of 0.30.

Exception 3 to Section 150.1(c)3A: In Climate Zone 1, 3, 5, and 16, for each dwelling unit up to 16 square feet of skylight area with a maximum U-factor of 0.55 and no SHGC requirement.

Exception 4 to Section 150.1(c)3A: New dwelling units with a conditioned floor area of 500 square feet or less in Climate Zones 5 through 10 and 15 may comply with a maximum U-factor of 0.3.

Exception 35 to Section 150.1(c)3A For fenestration containing chromogenic type glazing:

i. The lower-rated labeled U-factor and SHGC shall be used with automatic controls to modulate the amount of solar gain and light transmitted into the space in multiple steps in response to daylight levels or solar intensity;

ii. Chromogenic glazing shall be considered separately from other fenestration; and

iii. Area-weighted averaging with other fenestration that is not chromatic shall not be permitted and shall be determined in accordance with Section 110.6(a).

EXCEPTION 46 to Section 150.1(c)3A: For dwelling units containing unrated site-built fenestration that meets the maximum area restriction, the U-factor and SHGC can be determined in accordance with the Nonresidential Reference Appendix NA6 or use default values in Table 110.6-A and Table 110.6-B.

4. **Shading.** Where Table 150.1-A requires a maximum SHGC, the shading requirements shall be met by one of the following:

A. Complying with the required maximum SHGC pursuant to Section 150.1(c)3A; or

B. An exterior operable shading louver or other exterior shading device that meets the required maximum SHGC; or

C. A combination of Items A and B to achieve the same performance as achieved in Section 150.1(c)3A.

D. For south-facing glazing only, optimal overhangs shall be installed so that the south-facing glazing is fully shaded at solar noon on August 21 and substantially exposed to direct sunlight at solar noon on December 21.

E. Exterior shading devices must be permanently secured with attachments or fasteners that are not intended for removal.

Exception to Section 150.1(c)4E: Where the California Building Code (CBC) requires emergency egress or where compliance would conflict with health and safety regulations.

TABLE 150.1-A COMPONENT PACKAGE—Single- Family Standard Building Design

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Building Envelope	Floors		Slab Perimeter	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	U-0.58 R-7.0
			Raised	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U-0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U- 0.037 R-19	U-0.037 R-19	U-0.037 R-19	U-0.037 R-19	U- 0.037 R-19
			Concrete Raised	U 0.092 R-8.0	U 0.092 R-8.0	U 0.269 R-0	U 0.269 R-0	U 0.269 R-0	U 0.269 R-0	U 0.269 R-0	U 0.269 R-0	U 0.269 R-0	U 0.269 R-0	U 0.092 R-8.0	U 0.138 R-4.0	U 0.092 R-8.0	U 0.092 R-8.0	U 0.138 R-4.0	U 0.092 R-8.0
	Quality Insulation Installation (QII)			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Roofing Product	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
		Steep-Sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.20	0.20	0.20	0.20	0.20	0.20	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
	Fenestration		Maximum U-factor[7]	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~28	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27	0.~~30~~27
			Maximum SHGC	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 Total Area	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
			Maximum West Facing Area	NR	5%	NR	5%	NR	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	NR
	Door		Maximum U-factor	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Footnote requirements to TABLE 150.1-A:

7. New dwelling units with a conditioned floor area of 500 square feet or less in Climate Zones 5 through 10 and 15 may comply with a maximum U-factor of 0.3.

SUBCHAPTER 9 SINGLE-FAMILY RESIDENTIAL BUILDINGS - ADDITIONS AND ALTERATIONS TO EXISTING RESIDENTIAL BUILDINGS

SECTION 150.2—ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING SINGLE-FAMILY RESIDENTIAL BUILDINGS

(b) **Alterations.** Alterations to existing single-family residential buildings or alterations in conjunction with a change in building occupancy to a single-family residential occupancy shall meet either Item 1 or 2 below.

1. **Prescriptive approach.** The altered component and any newly installed equipment serving the alteration shall meet the applicable requirements of Sections 110.0 through 110.9 and all applicable requirements of Sections 150.0(a) through (l), 150.0(m)1 through 150.0 (m)10, and 150.0(p) through (q); and

   A. **Added fenestration**. Alterations that add vertical fenestration and skylight area shall meet the total fenestration area and west facing fenestration area, U-factor, and Solar Heat Gain Coefficient requirements of Section 150.1(c) and TABLE 150.1-A.

   ~~**Exception 1 to Section 150.2(b)1A:** Alterations that add fenestration area of up to 75 square feet shall not be required to meet the total fenestration area and west-facing fenestration area requirements of Sections 150.1(c)3B and C.~~

   Exception ~~2 to~~ Section 150.2(b)1A: Alterations that add up to 16 square feet of new fenestration or skylight area ~~with a maximum U-factor of 0.55 and a maximum SHGC of 0.30 area~~ shall not be required to meet the total fenestration area and west-facing fenestration area requirements of Sections 150.1(c)3B and C.

   B. **Replacement fenestration.** New manufactured fenestration products installed to replace existing fenestration products of the same total area shall meet the U-factor and Solar Heat Gain Coefficient requirements of Sections 150.1(c)3.A, and 150.1(c)4.

   Exception ~~1 to~~ Section 150.2(b)1B: Replacement of vertical fenestration no greater than ~~75~~16 square feet with a U-factor no greater than 0.40 in Climate Zones 1-16, and a SHGC value no greater than 0.35 in Climate Zones 2, 4, and 6 through ~~-~~15.

   Exception 2 to Section 150.2(b)1B: Replaced skylights must meet a U-factor no greater than 0.~~55~~40, and a SHGC value no greater than 0.30.

   NOTE: Glass replaced in an existing sash and frame, or sashes replaced in an existing frame are considered repairs, provided that the replacement is at least equivalent to the original in performance.

TABLE 150.2-D STANDARD DESIGN FOR AN ALTERED COMPONENT

Altered Component	Standard Design without Third Party Verification of Existing Conditions Shall be Based On	Standard Design with Third Party Verification of Existing Conditions Shall be Based On
Ceiling Insulation, Wall Insulation, and Raised-floor Insulation	The requirements of Sections 150.0(a), (c), and (d)	The existing insulation R-value
Fenestration	The requirements of Section 150.1(c)3A. ~~The U-factor of 0.40 and SHGC value of 0.35. The glass area shall be the glass area of the existing building.~~	If the proposed U-factor is ≤ 0.40 and SHGC value is ≤ 0.35, the standard design shall be based on the existing U-factor and SHGC values as verified. Otherwise, the standard design shall be based on the U-factor of 0.40 and SHGC value of 0.35. The glass area shall be the glass area of the existing building.
Window Film	The requirements of Section 150.1(c)3A. ~~The U-factor of 0.40 and SHGC value of 0.35.~~	The existing fenestration in the alteration shall be based on Table 110.6-A and Table 110.6-B.

Title 24, Part 11 (CALGreen)

Appendix A4 Residential Voluntary Measures, Division A4.2 – Energy Efficiency

A4.203.1.2.5 High performance vertical fenestration.

Meet a ~~the climate zone dependent U-factor and Solar Heat Gain Co-efficient (SHGC) specified in Title 24, Part 6, Section 110.6, M~~maximum U-factor of 0.21 in all climate zones, and a Maximum SHGC of 0.23 in Climate Zones 2, 4, and 6 through 15.

5.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

5.4 Single-Family Residential ACM Reference Manual

Section 2.5.6 Exterior Surfaces

Exterior Walls

PROPOSED DESIGN

The software allows the user to define walls, enter the gross area, and select a construction assembly for each. The user also enters the plan orientation (front, left, back, or right) or plan azimuth (value relative to the front, which is represented as zero degrees) and tilt of the wall.

The wall areas modeled are consistent with the actual building design, and the total wall area is equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side. Underground mass walls are defined with inside and outside insulation and the number of feet below grade. Walls adjacent to unconditioned spaces with no solar gains (such as knee walls or garage walls) are entered as an interior wall with the zone on the other side specified as attic, garage, or another zone, and the compliance manager treats that wall as a demising wall. An attached unconditioned space is modeled as an unconditioned zone.

The software will check that the wall assembly entered by the user meets the mandatory U-factor or insulation requirements. If it does not, the user will receive an error message during ruleset check and the simulation will not proceed.

Fenestration

PROPOSED DESIGN

The compliance software allows users to enter individual skylights and fenestration types, the U-factor, SHGC, area, orientation, and tilt.

Performance data (U-factors and SHGC) are from NFRC values or from the CEC default tables from Section110.6 of the Energy Code. In spaces other than sunspaces, solar gains from windows or skylights use the California Simulation Engine (CSE) default solar gain targeting.

Skylights are a fenestration with a slope of 60 degrees or more. Skylights are modeled as part of a roof.

The compliance software will check that the area weighted window U-factor for all fenestration meets the mandatory U-factor requirements. If it does not, the user will receive an error message during ruleset check and the simulation will not proceed.

STANDARD DESIGN

If the proposed design fenestration area is less than 20 percent of the conditioned floor area, the standard design fenestration area is set equal to the proposed design fenestration area. Otherwise, the standard design fenestration area is set equal to 20 percent of the conditioned floor area. The standard design fenestration area is distributed equally among the four main compass points — north, east, south, and west.

The standard design has no skylights.

The net wall area on each orientation is reduced by the fenestration area and door area on each façade. The U-factor and SHGC performance factors for the standard design are taken from Section150.1(c) and Table 150.1-A, which is ~~0.30 U-factor in all climate zones~~0.27 U-factor except in the following instances. Homes with greater than 500 square feet of conditioned floor area in Climate Zone 7 have a U-factor of 0.28. Homes with less than or equal to 500 square feet of conditioned floor area in Climate Zones 5-10 and 15 have a 0.30 U-factor. SHGC is 0.23 in Climate Zones 2, 4, and 6–15. Where there is no prescriptive requirement (Climate Zones 1, 3, 5, and 16), the SHGC is set to 0.35.

VERIFICATION AND REPORTING

Fenestration area, U-factor, SHGC, orientation, and tilt are reported on the CF1R. SHGC is reported on the CF1R as an allowable maximum and minimum for each window calculated as the SHGC entered by the user plus or minus 0.01.

5.5 Compliance Documents

The following compliance documents would need to be revised to reflect proposed updates to prescriptive U-factor values for windows and mandatory U-factor values for exterior walls. Other changes are to clarify the proposed requirement that the installed window SHGC match that from the performance model for projects that comply via the performance path. This requires only minor updates to existing forms, and it does not require the creation of any new forms. This clarification is necessary for market actors to avoid confusion and ensure compliance.

- CF1R-PRF-01E Performance Newly Constructed Building
    - See Appendix C for details.
- CF1R-ENV-03-E Solar Heat Gain Coefficient (SHGC) Worksheet
- CF1R-NCB-01-E Prescriptive Newly Constructed Building
- CF1R-ALT-01-E Prescriptive Alterations Building
- CF1R-ALT-05-E Prescriptive Alterations – Simple Non-HERS
- CF1R-ADD-01-E Prescriptive Residential Additions 1,000 ft^2 or Less
- CF1R-ADD-02-E Prescriptive Residential Additions That Do Not Requires HERS Field Verification
- CF2R-ENV-01-E Fenestration Installation
- CF2R-ENV-03-E Insulation Installation
- CF2R-ADD-02-E Prescriptive Residential Additions That Do Not Requires HERS Field Verification

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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). The CEC provided the construction estimates on March 27, 2023, at the Staff Workshop on Triennial California Energy Code Measure Proposal Template.

The Statewide CASE Team followed guidance provided in the CEC's New Measure Proposal Template (developed by the Energy Commission) to calculate statewide energy savings using the CEC's construction forecasts and assuming statewide weighting of 2 percent for the 500 square foot prototype, 42 percent for the 2,100 square foot prototype, and 56 percent for the 2,700 square foot prototype. In Sections 3.3 and 3.4, results are presented for a weighted average of the 2,100 square foot and 2,700 square foot new construction prototypes; results for each of the prototypes are similar. With the exclusion of the 500 square foot prototype, savings results are weighted 43 percent for the 2100 square foot prototype and 57 percent for the 2700 square foot prototype (Section 4.2 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 Energy Commission'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. Table 37 presents the number of homes, both newly constructed and existing, that the Statewide CASE Team assumed will be impacted by the proposed code change during the first year the 2025 code is in effect.

The window prescriptive U-factor code change proposal is the only measure that has statewide energy impacts to quantify. For new construction the measure will impact 100 percent of all new homes in Climate Zones 1 through 5, 11 through 14, and 16. Due to the exception for small homes 500 square feet and under in Climate Zones 6 through 10 and 15, the measure will impact 98 percent of homes in these climate zones. Even if a project does not meet the new prescriptive performance requirements, they will need to trade this off in the performance approach with another energy efficiency measure that would provide the same level of savings.

For existing buildings, the measure is estimated to impact 0.16 percent of existing homes. This value was deduced from 2019 RASS survey data (DNV, 2022), which showed 12.4 percent of homes having underwent a remodel in the past year, as well as CalCERTS data (CalCERTS, 2023) showing that 1.3 percent of alteration projects in the

2019 code cycle involved at least 1 window, as indicated via submission of CF2R-ENV-01 forms. This assumes that all window remodels submitted through CalCERTS complete a CF2R-ENV-01 form.

Table 37: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone

Building Climate Zone	Total Homes Completed in 2026 (New Construction) [A]	Percent of New Buildings Impacted by Proposal [B]	New Buildings Impacted by Proposal in 2026 C = A x B	Total Existing Homes in 2026 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2026 F = D x E
1	359	100%	359	44,875	0.16%	72
2	1,861	100%	1,861	265,807	0.16%	425
3	3,035	100%	3,035	972,513	0.16%	1,556
4	2,689	100%	2,689	497,321	0.16%	796
5	616	98%	604	97,271	0.16%	156
6	1,719	98%	1,685	594,544	0.16%	951
7	1,869	98%	1,832	494,355	0.16%	791
8	4,163	98%	4,080	926,278	0.16%	1,482
9	4,286	98%	4,200	1,250,479	0.16%	2,001
10	7,950	98%	7,791	1,067,399	0.16%	1,708
11	5,840	100%	5,840	335,468	0.16%	537
12	14,542	100%	14,542	1,318,779	0.16%	2,110
13	7,257	100%	7,257	634,709	0.16%	1,016
14	3,739	100%	3,739	247,852	0.16%	397
15	3,160	98%	3,097	177,670	0.16%	284
16	1,937	100%	1,937	97,937	0.16%	157
TOTAL	**65,022**	**-**	**64,547**	**9,023,257**	**-**	**14,437**

Source: (California Energy Commission, 2022)

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 residential buildings (CBECC-Res) 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 proposed code changes would need to be incorporated into the software to accommodate updates to the Standard Design to match new prescriptive requirements, incorporate software checks for mandatory requirements, and implement a new approach to reporting SHGC in the CF1R.

Description of Software Change

Background Information for Software Change

The proposed code change revises the window prescriptive U-factor requirements and changes mandatory requirements for window U-factor and exterior wall U-factor. The changes impact single family homes and are summarized below.

- Reduce the prescriptive U-factor requirement for windows from 0.30 to 0.27 in Climate Zones 1-6 and 8-16 and from 0.30 to 0.28 in Climate Zone 7. This applies to new construction and alterations. The prescriptive requirement for new homes with a conditioned floor area of 500 square feet or less will remain at 0.30 in Climate Zones 5-10 and 15.
- Reduce the mandatory window U-factor from 0.45 to 0.40.
- Require that the installed window SHGC match the modeled window SHGC within a range of ±0.01.
- Reduce the mandatory framed wall U-factor for 2x4 walls from 0.102 to 0.095, equivalent to R-15 cavity insulation in wood framed walls.
- Reduce the mandatory framed wall U-factor for 2x6 walls from 0.071 to 0.069, equivalent to R-21 cavity insulation in wood framed walls.

Existing CBECC-Res Building Energy Modeling Capabilities

CBECC-Res currently models all the window and wall characteristics referenced in this code change proposal. The 2022 Energy Code prescriptive U-factor and SHGC requirements are implemented in the Standard Design. CBECC-Res does not currently conduct verifications on user input to verify compliance with mandatory wall or window U-factor requirements.

Summary of Proposed Revisions to CBECC-Res

CBECC-Res would need to be updated to reflect the proposed prescriptive window U-factor requirements in the Standard Design and to incorporate verification that the Proposed Design meets mandatory requirements for wall and window U-factor.

User Inputs to CBECC-Res

There are no new recommended user inputs to CBECC-Res. To accommodate mandatory requirement checks, there will need to be new restrictions on the following values.

- Window U-factor
- Exterior wall construction assembly U-factor

The software would check that for all new and/or altered windows the average weighted window U-factor entered by the user is less than or equal to the mandatory U-factor requirement. If it does not the user would receive an error message and would need to update the window performance values before the simulation proceeds.

The software would check that each new or altered exterior wall surface assembly U-factor entered by the user is less than or equal to the mandatory U-factor requirement. If this condition is not met the user would receive an error message and would need to update the assembly details before the simulation proceeds.

Simulation Engine Inputs

There is no recommended change to how CBECC-Res translates user inputs into CSE inputs.

Simulation Engine Output Variables

The following output variables will be reviewed to confirm that the updates have been integrated properly into the software.

- Compliance rates and annual energy use.

Compliance Report

The recommended changes to the compliance report are intended to accommodate the proposed code change that requires the installed window SHGC to match the modeled window SHGC within a narrow range (±0.01). This would require a new column be added in the report and both maximum and minimum SHGC be specified. In the Fenestration / Glazing table of the CF1R-PRF-01E the following changes are recommended. A screenshot of the existing referenced report section is included below in Figure 6 for clarification.

- Change the #10 U-factor column title to “Maximum U-Factor”. This is for clarity since SHGC will now be called out as a maximum and minimum.
- Change the #12 SHGC column title to “Minimum SHGC”. This value will be reported as the user entered SHGC minus 0.01.
- Add a new column #13 titled “Maximum SHGC”. This value will be reported as the user entered SHGC plus 0.01.
- Rename existing column #13 SHGC Source to #14 SHGC Source.
- Rename existing column #14 Exterior Shading to #15 Exterior Shading. Consider whether this is a necessary software input and reportable value. Modeling windows with or without a bug screen does marginally change the compliance results. However, it is arguable that this should not be a variable that impacts compliance. In the Statewide CASE Team’s experience, this variable is rarely altered by the energy modeler and the default bug screen is typically modeled.

FENESTRATION / GLAZING													
01	02	03	04	05	06	07	08	09	10	11	12	13	14
Name	Type	Surface	Orientation	Azimuth	Width (ft)	Height (ft)	Mult.	Area (ft^2)	U-factor	U-factor Source	SHGC	SHGC Source	Exterior Shading
Zone1WinFront	Window	Zone1WallFront	Front	0	3	5	7	105	0.3	NFRC	0.35	NFRC	Bug Screen

Figure 6: CF1R-PRF-01E compliance report fenestration table example.

Compliance Verification

Verification of code compliance will be similar to the current process today. The one difference is that authorities having jurisdiction will need to verify that the SHGC falls within the required range, rather than verifying against an allowable maximum. See Sections 3.1.5 and 4.1.5 and Appendix E for further details.

Testing and Confirming CBECC-Res Building Energy Modeling

Table 38 describes the recommended testing to confirm software updates have been properly incorporated. Tests should be completed with the standard geometry prototypes that are set up to match the Standard Design properties. As part of these tests the compliance report will also be reviewed to confirm that the SHGC values are properly reported.

Table 38: Proposed New Construction CBECC-Res Testing

Measure	Climate Zone	Prototype	Objects Modified	Parameter Name	Design Parameter Value	Expected Test Outcome
Window Prescriptive U-Factor	CZ 1-5, 11-14, 16	2100 or 2700	Window Properties	U-factor	0.28	0% compliance
Window Prescriptive U-Factor	CZs 6-10, 15	2100 or 2700	Window Properties	U-factor	0.28	0% compliance
Window Prescriptive U-Factor	CZ 1-5, 11-14, 16	500	Window Properties	U-factor	0.28	0% compliance
Window Prescriptive U-Factor	CZs 6-10, 15	500	Window Properties	U-factor	0.30	0% compliance
Window Mandatory U-Factor	Any 1 CZ	Any prototype	Window Properties	U-factor	0.40	Simulation will proceed, <0% compliant
Window Mandatory U-Factor	Any 1 CZ	Any prototype	Window Properties	U-factor	0.41	Simulation will not proceed; appropriate error message appears
Wall Mandatory U-Factor	Any 1 CZ	Any prototype	Exterior Wall Construction Assembly	U-factor	2x4 wood-framed wall with R-15 cavity insulation, 0.095 U-factor	Simulation will proceed, <0% compliant
Wall Mandatory U-Factor	Any 1 CZ	Any prototype	Exterior Wall Construction Assembly	U-factor	2x4 wood-framed wall with R-13 cavity insulation, 0.102 U-factor	Simulation will not proceed; appropriate error message appears
Wall Mandatory U-Factor	Any 1 CZ	Any prototype	Exterior Wall Construction Assembly	U-factor	2x4 metal-framed wall with R-15 cavity insulation	Simulation will not proceed; appropriate error message appears
Wall Mandatory U-Factor	Any 1 CZ	Any prototype	Exterior Wall Construction Assembly	U-factor	2x6 wood-framed wall with R-21 cavity insulation, 0.069 U-factor	Simulation will proceed, <0% compliant
Wall Mandatory U-Factor	Any 1 CZ	Any prototype	Exterior Wall Construction Assembly	U-factor	2x6 wood-framed wall with R-20 cavity insulation, 0.071 U-factor	Simulation will not proceed; appropriate error message appears
Wall Mandatory U-Factor	Any 1 CZ	Any prototype	Exterior Wall Construction Assembly	U-factor	2x6 metal-framed wall with R-21 cavity insulation	Simulation will not proceed; appropriate error message appears

Description of Changes to ACM Reference Manual

See Section 5.4 for further details.

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 will not result in a significant effect on the environment.

Direct Environmental Impacts

Direct Environmental Benefits

Direct environmental benefits from the high-performance window proposal are energy savings, peak demand savings, and GHG emission reductions.

Direct Adverse Environmental Impacts

There are no direct adverse environmental impacts from the code change proposals.

Indirect Environmental Impacts

Indirect Environmental Benefits

There are no indirect environmental benefits from the code change proposals.

Direct Adverse Environmental Impacts

There are no direct adverse environmental impacts from the code change proposals.

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 determined this measure would not result in significant direct or indirect adverse environmental impacts and therefore, did not develop any mitigation measures.

Reasonable Alternatives to Proposal

If an EIR is developed, CEQA requires a lead agency to evaluate reasonable alternatives to proposals that would have a significant adverse effect on the environment, including a “no project” alternative. (Cal. Code Regs. Tit. 14, § 15002(h)(4) and 15126.6.)

The Statewide CASE Team has considered alternatives to the proposal and believes that no alternative achieves the purpose of the proposal with less environmental effect.

Water Use and Water Quality Impacts Methodology

The proposed code change produces 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 determined there were no material impacts for the proposed measures and therefore did not calculate emissions impacts associated with embodied carbon from a change in materials.

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

This appendix discusses how the recommended compliance process, which is described in 3.1.5 and 4.1.5, could impact various market actors. Table 39 identifies the market actors who will 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 ways negative impacts could be mitigated. The information contained in Table 39 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

The proposed measures will have minimum impact on the current compliance and enforcement process. The proposed compliance process fits within the current workflow of all market actors involved. There is no additional coordination required among market actors beyond what is currently done.

Table 39 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they will be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated.

Table 39: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) in current compliance process relating to the CASE measure	How will the proposed measure impact the current task(s) or workflow?	How will the proposed code change impact compliance and enforcement?	Opportunities to minimize negative impacts of compliance requirement
Architect/ Designer, General Contractor, and/or Specialty Contractor (Glass/Glazing for window measure; Framing for wall insulation measure)	• Identify relevant requirements and/or compliance path. • Install products to meet requirements. • Complete required compliance documents for permit application. • Coordinate with each other as applicable	• Quickly and easily determine requirements based on scope and climate zone; meet schedule. • Demonstrate compliance with code requirements. • Clearly communicate performance requirements to building owner. • Complete compliance documents required for permit sign-off.	• Ensure that products selected are compliant with the new code requirements. • Performance CF1R and CF2R forms will provide an allowable range for SHGC based on the modeled value.	• Revise compliance documents and/or software to automate compliance checks based on climate zone. • Provide updated fact sheets for distribution at local building department offices and websites.
Building Inspector/Plans Examiners	• Understand code requirement and confirm data on documents is compliant. • Confirm plans / specifications match data on compliance documents. • Provide correction comments if necessary.	• Quickly and easily determine requirements based on scope and climate zone. • Quickly and easily determine if data in documents meets requirements. • Quickly and easily determine if plans/specs match compliance documents. • Quickly and easily provide correction comments that would resolve issue.	• Check that proposed windows meet the allowable range for SHGC per the performance CF1R. • CBECC-Res will be updated to verify that mandatory requirements for window U-factor and exterior wall U-factor are met, reducing the burden on plans examiners.	• Compliance documents and/or software could auto-verify data compliance with standards. • Provide fact sheets for distribution at local building department offices and websites to distribute to all projects applying for applicable residential permits.
Building Owner	Little direct involvement unless responsible for pulling permit.	If pulling permit, obtain necessary compliance documents from contractor.	Could impact design options and/or costs until the market response to code changes settles.	Provide homeowner educational materials on comfort and utility bill impacts.

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 Final CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost effectiveness, market barriers, technical barriers, compliance and enforcement challenges, or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

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

Utility-Sponsored Stakeholder Meetings

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

The Statewide CASE Team hosted one stakeholder meeting for Single-Family High-Performance Envelope via webinar described in Table 40. 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 [(Statewide CASE Team, 2023a), (Statewide CASE Team, 2023b), (Statewide CASE Team, 2023c), (Statewide

CASE Team, 2023d)]. A second stakeholder meeting is planned for May 17th and will present updates on the window measure.

Table 40: Utility-Sponsored Stakeholder Meetings

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Utility-Sponsored Stakeholder Meeting: Nonresidential, Multifamily, Single Family Envelope Utility-Sponsored Stakeholder Meeting	Tuesday, February 14, 2023	https://title24stakeholders.com/event/nonresidential-multifamily-and-single-family-envelope-utility-sponsored-stakeholder-meeting/
Second Round of Utility-Sponsored Stakeholder Meeting: Single Family Buried Ducts & High-Performance Windows, Multifamily Envelope, and Indoor Air Quality Utility-Sponsored Stakeholder Meeting	Wednesday, May 17, 2023	https://title24stakeholders.com/event/single-family-buried-ducts-high-performance-windows-and-multifamily-envelope-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred in January and 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 planned for May 2023 and will provide updated details on proposed code changes. The second round of meetings will introduce results of energy, cost effectiveness, and incremental cost analyses, and solicit 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 depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page (and cross-promoted on the CEC 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/or phone with numerous stakeholders when developing this report. Those contacted for the proposals contained in this high-performance envelope CASE Report are listed in Table 41.

Table 41: Engaged Stakeholders

Organization/Individual Name	Market Role
2050 Partners	Energy Consultant
Alpen Windows	Manufacturers
Anderson Windows	Manufacturer
Beyond Efficiency	Architect
Build Smart Group	Energy Consultant
CalMTA	Market Transformation Advisory Board
CBIA	Builders/Developers & Industry Associations
Department of Energy (DOE)	National Laboratories
DeYoung Properties	Builders/Developers & Industry Associations
Harris & Sloan	HVAC Designer
IIBEC	Industry/Trade Associations
Jeld-Wen, Inc.	Manufacturers
KB Homes	Builders/Developers & Industry Associations
KB Homes	Builders/Developers & Industry Associations
Lawrence Berkeley National Laboratory (LBNL)	National Laboratories
Natural Resources Defense Council	Advocacy Group
Northwest Energy Efficiency Alliance (NEEA)	Industry/Trade Associations
Oak Ridge National Laboratory	National Laboratories
Owens Corning	Manufacturers
Pella Windows	Manufacturers
PGT Industries	Manufacturers
Responsible Energy Codes Alliance	Advocacy Group
Sika Corporation/Rmax	Manufacturers
Simpson, Gumpert & Heger	Energy Consultant
Western AeroBarrier	Manufacturers
Window & Door Manufacturers Association	Industry/Trade Associations

Builder Survey

As part of the stakeholder outreach conducted by the Statewide CASE Team, a survey was conducted to gather feedback from the building sector on numerous proposals. The survey was developed by the Statewide CASE Team with input from Evergreen Economics, who conducted the survey. The survey was sent out to members of the California Building Industry Association (CBIA) and to Title 24 Stakeholder email subscribers. The survey was open for a month and closed late June 2023. The survey results presented below are divided into two sections: one for the window measure, and one for wall insulation.

Windows

The first question related to windows sought information on how frequently new construction single-family projects already meet a window U-factor requirement of 0.28 or lower. Figure 7 reveals the majority (62 percent) of projects do meet the requirements, while 36 percent do so occasionally or rarely.

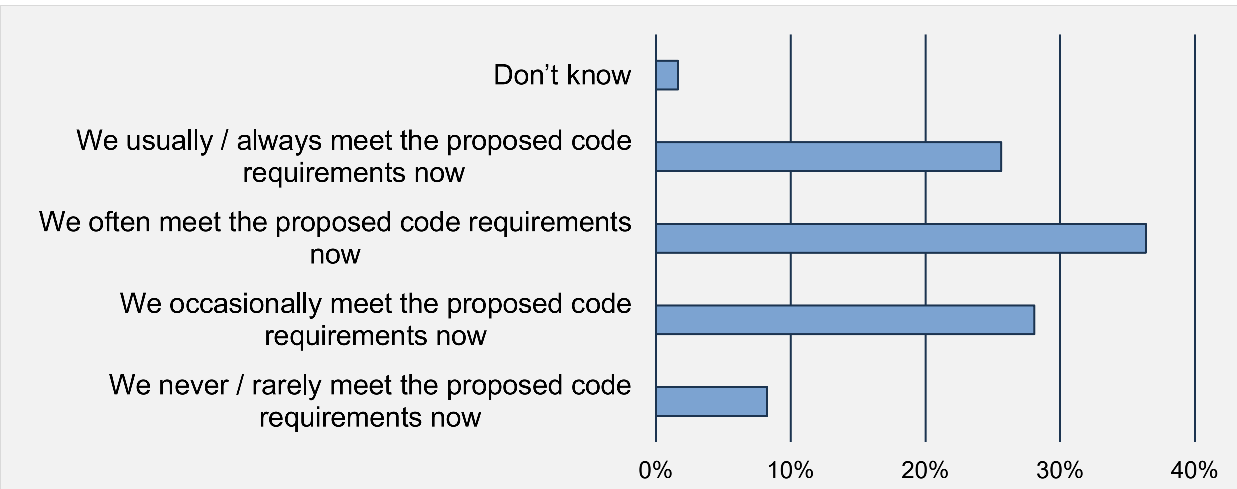

Figure 7: Responses to "How often do the single-family projects you work on already meet the proposed requirements?" Participants: 121.

In the survey, five topics were brought up and responses to their impact were asked from lowering the existing U-factor requirements. The following topics were given:

- Materially significant increases in total project costs.
- Energy savings at a level that will recoup any incremental costs.
- Improved project quality.
- Increased challenges with product availability.
- Challenges in installation due to the need for changed practices.

Table 42 depicts the results from the expected impact on the topics above. Materially, the majority believe that there will be "some" increase in total project costs. On energy savings, most believed that such will be higher than first-time incremental costs of windows with a lower U-factor. The majority also believed that project quality will be improved.

Table 42: Responses to "In what share of your projects would you experience the following if a lower U-factor requirement is put in place?" Participants: 119.

In what share of your projects would you experience the following if a lower U-factor requirement is put in place?	None or few	Some	Many	N/A
Materially significant increases in total project costs	19%	44%	35%	2%
Energy savings at a level that will recoup any incremental costs	26%	50%	20%	3%
Improved project quality	18%	45%	31%	6%
Increased challenges with product availability	11%	40%	43%	6%
Challenges in installation due to the need for changed practices	23%	44%	29%	5%

In Table 42, 83 percent of respondents replied that they expect increased challenges with product availability. Of these, 64 percent respond that this will last the first year or so, while 36 percent believe it will last longer.

On installation challenges, 73 percent replied that they expected "some" or "many", for which 29 percent believe such will last a year or less, while 71 percent expect these challenges to last longer.

During the survey, the participants were also asked if they had ever used a triple-pane window on a new construction project. Fifty-three percent responded that they had, and the remaining replied that they hadn't or didn't know if they had.

Figure 8 reveals information on how the participants expected the cost of labor to be impacted if triple-pane windows were required. Previously in the code cycle, the Statewide CASE Team considered U-factors down to 0.25, which for some window manufacturers will require a triple-pane window. Hence, the Statewide CASE Team chose not to propose a 0.25 in U-factor requirement; the survey results shown in Figure 8 serve as informational purpose only.

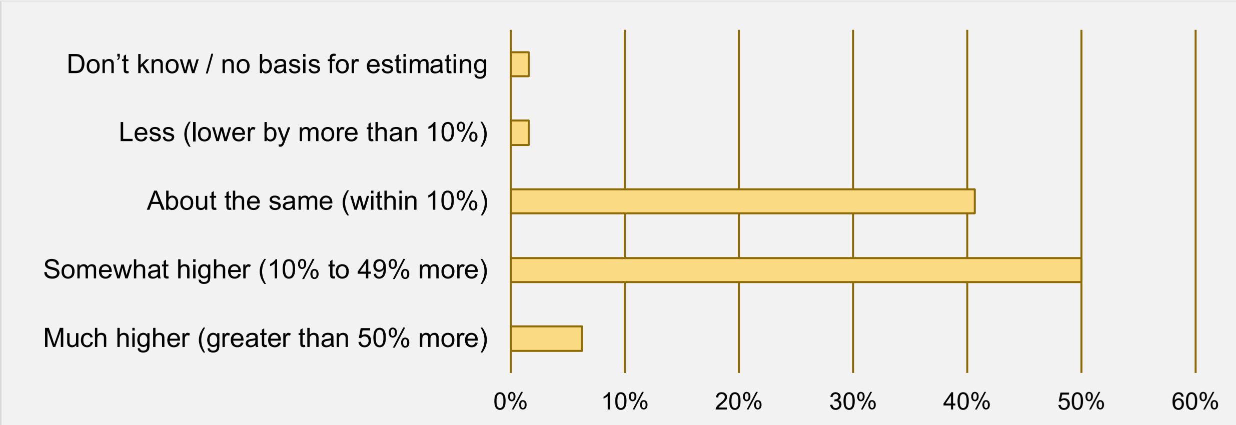

Figure 8: Responses to "How do the labor costs associated with installation for triple-pane windows compare to those for double-pane windows?" Participants: 64.

Table 43 summarizes the responses from asking how project costs, product acquisition, and installation practices would be affected by lowering the overall mandatory maximum U-factor from 0.45 to 0.40. Most participants chose either "some" or "many". Based on in-person discussions and interviews with stakeholders, it's likely that this question was misinterpreted as if no installed window is allowed to have a U-factor higher than 0.40. The code specifies this requirement as an overall area-weighted average. That is, the proposed change does not prohibit the use of windows with a higher U-factor than 0.40 as long as the area-weighted average of all windows does not exceed this value.

Table 43: Responses to "In what share of your projects would a change in mandatory maximum U-factor from 0.45 to 0.40 affect your…?" Participants: 117

In what share of your projects would a change in mandatory maximum U-factor from 0.45 to 0.40 affect your…?	None or few	Some	Many	Not applicable
Project costs	20%	41%	39%	0%
Product acquisition	19%	44%	37%	0%
Installation practices	29%	44%	27%	0%

Other comments on the window measure provided in the survey are summarized as:

- Triple pane windows are a significant cost because you must increase your framing size.
- I don't understand the need for energy efficiency, when PVC panels are also required. One or the other please!
- While there may be products produced today that meet the standards that you are proposing, those products are significantly more costly than their

counterparts. This will increase construction costs on glazing products that are already high priced. The glazing companies are still struggling to keep up with the demand that they have which would possibly delay production and delivery of the glazing.

- It’s a waste of money to make a home more energy efficient without also reducing its flammability in materials and building detailing. Every burnt-down home has a huge carbon footprint.
- The hardship to comply with a change in u-value code greatly outweighs the small benefit.
- Knowing that glazing is the "weak link" in the building envelope, I've been a proponent of triple pane windows. Unfortunately, cost is prohibitive, relative to the boost in Title 24 compliance. In lieu of making the lower U-value mandatory, it would possibly be better received by the building industry if a significant compliance credit were available for using the better windows.
- I am on board with energy efficiency and combating global warming but factors like current conditions of the economy and housing crisis need to play a bigger part in determining what to implement and how much to implement with each update. There is nothing unsafe about a higher u factor window. But facts are a Triple pane window requires 2x6 framing and is just one example of a huge cost that will ultimately increase housing prices.
- You need to make sure this doesn't impact the ability to reuse existing dual pane non-metal windows in things like garage conversions. We need to be able to use default values.
- Triple-pane windows add significant costs and changes to Architectural and constructability as well as structural design and costs.

Many of the comments above are either related to cost-effectiveness or requirement for triple-pane windows. However, cost-effectiveness is thoroughly evaluated by the Statewide CASE Team. Regarding the comments related to triple-pane window requirements, the Statewide CASE Team confirmed that a window with a U-factor of 0.27—and even lower—can be achieved with a double-glazed window unit.

Exterior Wall Insulation

The first question given to the survey participants stated how common it is for builders to install the proposed mandatory requirements today. Here, 57 percent replied that they already install R-15 or R-21 or higher insulation in framed walls. Forty-one percent responded that they do it occasionally to never, as also depicted in Figure 9.

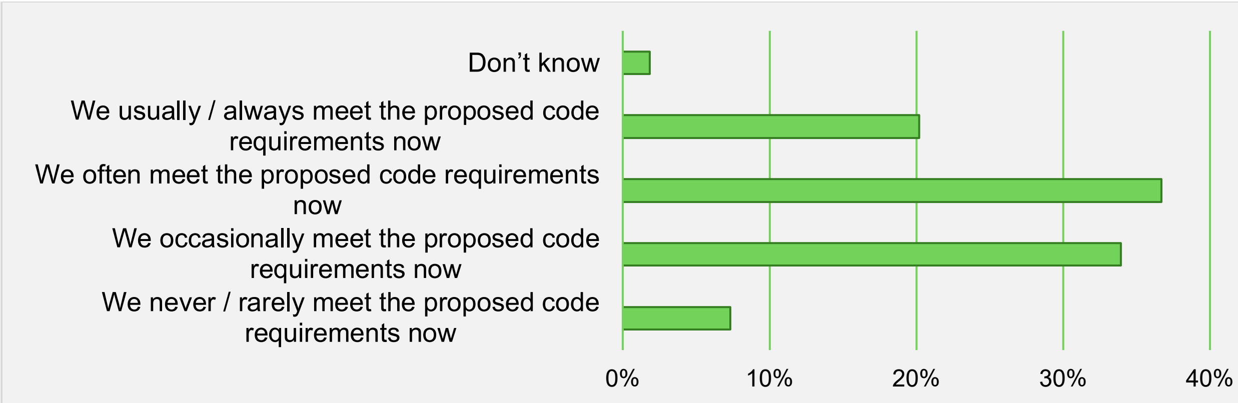

Figure 9: Responses to "How often do the single-family projects you work on already meet the proposed requirement of R-15 and R-21?" Participants: 109.

The second question requested feedback on the validity of the following statements:

- Materially significant increases in total project costs.
- Energy savings at a level that will recoup any incremental costs.
- Improved project quality.
- Increased challenges with product availability.
- Challenges in installation due to the need for changed practices.

As seen in Table 44, 106 people responded to this set of questions. And the overall survey response was that the majority expect "some" or "many/much" material cost increase on total project cost. At same time, the majority believes that future energy savings will overcome the initial costs. On improved project quality, the response was fairly even between "none or few", "some", and "many".

Table 44: Responses to "In what share of your projects would you experience the following if a lower U-factor requirement is put in place?" Participants: 106.

In what share of your projects would you experience the following if a lower U-factor requirement is put in place?	None or few	Some	Many	N/A
Materially significant increases in total project costs	21%	44%	35%	0%
Energy savings at a level that will recoup any incremental costs	28%	42%	31%	0%
Improved project quality	32%	37%	31%	0%
Increased challenges with product availability	28%	43%	29%	0%
Challenges in installation due to the need for changed practices	30%	41%	30%	0%

In Table 44, 43 percent of the respondents believes that the proposed measure will result in some reduction in product availability. As a follow up question, of the respondents that indicated they expect reduced product availability, 70 percent replied that they expect this challenge to last for a few years.

Lastly, in Table 44, the impact on installation was requested. On this topic, 41 percent believed that there will be “some” impact on the need to change installation practices. 30 percent expected a big impact. As a follow up question to these groups, 67 percent replied that they expect such challenges to diminish within the first year or so.

Other thoughts around the mandatory wall insulation measure provided in the survey are summarized verbatim as:

- Exterior rigid insulation should never be mandatory.
- Costs and construction delays due to the need for different insulation materials to meet proposed requirement. Higher skilled workers are required and as is increased time to complete construction.
- The insulation manufacturers will have to produce a higher R value insulation product for us to meet the new requirements.
- Retrofit of existing walls with blown dense pack has its limitations due to short circuiting by the studs. Retrofitting/adding external insulation is a major undertaking. But if the new outer layer is fire resistant (stucco over rock wool?) it is more attractive (especially if it helps you keep your fire insurance coverage).
- Costs of building material might deter general contractors.
- Additional costs should be minimal.
- This change would effectively ban dense-pack cellulose insulation, which has better performance than batts, even at a lower R-value. (R13 and R20, respectively, which outperform R15 and R21 batts.) The CASE team should be looking for tricks to compel builders to use dense-pack cellulose, such as automatically passing QII when dense-pack is used, because the "default" quality is so much better than batts.
- Higher R-value means higher costs. Home buyers might save a small amount, but there's no way for builders to recoup added costs.
- We use 2x6 R-21 walls for all our projects now. I do not like the use of rigid insulation on the exterior of the plywood sheathing.
- The additional cost does not gain efficiency or saving offset to the homeowner.
- Measures like this result in less affordable housing.
- We use one coat stucco in conjunction with 1" rigid foam with an additional R-4 to the exterior.

- All of my residential projects are remodels or renovations and the 2x4 existing stud walls can only take on the R-15 max.
- Good idea
- Most general contractors and structural engineers have a hard time with continuous insulation.
- Batt insulation is the most economical way to insulate, but increased R values will force other products to not be used.
- I would caution that any deviation from the products most widely used could jeopardize availability.
- With 1 coat stucco, we also install 1" rigid foam with a 4 R value on all homes.
- The depletion of our natural resources, albeit renewable, is not worth it.

Many of the concerns above are related to the need for continuous insulation and that such would be disruptive to common practice, require more skilled installers, and result in less affordable homes. First, the proposed measure includes exceptions for alterations, for which R-13 and R-20 cavity insulation is still allowed for 2 x 4, and 2 x 6 framing. In addition, the proposed code change is given as U-factor requirements, and not as R-value. Alternative framing, and/or larger spacing than 16 inch-on-center will improve the overall U-factor and may thus allow for cavity insulation levels lower R-15 and R-21 respectively. For example, R-20 cavity insulation between 2 x 6 wood framing at 24 inch-on-center has a U-value of 0.68, which is lower than the proposed code requirement of 0.69.

Appendix G: Energy Cost 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 section 3.4 of this report for the high performance window measure (a cost-effectiveness analysis for the mandatory wall insulation proposal is not needed as described in section 4.4 of this report). This appendix presents the same energy cost savings, but in nominal dollars, for high performance windows.

Table 45: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction – Prescriptive Window U-factor

Climate Zone	30-Year Life Cycle Electricity Cost Savings (Nominal $)	30-Year Life Cycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Life Cycle Energy Cost Savings (Nominal $)
1	$221	$6,605	$6,826
2	$134	$4,484	$4,618
3	$1,705	$0	$1,705
4	$2,076	$0	$2,076
5	$111	$3,395	$3,506
6	$24	$1,200	$1,223
7	-$32	$781	$749
8	-$221	$1,460	$1,239
9	-$111	$1,683	$1,573
10	-$111	$1,721	$1,610
11	$63	$3,777	$3,840
12	$0	$3,805	$3,805
13	$1,445	$0	$1,445
14	$2,205	$0	$2,205
15	$419	$698	$1,116
16	$79	$6,789	$6,868

Table 46: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction – Prescriptive Window U-factor

Climate Zone	30-Year Life Cycle Electricity Cost Savings (Nominal $)	30-Year Life Cycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Life Cycle Energy Cost Savings (Nominal $)
1	$34	$933	$967
2	$0	$586	$586
3	$226	$0	$226
4	$283	$0	$283
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	-$11	$546	$535
12	-$57	$533	$477
13	$249	$0	$249
14	$362	$0	$362
15	N/A	N/A	N/A
16	-$45	$1,093	$1,047

Table 47: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – Alterations – 1665 Existing Building – Prescriptive Window U-factor

Climate Zone	30-Year Life Cycle Electricity Cost Savings (Nominal $)	30-Year Life Cycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Life Cycle Energy Cost Savings (Nominal $)
1	$226	$5,015	$5,241
2	$113	$4,172	$4,285
3	$0	$2,308	$2,308
4	-$38	$4,172	$4,134
5	-$38	$2,175	$2,137
6	-$38	$1,242	$1,205
7	-$113	$710	$597
8	-$377	$1,509	$1,132
9	-$264	$1,730	$1,466
10	-$151	$1,775	$1,624
11	$75	$3,639	$3,714
12	-$113	$3,728	$3,615
13	$226	$2,885	$3,111
14	$113	$4,171	$4,284
15	$490	$843	$1,333
16	-$226	$5,990	$5,764

Appendix H: Description of Existing Building Prototype

The single-family alteration prototype was developed from the alteration prototypes described in the ACM Approval Manual. The manual presents two prototypes, a 1,440 square foot existing alteration prototype and a second which is the same 1,440 square foot existing home with a 225 square foot addition. The average size of existing homes in the United States built in the 1970s was between 1,650 and 1,750 square feet, with size steadily increasing over time. To better represent the existing building stock, the alteration with addition prototype was revised to reflect a 1,665 square feet existing home. See Table 48 for a description of the prototype.

The total window area is 218 square feet, or 13.1 percent of the conditioned floor area, based on the alteration prototype floor plan with addition in Figure A-16 of the ACM Approval Manual. The total opaque door area of 40 square feet (two standard size doors) is also based on Figure A-16. The model was converted to be orientation neutral with wall, window, and door area equally divided across the four cardinal directions. The number of bedrooms was defined to reflect the predominant number of bedrooms in California homes per the 2013-2017 American Community Survey 5-Year Estimates (U.S. Census Bureau, 2017b).

Table 48: Single Family Alteration Prototype Description

Building Component	Assumption
Conditioned Floor Area	1,665 square feet (~41 feet x 41 feet)
Ceiling Height	8 feet
Wall Area	1,312 square feet
Window Area	218 square feet
Opaque Door Area	40 square feet
Number of Bedrooms	3
Attached Garage	2-car garage

There is no defined protocol for assigning building characteristics for existing home prototypes. Characteristics were applied to represent a home that was constructed in the 1990s with mechanical equipment replaced between 2010 and 2015, and are based on prior Title 24, Part 6 code requirements, literature review and industry standards. The primary prototypes are mixed fuel with natural gas used for space heating, water heating, cooking, and clothes drying to represent most existing residential buildings. Eighty-five percent of residential buildings use natural gas for space heating and 86 percent use natural gas for water heating (California Energy Commission, 2009).

Table 49 summarizes the baseline building characteristics for the alteration prototypes used in the analysis along with the basis for the assumptions where applicable. A more detailed discussion of the rationale is included for select building characteristics.

Table 49: Alteration Prototype Baseline Assumptions

Building Component Category	Building Component Efficiency Feature	Baseline Assumption	Reference
Envelope	Exterior Walls & Demising Walls	2x4 16"oc Wood Frame, R-13 cavity insulation	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission, 2014)
Envelope	Foundation Type & Insulation	Uninsulated slab	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission, 2014)
Envelope	Roof/Ceiling Insulation & Attic Type	R-19 (@ ceiling for attic & rafter for low-sloped)	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission, 2014)
Envelope	Roofing Material & Color	Asphalt shingles, default values (0.10 reflectance, 0.85 emittance)	CBECC-Res default
Envelope	Radiant Barrier	No	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission, 2014)
Envelope	Window Properties: U-Factor/Solar Heat Gain Coefficient (SHGC)	Metal, Dual Pane 0.79 U-factor 0.70 SHGC CZ 1-7,16 0.40 SHGC CZ 8-15	2013 T24 Residential Vintage Table 110.6-A and 110.6-B. U-factor default for metal double-pane operable windows; SHGC default for metal double-pane operable windows in CZ 1-7,16 and low-e elsewhere. (California Energy Commission, 2014) Basis for selecting window types discussed in detail below.
Envelope	Opaque Doors	0.50	CBECC-Res default
Envelope	Quality Insulation Inspection Credit (HERS)	No	CBECC-Res default
Envelope	House Infiltration	10 ACH50 (single family) 7 ACH50 (multifamily)	10 ACH50 Based on a literature review of blower door test data for existing homes. See detailed discussion below. 7 ACH50 is the CBECC-Res default for multifamily
HVAC Equipment	System Type & Description	Ducted FAU split system with gas furnace & A/C	Typical system for California homes
HVAC Equipment	Heating Efficiency	0.78 AFUE	Federal minimum efficiency level in effect around 2015.

Building Component Category	Building Component Efficiency Feature	Baseline Assumption	Reference
HVAC Equipment	Cooling Efficiency	13 SEER 11 EER	Federal minimum efficiency level in effect around 2015 for SEER. EER estimated based on CBECC-Res equations.
HVAC Equipment	Duct Location & Insulation	Attic, R-4.2, 15% leakage	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage for duct insulation. (California Energy Commission, 2014) Assume ducts were sealed and tested when HVAC system last replaced.
HVAC Equipment	Mechanical Ventilation	None	CBECC-Res default
HVAC Equipment	Verified Refrigerant Charge (HERS)	No	CBECC-Res default
HVAC Equipment	Verified Cooling Airflow ≥350 cfm/ton (HERS)	No, 350 cfm/ton	CBECC-Res default
HVAC Equipment	Verified Fan Watt Draw ≤0.58 W/cfm (HERS)	Single Speed PSC 0.58	CBECC-Res default
Water Heating Equipment	System Type & Description	Gas Storage	Typical system for California homes
Water Heating Equipment	Water Heater Efficiency	0.575 EF	Federal minimum efficiency level in effect around 2015.
Water Heating Equipment	Water Heater Size (gal.)	40	Typical for residential storage gas water heaters.
Appliances & Lighting	Lighting Type	per CBECC-Res	CBECC-Res default
Appliances & Lighting	Appliances	per CBECC-Res	CBECC-Res default
Appliances & Lighting	Cooking	Gas	Typical for mixed fuel home
Appliances & Lighting	Clothes Dryer	Gas	Typical for mixed fuel home

Appendix I: Cost-Effectiveness Results with Heat Pump Space Heating

This Appendix displays tables like those in the body of the report. The main difference is that the tables below reflect energy savings and cost benefits under the assumption that all homes use heat pumps for heating and cooling. In other words, the window measure is evaluated against a heat pump baseline that would prescriptively require heat pump space heaters in the proposed climate zones for single family homes. Because much of the explanatory information becomes redundant, the text accompanied by the tables in this Appendix is brief. For further information, the reader is referred to Section 3.3 through 3.5.

Energy Savings

This section of the CASE Report applies to the window prescriptive U-factor code change proposal, which would increase the stringency of the existing California Energy Code.

Energy Savings Methodology

To quantify key impacts, the Statewide CASE Team measured per unit energy savings expected from the proposed code changes in several ways.

First, electricity savings are measured in terms of both energy usage and peak demand reduction. Second, the Statewide CASE Team calculated savings in the total amount of raw fuel required to operate a building, called Source Energy Savings. 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.[21] Finally, the Statewide CASE Team calculated LSC savings. LSC Savings are calculated using hourly LSC factors for electricity 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 CO_2 emissions.[12]

The CEC directed the Statewide CASE Team to model the energy impacts using prototypical building models that represent building geometries for different types of buildings (California Energy Commission, 2022). The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 50.

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

Energy savings are calculated using three new construction prototypes, a 500 square foot small home, a single story 2,100 square foot home, and a two-story 2,700 square foot home. Statewide results are weighted 2 percent for the 500 square foot prototype, 42 percent for the 2,100 square foot prototype and 56 percent for the 2,700 square foot prototype. Energy savings and overall impacts are similar across the 2,100 and 2,700 square foot prototypes. In this report where individual prototype results are presented, results of the 2,100 and 2,700 square foot homes are presented as a weighted average based on the statewide distribution.

Table 50 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume a reduction in U-factor from the prescriptive value of 0.30. There is no change in the proposed conditions for the SHGC proposal.

Table 50: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
2100, 2700	1-5, 11-14, 16	Window Properties	U-factor	0.30	0.27
1665	All	Window Properties	U-factor	0.30	0.27
500	1-4, 11-14, 16	Window Properties	U-factor	0.30	0.27

CBECC-Res calculates whole building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2025 LSC hourly factors to calculate LSC in 2026 present value dollars (2026 PV$). Source Energy hourly factors are used to calculate Source Energy Use in kilo British thermal units per year (kBtu/yr), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent per year (metric tons or “tonnes” of CO_2e/yr). CBECC-Res also calculates annual peak electricity demand measured in kilowatts (kW).

Per Unit Energy Impacts Results

Energy savings results are separately presented for three prototypes. Energy savings and peak demand reductions per unit are presented in Table 51 through Table 55. Savings are presented for new construction and alterations.

The per unit energy savings do not account for naturally occurring market adoption or compliance rates.

Per-unit savings for the first year are expected to range from -78 to 198 kWh per year on electricity for the 2100/2700 weighted new construction prototype. For small homes, the electricity savings vary between 10 to 30 kWh per year. Alterations present a range of -27 to 32 kWh per year.

As seen in Table 52, the proposed measure reduces peak demand in electricity in most cases with up to 0.04 kW in peak demand reduction.

Table 51: First Year Electricity Savings (kWh) Per Home—Prescriptive Window U-Factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	188	30	11
2	131	15	5
3	88	10	-6
4	120	14	-6
5	101	N/A	-8
6	N/A	N/A	-5
7	N/A	N/A	-13
8	N/A	N/A	-28
9	N/A	N/A	-23
10	N/A	N/A	-18
11	103	13	2
12	98	10	-8
13	78	11	9
14	120	19	4
15	N/A	N/A	32
16	198	28	-27

Table 52: First Year Peak Demand Reduction (kW) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.031	0.009	0.001
2	0.026	0.005	0.001
3	0.029	0.005	0.001
4	0.032	0.007	0.002
5	0.033	N/A	0.002
6	N/A	N/A	0.001
7	N/A	N/A	0
8	N/A	N/A	0
9	N/A	N/A	0.001
10	N/A	N/A	0
11	0.027	0.006	0
12	0.026	0.006	0.001
13	0.022	0.005	0
14	0.041	0.009	0.002
15	N/A	N/A	0
16	0.039	0.008	0.002

Table 53: First Year Natural Gas Savings (therms) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	0.0	0.0	15.3
2	0.0	0.0	12.5
3	0.0	0.0	6.9
4	0.0	0.0	12.5
5	0.0	N/A	6.4
6	N/A	N/A	3.6
7	N/A	N/A	3.3
8	N/A	N/A	4.5
9	N/A	N/A	5.2
10	N/A	N/A	5.2
11	0.0	0.0	10.9
12	0.0	0.0	11.2
13	0.0	0.0	8.5
14	0.0	0.0	12.4
15	N/A	N/A	2.4
16	0.0	0.0	18.1

Table 54: First Year Source Energy Savings (kBtu) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	464	85	1,399
2	356	55	1,166
3	279	45	649
4	366	60	1,149
5	290	N/A	566
6	N/A	N/A	333
7	N/A	N/A	300
8	N/A	N/A	383
9	N/A	N/A	466
10	N/A	N/A	483
11	321	60	999
12	293	50	1,032
13	244	45	783
14	401	70	1,149
15	N/A	N/A	233
16	524	95	1,632

Table 55: First Year LSC Savings (2026 PV$) Per Home—Prescriptive Window U-factor

Climate Zone	2100/2700 Weighted New Construction	500 Square Foot Small Home New Construction	1,665 Square Foot Alteration
1	$1,434	$245	$1,981
2	$1,023	$145	$1,615
3	$754	$100	$866
4	$918	$125	$1,548
5	$803	N/A	$799
6	N/A	N/A	$450
7	N/A	N/A	$366
8	N/A	N/A	$400
9	N/A	N/A	$533
10	N/A	N/A	$599
11	$817	$120	$1,399
12	$768	$105	$1,349
13	$639	$110	$1,182
14	$974	$160	$1,615
15	N/A	N/A	$533
16	$1,557	$250	$2,148

Cost and Cost Effectiveness

An analysis of costs and cost effectiveness of the prescriptive U-factor code change proposal is presented in the following sections. Results are presented for a weighted average of the 2,100 square foot and 2,700 square foot new construction prototypes (the 2100/2700 weighted prototype) since results for each of these two prototypes are similar. Results are separately presented for the 500 square foot single family new construction prototype. While this code change proposal will impact alterations, incremental costs are estimated to be the same for alterations as for new construction. Estimated energy savings for alterations are greater than that for new construction in all cases due to the higher heating and cooling loads in existing buildings. As such, for this proposal cost effectiveness will also be greater for alterations than for new construction and so cost effectiveness is not presented for alterations.

Energy Cost Savings Methodology

Energy cost savings were calculated by applying the LSC hourly factors to the energy savings estimates that were derived using the methodology described earlier. LSC hourly factors are a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the 30-year period of analysis.

Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and additions in terms of LSC savings realized over the 30-year period of analysis are presented as 2026 present value dollars (2026 PV$) in Table 56 and Table 57. Savings for alterations are presented in Table 58. The LSC methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 56: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction – Prescriptive Window U-factor

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	$1,434	$0	$1,434
2	$1,023	$0	$1,023
3	$754	$0	$754
4	$918	$0	$918
5	$803	$0	$803
6	N/A	N/A	N/A

7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$817	$0	$817
12	$768	$0	$768
13	$639	$0	$639
14	$974	$0	$974
15	N/A	N/A	N/A
16	$1,557	$0	$1,557

Table 57: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction – Prescriptive Window U-factor

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	$245	$0	$245
2	$145	$0	$145
3	$100	$0	$100
4	$125	$0	$125
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$120	$0	$120
12	$105	$0	$105
13	$110	$0	$110
14	$160	$0	$160
15	N/A	N/A	N/A
16	$250	$0	$250

Table 58: 2026 PV LSC Savings Over 30-Year Period of Analysis – Per Home – Alterations – 1665 Existing Building – Prescriptive Window U-factor

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	$100	$1,881	$1,981
2	$50	$1,565	$1,615
3	$0	$866	$866
4	-$17	$1,565	$1,548
5	-$17	$816	$799
6	-$17	$466	$450
7	-$50	$266	$216
8	-$166	$566	$400
9	-$117	$649	$533
10	-$67	$666	$599
11	$33	$1,365	$1,399
12	-$50	$1,399	$1,349
13	$100	$1,082	$1,182
14	$50	$1,565	$1,615
15	$216	$316	$533
16	-$100	$2,248	$2,148

Incremental First Cost

Incremental first costs (or incremental costs) used to estimate cost-effectiveness are presented in Section 3.4.3.

In summary, the incremental costs associated with the prescriptive U-factor reduction proposal are shown in Table 59.

Table 59: Window Incremental Costs

Window U-Factor Reduction	Incremental Material Cost, with Multiplier	Incremental Labor Cost	Total Incremental Cost
0.3 → 0.27 (CZs 1-5, 11-14, and 16)	$0.84/ft^2$	N/A	$0.84/ft^2$

For alterations, the costs are not expected to differ from new construction/additions.

The incremental first costs are not expected to increase over time. The price of windows in general may increase over time, but the impact on incremental cost is assumed negligible. This assumption has also been confirmed by various stakeholders.

Cost Effectiveness

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 B/C ratio was calculated using 2026 PV costs and cost savings.

Results of the per-unit cost effectiveness analyses are presented in Table 60 through Table 61 for the 2100/2700 weighted and small home new construction prototypes, respectively. Table 62 presents results for alterations.

The proposed measure is cost effective in every applicable climate zone for all new construction prototype and for alterations.

Table 60: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – 2100/2700 Weighted New Construction – Prescriptive Window U-factor with Heat Pump Space Heating

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,434	$410	3.50
2	$1,023	$410	2.49
3	$754	$410	1.84

4	$918	$410	2.24
5	$803	$410	1.96
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$817	$410	1.99
12	$768	$410	1.87
13	$639	$410	1.56
14	$974	$410	2.37
15	N/A	N/A	N/A
16	$1,557	$410	3.79

c. **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.

d. **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.

Table 61: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – Small Homes New Construction – Prescriptive Window U-factor with Heat Pump Space Heating

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	$245	$84	2.92
2	$145	$84	1.73
3	$100	$84	1.19
4	$125	$84	1.49
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$120	$84	1.43
12	$105	$84	1.25
13	$110	$84	1.31
14	$160	$84	1.90
15	N/A	N/A	N/A
16	$250	$84	2.98

e. **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.

f. **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.

Table 62: 30-Year Cost-Effectiveness Summary Per Home – Alterations – 1665 Existing Building – Prescriptive Window U-factor

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs[b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,981	$183	10.82
2	$1,615	$183	8.82
3	$866	$183	4.73
4	$1,548	$183	8.46
5	$799	$183	4.36
6	$450	$183	2.45
7	$366	$183	2.00
8	$400	$183	2.18
9	$533	$183	2.91
10	$599	$183	3.27
11	$1,399	$183	7.64
12	$1,349	$183	7.36
13	$1,182	$183	6.46
14	$1,615	$183	8.82
15	$533	$183	2.91
16	$2,148	$183	11.73

g. **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.

h. **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.

Table 63 presents results for the 2100/2700 weighted new construction prototype for a 0.28 U-factor. Similar to the results for a 0.27 U-factor, this is not cost-effective in Climate Zones 6 through 10 and 15.

Table 63: 30-Year Cost-Effectiveness Summary Per Home – New Construction/Additions – 2100/2700 Weighted New Construction – Prescriptive Window U-factor of 0.28 with Heat Pump Space Heating

Climate Zone	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
1	$1,434	$410	3.50
2	$1,023	$410	2.49
3	$754	$410	1.84
4	$918	$410	2.24
5	$803	$410	1.96
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	$817	$410	1.99
12	$768	$410	1.87
13	$639	$410	1.56
14	$974	$410	2.37
15	N/A	N/A	N/A
16	$1,557	$410	3.79

First-Year Statewide Impacts

Statewide savings for the prescriptive U-factor code change proposal is presented in the following sections.

Statewide Energy and Energy Cost 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 in 2026.

In the case of alterations, the statewide savings associated with this proposal rely heavily on the estimated number of homes completing alterations involving windows.

The tables below present the first-year statewide energy savings and 30-year cost savings from newly constructed buildings, additions, and alterations by climate zone.

Table 64 presents combined savings data across all climate zones for new construction, additions, and alterations.

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 65 shows negative electrical savings for some climates. The reasons for this are mentioned in Section 3.3.2 and derive from the phenomenon that a higher U-factor can help to release some of the heat gain inside a building. This effect is stronger for smaller homes which in general have a larger heat gain per square foot and thus more impacted by additional heat gains.

Table 64: Statewide Energy and Energy Cost Impacts—New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	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	359	0.07	0.01	-	0.16	$0.50
2	1,861	0.24	0.05	-	0.65	$1.86
3	3,035	0.26	0.09	-	0.83	$2.24
4	2,689	0.32	0.08	-	0.97	$2.43
5	604	0.06	0.02	-	0.17	$0.48
6	N/A	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A	N/A	N/A
11	5,840	0.59	0.15	-	1.86	$4.68
12	14,542	1.40	0.37	-	4.19	$10.95
13	7,257	0.56	0.16	-	1.74	$4.58
14	3,739	0.44	0.15	-	1.47	$3.57
15	N/A	N/A	N/A	N/A	N/A	N/A
16	1,937	0.38	0.07	-	0.99	$2.95
Total	**64,547**	**4.31**	**1.15**	**-**	**13.05**	**$34.25**

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

Table 65: Statewide Energy and Energy Cost Impacts—Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Buildings)	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	72	0	0	0	0.10	$0.14
2	425	0	0.001	0.01	0.50	$0.69
3	1,556	-0.01	0.002	0.01	1.01	$1.35
4	796	0	0.001	0.01	0.91	$1.23
5	156	0	0	0	0.09	$0.12
6	951	0	0	0	0.32	$0.43
7	791	-0.01	0	0	0.24	$0.29
8	1,482	-0.04	0.001	0.01	0.57	$0.59
9	2,001	-0.05	0.001	0.01	0.93	$1.07
10	1,708	-0.03	0.001	0.01	0.82	$1.02
11	537	0	0	0.01	0.54	$0.75
12	2,110	-0.02	0.002	0.02	2.18	$2.85
13	1,016	0.01	0	0.01	0.79	$1.20
14	397	0	0.001	0	0.46	$0.64
15	284	0.01	0	0	0.07	$0.15
16	157	0	00	0	0.26	$0.34
Total	**14,437**	**(0.15)**	**0.011**	**0.11**	**9.77**	**$12.86**

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

Table 66: 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	4.29	1.14	-	12.98	34.25
Alterations	-0.15	0.01	0.11	9.77	12.86
Total	4.14	1.16	0.11	22.75	47.11

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

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 CEC developed along with the 2025 LSC hourly factors and an assumed cost of $123.15 per metric ton of carbon dioxide equivalent emissions (metric tons CO2e). (California Energy Commission, 2020)

Table 67 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 3,231 (metric tons CO2e) would be avoided.

Table 67: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO2e)	Natural Gas Savings[a] (Million Therms/yr)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO2e)	Total Reduced GHG Emissions[b] (Metric Ton CO2e)	Total Monetary Value of Reduced GHG Emissions[c] ($)
TOTAL	4	706	0.11	623	1,329	$163,693

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

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

f. 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