

Single Family High Performance Windows and Walls



Envelope
Prepared by Frontier Energy, Inc.

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Draft CASE Report



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Table of Contents

Executive Summary	vi
1. Introduction	1
2. High Performance Windows	5
2.1 Measure Description	5
2.2 Market Analysis	12
2.3 Energy Savings	28
2.4 Cost and Cost Effectiveness	35
2.5 First-Year Statewide Impacts	41
3. Mandatory U-Factor Requirements for Framed Walls	47
3.1 Measure Description	47
3.2 Market Analysis	51
3.3 Energy Savings	54
3.4 Cost and Cost Effectiveness	54
3.5 First-Year Statewide Impacts	56
4. Addressing Energy Equity and Environmental Justice	57
4.1 Research Methods and Engagement	58
5. Proposed Revisions to Code Language	59
5.1 Guide to Markup Language	59
5.2 Standards	59
5.3 Reference Appendices	65
5.4 Single-Family Residential ACM Reference Manual	65
5.5 Compliance Documents	66
6. Bibliography	68
Appendix A : Statewide Savings Methodology	71
Appendix B : Embedded Electricity in Water Methodology	73
Appendix C : California Building Energy Code Compliance (CBECC) Software Specification	74
Appendix D : Environmental Analysis	79
Appendix E : Discussion of Impacts of Compliance Process on Market Actors	81
Appendix F : Summary of Stakeholder Engagement	83
Appendix G : Energy Cost Savings in Nominal Dollars	87
Appendix H : Description of Existing Building Prototype	89

Tables

Table 1: Scope of Mandatory Code Change Proposal: High Performance Windows.....	ix
Table 2: Scope of Prescriptive Code Change Proposal: High Performance Windows.....	ix
Table 3: Scope of Code Change Proposal: Mandatory R-Value Requirements for Framed Walls	ix
Table 4: Estimated Impacts for Key Sectors: Prescriptive High Performance Window Proposal.....	xii
Table 5: Summary of Impacts for High Performance Windows	xv
Table 6: California Construction Industry, Establishments, Employment, and Payroll in 2022 (Estimated)	15
Table 7: Estimated Subsectors of the California Residential Building Industry in 2022 .	16
Table 8: Estimated California Building Designer and Energy Consultant Sectors in 2022	17
Table 9: California Housing Characteristics in 2021 ^a	18
Table 10: Distribution of California Housing by Vintage in 2021 (Estimated).....	19
Table 11: Estimated Owner- and Renter-Occupied Housing Units in California by Income in 2021	19
Table 12: Estimated Employment in California State and Government Agencies with Building Inspectors in 2022.....	21
Table 13: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector	23
Table 14: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors.....	23
Table 15: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents	24
Table 16: Net Domestic Private Investment and Corporate Profits, U.S.	25
Table 17: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis.....	30
Table 18: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change.....	31
Table 19: First Year Electricity Savings (kWh) Per Home—Prescriptive Window U-Factor.....	32

Table 20: First Year Peak Demand Reduction (kW) Per Home—Prescriptive Window U-factor	33
Table 21: First Year Natural Gas Savings (therms) Per Home—Prescriptive Window U-factor	33
Table 22: First Year Source Energy Savings (kBtu) Per Home—Prescriptive Window U-factor	34
Table 23: First Year Long-term Systemwide Cost Savings (2026 PV\$) Per Home—Prescriptive Window U-factor.....	34
Table 24: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction.....	36
Table 25: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction.....	37
Table 26: Window Incremental Costs	39
Table 27: 30-Year Cost effectiveness Summary Per Home – New Construction/Additions – 2100/2700 Weighted New Construction	40
Table 28: 30-Year Cost effectiveness Summary Per Home – New Construction/Additions – Small Homes New Construction	41
Table 29: Statewide Energy and Energy Cost Impacts—New Construction and Additions	43
Table 30: Statewide Energy and Energy Cost Impacts—Alterations	44
Table 31: Statewide Energy and Energy Cost Impacts—New Construction, Additions, and Alterations.....	45
Table 32: First-Year Statewide GHG Emissions Impacts	46
Table 33: Current and proposed U-factor and R-value requirements for exterior walls in new constructions, additions, and alterations.....	47
Table 34: Incremental cost for proposed increased mandatory wall insulation requirements.....	56
Table 35: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone	72
Table 36: Compliance Report Table of CF1R-PRF-01E.....	76
Table 37: Proposed CBECC-Res Testing	77
Table 38: Roles of Market Actors in the Proposed Compliance Process	82

Table 39: Utility-Sponsored Stakeholder Meetings	84
Table 40: Engaged Stakeholders.....	85
Table 41: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction.	87
Table 42: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction.....	88
Table 44: Single Family Alteration Prototype Description.....	89
Table : Alteration Prototype Baseline Assumptions	90

Figures

Figure 1: ENERGY STAR Version 7.0 program requirements for windows.....	8
Figure 2: Window label for energy performance rating and proof of NFRC certification	12
Figure 3: ENERGY STAR incremental consumer cost model (green line) based on window U-factor.....	38
Figure 4: Price of cavity insulation. Products included are on rolls or packaged flat, faced and unfaced.....	55

Executive Summary

This is a draft report. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented in this draft report. When possible, provide supporting data and justifications in addition to comments. Suggested revisions will be considered when refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in Summer 2023.

Email comments and suggestions to Simon Pallin (spallin@frontierenergy.com) and info@title24stakeholders.com by Tuesday, May 30, 2023. Comments will not be released for public review or will be anonymized if shared.

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission’s (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>.

The Statewide CASE Team gathered input from stakeholders to inform the proposal and associated analyses and justifications. Stakeholders also provided input on the code compliance and enforcement process.

The Statewide CASE Team spoke with 19 stakeholders to gather information on costs, market, and energy assumptions. Depending on the measure and component, the

Statewide CASE Team confirmed cost ranges found through research and, in the case of windows, adjusted cost assumptions to reflect direct feedback from distribution chain stakeholders. The Statewide CASE Team also spoke with building-oriented stakeholders to gather information on technical and market feasibility, which inspired key adjustments to proposed code language as described in Section 2.2. See Appendix F for a summary of stakeholder engagement.

The goal of this CASE Report is to present a cost-effective code change proposal for high performance windows and mandatory R-value requirements for framed walls. The report contains pertinent information supporting the code change.

Proposal Description

Proposed Code Change

There are two measures included in this proposal. One is the high-performance window proposal, which has three components:

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

The other measure is the Mandatory R-Value Requirements for Framed Walls measure, which proposes to increase required minimum cavity insulation from R to R for 2x4 wall assemblies, and R to R for 2x6 assemblies.

Justification

Windows and walls can be a significant source of heat gain or loss within a home, which can lead to wasted HVAC system energy use. Therefore, these envelope components have been the subject of building energy code revision through many code cycles (see sections 2.1.2.2 and 3.1.2.2), including this current proposal. Two measures in this proposal call for a change in material and assembly thermal performance characteristics whose relationship to energy use is well understood and modeled. In both cases the performance characteristic is the assembly U-factor.

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. For these reasons, the Environmental Protection Agency (EPA) is enacting similar U-factor (along with SHGC) changes in the latest updates to ENERGY STAR® window criteria (Version 7). Such national changes

will 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.

The wall insulation market, like windows, boasts readily available products with the proposed R-values and is in fact already used in roughly half of new construction projects (CalCERTS, 2023). As such, 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. In addition, wall insulation typically remains untouched over the building lifetime, therefore it is essential to install levels of insulation that will meet the future needs of thermal performance.

Background Information

Heat transfer across a building envelope is dictated by the thermal properties of the materials and assemblies therein. For window assemblies, the ability to transfer energy is defined as a U-factor [in $\text{Btu}/(\text{h}\cdot\text{ft}^2\cdot^\circ\text{F})$] which can be seen as an indicator of conductance. SHGC is another thermal property addressed in this measure. SHGC indicates the fraction of solar radiation hitting a surface that is transmitted either directly or absorbed then rereleased into a living space. SHGC is a fractional variable between zero and one; the higher the value, the larger the relative heat gain through the window assembly. Because solar radiation carries both heat and light, SHGC is usually directly related to visual transmittance, or visibility.

For wall assemblies, the performance specifications considered for the wall insulation measure include U-factors and R-values. While R-values, like U-factors, measure heat transfer, they are in fact opposites: U-factors measure conductance and R-values measure resistance (refer to section 3.1.2.2 for more information).

The majority of single family exterior walls are constructed with 2 x 4 or 2 x 6 inch wood framing (CalCERTS, 2023), in which typically the space, or cavity, between the studs is insulated. 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. The advantage of continuous rigid insulation, placed over the studs, is that it does not contribute to significant thermal bridges (areas of high conductivity relative to surrounding areas).

As mentioned in the previous section, the ENERGY STAR program recently updated their window criteria regarding U-factor and SHGC. The U-factor and SHGC requirements (see section 2.1.2.2) are based on a highly researched and collaborative work between EPA, window and glass manufacturers, and other industry stakeholders

(EPA, ENERGY STAR Residential Windows, Doors, and Skylights Version 7.0, 2022). Therefore, the Statewide CASE Team aimed for alignment with ENERGY STAR except for deviations described in section 2.1.2.2.

Scope of Code Change Proposal

Table 2 and Table 3 summarize the scope of the proposed changes and which sections of the Energy Code, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents that would be modified as a result of the proposed changes.

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
Would Compliance Software 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
Would Compliance Software 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

Table 3: 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

Market Analysis and Regulatory Assessment

The Statewide CASE Team performed a full market analysis around the high performance window proposal, and a brief analysis for the higher wall insulation U-factor proposal as it is less stringent than the current prescriptive baseline. Analyses were informed by research of retail products, HERS registry data, and numerous reports regarding California's home building market; as well as through outreach with stakeholders including utility program staff, CEC staff, and a wide range of industry actors. In the case of high performance windows, the EPA's extensive market analysis used to develop the latest ENERGY STAR window criteria also informed the Statewide CASE Team's market analysis.

For both high performance windows and wall cavity insulation meeting proposed U-factors, the current markets are well-established and mature, with numerous window products currently on the market that meet the proposed requirements EPA, ENERGY STAR Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report, 2021).

Current Market

The proposed U-factors of 0.28 are easily met through double-paned windows; however as maximum U-factors decrease, the market becomes increasingly limited to triple-paned windows. Concerns voiced by stakeholders for such windows include a bulky aesthetic unless they are more costly "thin triples", increased costs and payback times triple relative to dual-paned windows, 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. Regarding any potential change to SHGC, stakeholders cautioned against reductions beyond 0.23 SHGC, which can require either colored glass or darker coatings that are unpopular among customers and may interfere with visual transmittance. Both costs and the range of product styles are expected to improve as manufacturers adjust to both new building code and new 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 mandatory framed wall U-factor 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, no significant net changes in economic impact due to the proposed code change are expected, and full economic, market, and fiscal analyses were not performed. However, an overview of the current market structure as well as technical feasibility and market availability is presented in section 3.2 and summarized here. Current exterior wall insulation products, as detailed in section 3.2.2, include cavity insulation (including fiberglass, cellulose, mineral wool, and open or closed-cell spray foam), rigid continuous insulation (such as EPS, XPS, Polyiso, and rockwool), and other configurations such as structural insulation panels like

oriented strand board (OSB) and the use of double frames. CalCERTS data for single family homes constructed under Title 24 2019 code reveals that most exterior walls are constructed with either 2 x 4 inch or 2 x 6 inch wall framing. For 2 x 4 inch assemblies, R-13 and R-15 cavity insulation make up most of insulation, while insulation in 2 x 6 inch assemblies is mostly R-21 but also includes R-18 and R-19. Across all framing dimensions, fiberglass is most widely used followed by Cellulose then spray foam. Because all these products are readily available on the market, no barriers in technical feasibility or market availability are foreseen.

Market, Economic, and Fiscal Impacts

Market impacts are reported only for the window prescriptive U-factor code change proposal. The other measure components – mandatory U-factor and modeled vs. installed SHGC – do not require a market analysis because only the U-factor proposal would change the compliance baseline. The impacts are detailed throughout section 2.2.3, including a breakdown of the number, type, vintage, and occupancy of existing and newly constructed homes, which is critical for developing meaningful estimates of the economic impacts associated with proposed code changes. Section 2.2.3 also provides an overview of the companies and employees in the California construction industry, along with the single-family subsectors expected to be impacted by the proposal, resulting in the following conclusions:

- Builders and building designers/energy consultants will likely be impacted, which is expected as it is within the normal practices of these businesses to adjust to changes in building codes, but employment of building inspectors is not expected to be impacted, nor are regulations applicable to builders regarding occupational safety and health.
- While minor material impacts regarding glass, krypton and argon are possible – as they are the primary strategies in developing thermally high performing windows – no significant material impacts on California component retailers, manufacturers, and distributors are expected.
- 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 are quantified and presented in section 2.2.4, along with the methodology used. In brief, the IMPLAN model software,¹ along with economic information from published sources and professional judgement, were used to create a

¹ 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.

simplified estimate of macroeconomic job creation due to code change as a function of incoming cash flow into economic sectors. For the proposed U-factor prescriptive requirement, estimated impacts for key sectors are summarized in Table 4.

Table 4: 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	35.1	\$2,609,047	\$9,744,239	\$16,558,256
California Building Designers and Energy Consultants Sectors	6.2	\$563,388	\$698,643	\$1,110,836
Discretionary Spending by California Residents	0.9	\$64,644	\$116,737	\$185,655
Total Economic Impacts	42.2	\$3,237,079	\$10,559,619	\$17,854,747

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.²

Other potential economic impacts identified by the Statewide CASE Team include 1) a net statewide private investment estimated at \$684,637, considered minor as it is less than \$1,000,000 (as discussed in section 2.2.4.4), and 2) product and material innovations may be spurred by this proposal as well as 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 similarly would not necessarily lead to a competitive advantage or disadvantage for California businesses. While employment within existing job types may be slightly impacted, the creation of new job types or businesses is not expected. The proposal is also not expected to impact California’s General Fund, any state special funds, or local government funds aside from existing code and compliance related allocations in state and local government budgets as part of the recurring code development process. Lastly, no noteworthy statewide fiscal impacts to local agencies, school districts, state agencies (except those tasked with managing and enforcing these measures), and federal funding to the state are expected as the proposals in this report apply to single family construction. For fiberglass R-15 and R-21 insulation, these products are considered high-density. In comparison with lower R-value insulation materials, R-15 and R-21 fiberglass cavity insulation consist of more compressed fiberglass providing a higher thermal resistance.

² IMPLAN® model, 2020 Data, IMPLAN Group LLC, IMPLAN System (data and software), 16905 Northcross Dr., Suite 120, Huntersville, NC 28078 www.IMPLAN.com

In terms of regulatory impacts, high performance window criteria partially overlap with EPA's voluntary ENERGY STAR program (as detailed in section 2.1.2.2) and with the IECC 2021 International Energy Conservation Code, Table R402.1.3 (as described in section 2.1.5). Otherwise, there are no conflicts with existing state or federal regulations nor any other part of Title 24, Part 6 building code. Though 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 being used. Any combination of insulation materials can be installed as long as the 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 is 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.

For walls, market impacts described in section 3.2.3 reflect the market conditions described above—that is, some existing level of uptake within the industry such 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 3.4. 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 report. No other significant economic or fiscal impacts are expected. Similarly, there are no relevant local, state, or federal laws or regulations, nor are there relevant industry standards or model codes.

Cost Effectiveness

The prescriptive U-factor component of the high performance window code change was found to be cost-effective, or close to cost-effective, for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio over the 30-year period of analysis ranged, by climate zone, between 0.97 and 15.13 for the 2100/2700 Weighted New Construction prototype and 0.77 and 10.14 for the Small Homes New Construction prototype in applicable climate zones (climate zones 6-10 and 15 are proposed to be excluded because negative or too low B/C ratio). See more details in sections 2.4 and 3.4.

California consumers and businesses would save more money on energy than they would spend to finance the efficiency measure. As a result, over time this proposal would leave more money available for discretionary and investment purposes once the initial cost is paid off.

See sections 2.4 and 3.4 for the methodology, assumptions, and results of the cost effectiveness analyses. Note that for the mandatory window U-factor, and exterior wall U-factor code change proposals – a summary of cost implications is presented in lieu of

full cost effectiveness analyses because these measures introduce requirements that are less stringent than the existing prescriptive requirements used to set the compliance baseline.

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

Table 5 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.

First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/y), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/y), source energy savings in millions of kilo British thermal units per year (million kBtu/y), and life cycle energy savings in millions of kilo British thermal units per year (million kBtu/y). See sections 2.5 and 3.5 for more details on the first-year statewide impacts. Sections 2.3.2 and 3.3 contain details on the per unit energy savings.

Avoided GHG emissions due to energy savings are measured in metric tons of carbon dioxide equivalent (metric tons CO₂e). Assumptions used in developing the GHG savings are provided in and Appendix C of this report. The monetary value of avoided GHG emissions is included in the Life Cycle Cost Hourly Factors provided by CEC and is thus included in the cost effectiveness analysis. These measures do not have additional reductions from embodied carbon.

Estimating the energy and cost savings from the prescriptive window proposal reflect changing only the U-factor from 0.3 to 0.28 only, for all newly constructed single family homes except exempted climate zones for small homes. For these buildings, 30-Year Present Valued LSC Savings ranged from \$510,000 to \$13,610,000. For alterations to existing buildings, estimates relied heavily on the estimated number of homes completing alterations involving windows. Resulting cost savings for these buildings ranged from \$80,000 to \$1,900,000.

For mandatory measures that are less stringent than prescriptive requirements, including the wall insulation and window proposals in this report, 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 benefits is provided. By promoting higher overall wall cavity insulation levels, even small but persistent savings can add up over the product lifetime. Since cavity insulation inside exterior walls typically remains untouched over the building 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” 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.

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

In the case of mandatory U-factors for windows and walls, these code change proposals are not modifying the stringency of the baseline used to measure compliance (i.e., the prescriptive standard), therefore there would be no net energy savings, water savings, or GHG reductions. Still, such measures are of value: 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. In the case of insulation of exterior walls, it is essential to install levels of insulation that will meet the future needs of thermal performance because exterior walls typically remain untouched over the building’s lifetime. In addition, mandatory window and wall measures enable a minimal level of occupant comfort.

Table 5: Summary of Impacts for High Performance Windows

Category	Metric	New Construction and Additions	Alterations
Cost Effectiveness	Benefit-Cost Ratio Range (varies by climate zone and building type)	0- 15.7	1.69 - 11.33
Statewide Impacts During First Year	Electricity Savings (GWh)	1.01	-0.10
	Peak Electrical Demand Reduction (MW)	0.34	0.01
	Natural Gas Savings (Million Therms)	0.31	0.07
	Source Energy Savings (Million kBtu)	31.72	6.62
	Life Cycle Electricity Savings (Million kBtu)	8.77	-0.42
	Life Cycle Gas Savings (Million kBtu)	39.57	8.99
	Total Life Cycle Energy Savings (Million kBtu)	48.35	8.56
	Avoided GHG Emissions (Metric Tons CO ₂ e)	2,034.99	421.05
	Monetary Value of Avoided GHG Emissions (\$2026)	250,604	51,851
	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	Electricity Savings (kWh)	15.66	-6.62
	Peak Electrical Demand Reduction (W)	5.34	0.53

Category	Metric	New Construction and Additions	Alterations
During First Year	Natural Gas Savings (kBtu)	487.71	494.67
	Source Energy Savings (kBtu)	491.36	458.45
	Life Cycle Energy Savings (kBtu)	748.85	593.05
	Avoided GHG Emissions (kg CO ₂ e)	31.52	29.16
	On-site Indoor Water Savings (Gallons)	0	0
	On-site Outdoor Water Savings (Gallons)	0	0
	Embedded Electricity in Water Savings (kWh)	0	0

Compliance and Enforcement

Overview of Compliance Process

The compliance processes and impacts that the proposed measures would have on market actors are described in sections 2.1.5 and 3.1.5 and in Appendix E. Only one noteworthy compliance impact is expected: the adjustment to the new window SHGC verification requirements, as there currently are none. If adopted, building contractors must install windows with a SHGC within ± 0.01 of the modeled value. Other than this, the proposed window and wall insulation performance metrics are already incorporated into existing compliance processes; because the remaining code change proposals are limited to the magnitude of already regulated metrics, the same compliance processes would be used.

Field Verification and Diagnostic Testing

High performance window criteria are verified through a label that comes on all windows specifying the U-factor and SHGC, and it is checked by a building inspector or any other third-party inspector. This inspection would occur at the same time as the final inspection so would not add complexity to the compliance process, nor add any incremental time for inspection. Similarly, the compliance verification process for wall insulation would remain the same with this code change; only the value of the overall mandatory assembly U-factor would change.

Addressing Energy Equity and Environmental Justice

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. DIPs refers to the areas 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. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.³ 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).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and grappling with the unjust legacies of the past all serve as critical steps to achieving energy equity. Code change proposals must be developed and adopted with intentional screening for unintended consequences, otherwise they risk perpetuating systemic injustices and oppression.

The Statewide CASE Team assessed the potential impacts of the proposed measure. As outlined throughout the report, both proposals are cost effective and would minimally disrupt current building practices and no explicit barriers to proposal adoption are foreseen. Therefore, based on this preliminary review, the measure is unlikely to have significant impacts on energy equity or environmental justice, therefore reducing the impacts of disparities in DIPs. The Statewide CASE Team does not recommend further research or action at this time but is open to receiving feedback and data that may prove otherwise. Please reach out to Nancy Metayer (nmetayer@energy-solution.com) and Marissa Lerner (mlerner@energy-solution.com) for further engagement. Full details addressing energy equity and environmental justice can be found in Section 4. Addressing Energy Equity and Environmental Justice of this report.

³ 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.

1. Introduction

This is a draft report intended to allow for public review and comment before the Final Report is issued. The Statewide CASE Team encourages readers to provide comments on the proposed code changes and the analyses presented. When possible, include supporting data and justifications in addition to comments. The Statewide CASE Team will review all suggestions and consider them when revising and refining proposals and analyses. The Final CASE Report will be submitted to the California Energy Commission in Summer 2023.

Email comments and suggestions to Simon Pallin (spallin@frontierenergy.com) and info@title24stakeholders.com by Tuesday, May 30, 2023. Comments will not be released for public review or will be anonymized if shared with stakeholders.

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (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—High Performance Windows

- **Section 2.1—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 2.2—Market Analysis** includes a review of the current market structure. Section 2.2.2 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 2.3—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 0—**

- **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 2.5—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 3—Mandatory U-Factor Requirements for Framed Walls

- **Section 3.1—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 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, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- **Section 3.3—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 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.

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

- **Section 4—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 underlined (additions) language for the Standards, Reference Appendices, and Alternative Calculation Method (ACM) Reference Manual. Generalized proposed revisions to sections are included for the Compliance Manual and compliance 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.

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](https://www.energycodeace.com) to learn more and to access content, including a glossary of terms.

2. High Performance Windows

2.1 Measure Description

2.1.1 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.

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 0.28 for all climate zones, except for small homes in Climate Zones 6 through 10, and 15 where a U-factor requirement of 0.30 would remain.

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 not be changed.

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 confirmed that the compliance impacts of higher or lower SHGC are not always intuitive. 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 minimum or maximum value. A range of plus or minus 0.01 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.

2.1.2 Justification and Background Information

2.1.2.1 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 for the 2019 code cycle (Nittler, 2018). There is also a parallel 2025 code proposal for multifamily buildings with similar U-factor requirements.⁴

Products with lower U-factor than 0.30 are readily available using either double-pane (double glazing) with additional features such as low-e films or use of argon or krypton gas between the panes or using triple-paned construction.

As a reflection of the current window market and expected energy savings, the Environmental Protection Agency (EPA) is enacting similar U-factor reductions in the latest updates to ENERGY STAR® window criteria (Version 7). Such changes at the national level will enable code compliance within California in terms of product availability, 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 (EPA, ENERGY STAR Windows, Doors, and Skylights Version 7.0 Criteria Analysis Report, 2021).

2.1.2.2 Background Information

Windows are a critical piece in the energy efficiency of a building envelope. Compared to other building envelope components, such as walls and roofs, windows typically act as a thermal bridge because energy can transfer more easily through windows than many other areas of a building. The implication of building envelope energy losses is that the HVAC system will 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·ft²·°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 results in higher visibility. 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.

⁴ <https://title24stakeholders.com/measures/cycle-2025/multifamily-envelope/>

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 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.

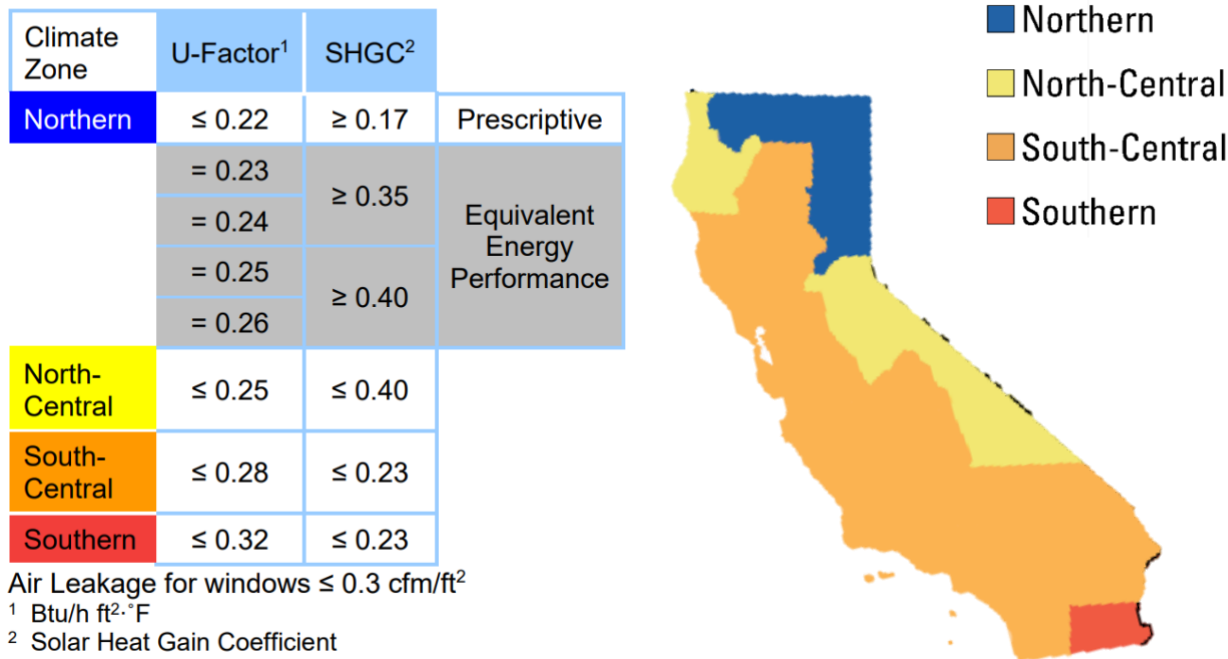


Figure 1: ENERGY STAR Version 7.0 program requirements for windows.

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

2.1.3 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.⁵ See Section 5 of this report for detailed proposed revisions to code language.

⁵ Visit [EnergyCodeAce.com](https://www.energycodeace.com) for training, tools and resources to help people understand existing code requirements.

2.1.3.1 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.

2.1.3.2 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 a range represented by the modeled SHGC 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.

2.1.3.3 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 2.1.1, where the changes would reflect the updated code requirements for mandatory and prescriptive U-factors.

2.1.3.4 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 0.28 as a reflection of this proposal. 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 Ft² 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

2.1.4 Regulatory Context

2.1.4.1 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.

2.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal or local laws or regulations.

2.1.4.3 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 2.1.2.2.

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.

2.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors 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. For projects in newly regulated climate zones, addressing SHCG 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 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. 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.



Figure 2: Window label for energy performance rating and proof of NFRC certification

Source: National Fenestration Rating Council via Energy Code Ace.

2.2 Market Analysis

2.2.1 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.

2.2.2 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.

This collective feedback contributed to the middle-ground proposal of a 0.28 prescriptive maximum U-factor across all California Climate Zones. 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 code 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.

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. 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.

2.2.3 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.

2.2.3.1 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 Table 6). 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 2.2.4 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.)

2.2.3.2 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)⁶ 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

⁶ NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was developed jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadística y Geografía, 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.⁷ It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 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.

2.2.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (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.

2.2.3.4 Impact on Building Owners and Occupants Including Homeowners and Potential First-Time Homeowners

Residential Buildings

According to data from the U.S. Census, American Community Survey (ACS), there were more than 14.5 million housing units in California in 2021 and nearly 13.3 million were occupied (see Table 9). Most housing units, nearly 9.42 million, were either detached or attached single family homes, approximately two million homes were in

⁷ Establishments in this sector include businesses primarily engaged in evaluating a building’s structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminants, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

buildings 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 costs by about \$282 per single family home, but the measure would also result in a savings of \$273 in electricity and natural gas over 30 years, depending on climate zone. This is roughly equivalent to a \$0.78 per month increase in payments for a 30-year mortgage and a \$0.76 per month reduction in energy costs.

2.2.3.5 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 2.5.4). 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.

2.2.3.6 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.

2.2.3.7 Impact on Statewide Employment

As described in Sections 2.2.3.1 through 2.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 2.2.4, the Statewide CASE Team estimated the proposed change in 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.

2.2.4 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,⁸ 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

⁸ 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.

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.⁹ There may also be some nonresidential customers that are impacted by this proposed code change; however, the Statewide CASE Team does not anticipate such impacts to be materially important to the building owner and would have measurable economic impacts.

⁹ 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.

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)	8.65	\$651,028	\$6,450,438	\$11,024,929
Indirect Effect (Additional spending by firms supporting Residential Builders)	22.02	\$1,658,502	\$2,757,505	\$4,679,741
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	4.40	\$299,516	\$536,297	\$853,586
Total Economic Impacts	35.1	\$2,609,047	\$9,744,239	\$16,558,256

Source: Statewide CASE Team analysis of data from the IMPLAN modeling software.¹⁰

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 (Millions)	Total Value Added (Millions)	Output (Millions)
Direct Effects (Additional spending by Building Designers & Energy Consultants)	3.1	\$337,174	\$333,798	\$527,599
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consultants)	1.2	\$100,394	\$139,527	\$224,610
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1.8	\$125,821	\$225,318	\$358,627
Total Economic Impacts	6.2	\$563,388	\$698,643	\$1,110,836

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

¹⁰ 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 (Millions)	Total Value Added (Millions)	Output (Millions)
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)	0.9	\$64,644	\$116,737	\$185,655
Total Effect	0.9	\$64,644	\$116,737	\$185,655

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

2.2.4.1 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 2.2.4 would lead to modest changes in employment of existing jobs.

2.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 2.2.4.1, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. The proposed change may represent a modest change to material demands (see section 2.5.4 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.

2.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.¹¹ Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2025 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

2.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm’s capital stock (referred to as net private domestic investment, or NPDI).¹² 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	Fill / “Intentionally blank”	Fill / “Intentionally blank”	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

¹¹ 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.

¹² 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.

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.¹³ For the prescriptive high performance window proposal, the resulting net private investment is estimated at \$\$684,637. Because this is less than \$1,000,000, the Statewide CASE Team determines this is a minor impact relative to California’s economy.

2.2.4.5 Incentives for Innovation in Products, Materials, or Processes

As discussed in Section 2.2.2, 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 2.1.2.2, 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.

2.2.4.6 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

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

by the IOU Codes and Standards program (such as Energy Code Ace) and the CEC's [Outreach and Education Unit](#). As noted in Section 2.1.5 and Appendix E, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

2.2.4.7 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. Refer to Section 4 for more details addressing energy equity and environmental justice.

2.2.5 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.

2.2.5.1 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.

2.2.5.2 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.

2.2.5.3 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).

2.2.5.4 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.

2.2.5.5 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.

2.3 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 4 for more details addressing energy equity and environmental justice.

2.3.1 Energy Savings Methodology

2.3.1.1 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.

2.3.1.2 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.¹⁴ 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,

¹⁴ 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>

transmission and distribution, fuel, capacity, losses, and cap-and-trade-based CO₂ 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.

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. 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 due to similar savings and overall impacts across these two prototypes. 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 (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 G.

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 (SF2100)	1	2,100	Single story 3-bedroom house with attached garage, 9-ft ceilings, vented attic, and steep-sloped roof.
Two-Story Single Family (SF2700)	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 (SF500)	1	500	Detached single story 1-bedroom small home, 9-ft ceilings.
Single Family Existing Building (SF1665)	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.¹⁵ 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.

¹⁵ 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
All	All	Window Properties	U-factor	0.30	0.28

CBEEC-Res calculates whole building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/y) and therms per year (therms/y). It then applies the 2025 LSC hourly factors to calculate LSC in 2026 present value dollars (2026 PV\$). Source Energy hourly factors are used to calculate Source Energy Use in kilo British thermal units per year (kBtu/y), and hourly GHG emissions factors to calculate annual GHG emissions in metric tons of carbon dioxide emissions equivalent per year (metric tons or “tonnes” of CO_{2e}/y). CBEEC-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.

2.3.1.3 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.

2.3.2 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 -11 to 84 kWh per year on electricity for the 2100/2700 weighted new construction prototype. For small homes, the electricity savings vary between -11 to 13 kWh per year. Alterations fall between these two with a range of -19 to 21 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 34.4 therms per year for the 2100/2700 weighted new construction prototype. For small homes, heating energy savings range from 0 to 5.4 therms per year, and from 1.6 to 12.1 for alterations.

As seen in Table 20, the proposed measure reduces peak demand in electricity in most cases with up to 0.003 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	21	1	8
2	5	-2	4
3	59	6	-4
4	80	9	-4
5	4	-2	-5
6	-1	N/A	-4
7	-3	N/A	-9
8	-11	N/A	-19
9	-8	N/A	-15
10	-6	N/A	-12
11	2	-1	2
12	-1	-3	-5
13	52	8	6
14	84	13	3
15	17	N/A	21
16	0	-11	-18

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	0.002	0.002	0.001
2	0.001	0.000	0.001
3	0.019	0.003	0.001
4	0.021	0.005	0.001
5	0.001	N/A	0.001
6	0.000	N/A	0.000
7	0.000	N/A	0.000
8	0.000	N/A	0.000
9	0.000	N/A	0.000
10	0.000	N/A	0.000
11	0.000	0.000	0.000
12	0.001	0.000	0.001
13	0.015	0.003	0.000
14	0.030	0.006	0.001
15	0.000	N/A	0.000
16	0.003	-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	33.6	4.6	10.2
2	9.0	1.2	8.4
3	0.0	0.0	4.6
4	0.0	0.0	8.5
5	6.8	N/A	4.3
6	2.5	N/A	2.4
7	2.2	N/A	2.2
8	2.9	N/A	3.0
9	3.3	N/A	3.5
10	3.4	N/A	3.5
11	7.5	1.1	7.3
12	7.6	1.1	7.5
13	0.0	0.0	5.7
14	0.0	0.0	8.2
15	1.4	N/A	1.6
16	34.4	5.4	12.1

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	3,106	415	949
2	817	100	766
3	195	30	433
4	244	40	783
5	618	25	366
6	241	N/A	250
7	195	N/A	216
8	230	N/A	266
9	269	N/A	316
10	293	N/A	316
11	695	100	666
12	695	105	699
13	161	30	533
14	293	50	766
15	129	N/A	167
16	3,106	485	1,082

Table 23: First Year Long-term Systemwide Cost 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	\$4,272	\$595	\$1,315
2	\$1,159	\$155	\$1,066
3	\$499	\$70	\$583
4	\$597	\$85	\$1,066
5	\$900	\$45	\$533
6	\$328	N/A	\$300
7	\$279	N/A	\$216
8	\$293	N/A	\$266
9	\$401	N/A	\$350
10	\$426	N/A	\$400
11	\$977	\$135	\$949
12	\$953	\$125	\$899
13	\$419	\$75	\$783
14	\$674	\$105	\$1,049
15	\$300	N/A	\$350
16	\$4,335	\$630	\$1,449

2.4 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 2400/2700 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.

2.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the Long-term Systemwide Cost (LSC) hourly factors to the energy savings estimates that were derived using the methodology described in Section 2.3.1. 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.

2.4.2 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 through Table 25. 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 4 for more details addressing energy equity and environmental justice.

Table 24: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction

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	\$157	\$4,115	\$4,272
2	\$35	\$1,124	\$1,159
3	\$499	\$0	\$499
4	\$597	\$0	\$597
5	\$38	\$862	\$900
6	\$24	\$304	\$328
7	-\$14	\$293	\$279
8	-\$73	\$366	\$293
9	-\$24	\$426	\$401
10	-\$24	\$450	\$426
11	\$24	\$953	\$977
12	\$0	\$953	\$953
13	\$419	\$0	\$419
14	\$674	\$0	\$674
15	\$126	\$175	\$300
16	\$70	\$4,265	\$4,335

Table 25: 2026 PV Long-term Systemwide Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction

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	\$20	\$575	\$595
2	\$5	\$150	\$155
3	\$70	\$0	\$70
4	\$85	\$0	\$85
5	\$0	\$45	\$45
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	\$0	\$135	\$135
12	-\$10	\$135	\$125
13	\$75	\$0	\$75
14	\$105	\$0	\$105
15	N/A	N/A	N/A
16	-\$40	\$670	\$630

2.4.3 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). 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.

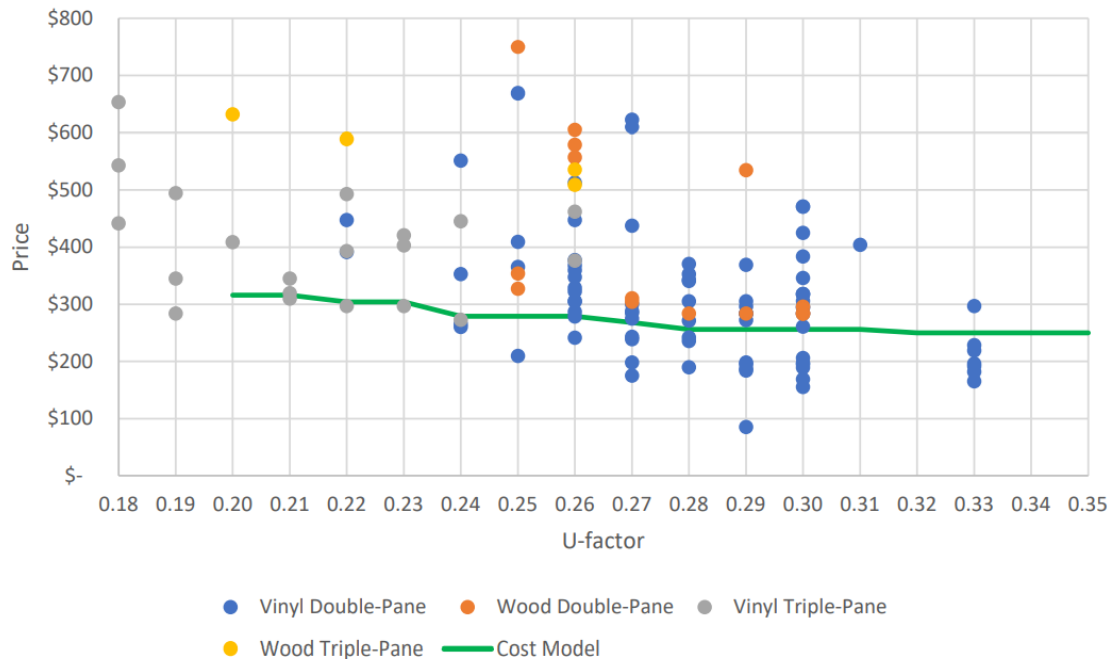


Figure 3: ENERGY STAR incremental consumer cost model (green line) based on window U-factor

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

As seen in Figure 3 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. One window manufacturer estimates their product prices at 10 to 15 percent higher than the estimates provided by ENERGY STAR. The Statewide CASE Team took the upper end of this range as a conservative approach to cost effectiveness calculations. As a result, the estimated incremental material costs are \$0.59/ft² of window going from U-0.30 to U-0.28.

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 2.2.2). The

Statewide CASE Team, supported by stakeholder input, does not anticipate any increase in labor for windows with a U-factor of 0.28, 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 26.

Table 26: Window Incremental Costs

Window U-Factor Reduction	Incremental Material Cost, with Multiplier	Incremental Labor Cost	Total Incremental Cost
0.3 → 0.28 (CZ 2-15)	\$0.59/ft ²	N/A	\$0.59/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 2.4.

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.

2.4.4 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.

2.4.5 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 27 through Table 28 for the 2100/2700 weighted and small home new construction prototypes, respectively.

The proposed measure is cost effective in every climate zone for the 2100/2700 weighted new construction prototype, except in Climate Zone 7 where it is close to being cost effective. For the small home prototype, the measure is cost effective in Climate Zones 1 through 4, 11 through 14, and 16. Where it is not cost effective the net increase in costs over the 30-year analysis period is low, \$14 to \$104. The Statewide CASE Team recommends applying an exception for small homes in Climate Zone 6 through 10, and 15 which don't show cost-effectiveness, as seen in Table 28.

Table 27: 30-Year Cost effectiveness Summary Per Home – New Construction/Additions – 2100/2700 Weighted New Construction

Climate Zone	Benefits SLCC Savings + Other PV Savings ^a (2026 PV\$)	Costs Total Incremental PV Costs ^b (2026 PV\$)	Benefit- to-Cost Ratio
1	\$4,272	\$287	14.91
2	\$1,159	\$287	4.04
3	\$499	\$287	1.74
4	\$597	\$287	2.08
5	\$900	\$287	3.14
6	\$328	\$287	1.14
7	\$279	\$287	0.97
8	\$293	\$287	1.02
9	\$401	\$287	1.40
10	\$426	\$287	1.49
11	\$977	\$287	3.41
12	\$953	\$287	3.33
13	\$419	\$287	1.46
14	\$674	\$287	2.35
15	\$300	\$287	1.05
16	\$4,335	\$287	15.13

- a. **Benefits: Long-term Systemwide Cost 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 28: 30-Year Cost effectiveness Summary Per Home – New Construction/Additions – Small Homes New Construction

Climate Zone	Benefits Life Cycle Energy Cost Savings + Other PV Savings ^a (2026 PV\$)	Costs Total Incremental PV Costs ^b (2026 PV\$)	Benefit-to-Cost Ratio
1	\$595	\$59	10.14
2	\$155	\$59	2.64
3	\$70	\$59	1.19
4	\$85	\$59	1.45
5	\$45	\$59	0.77
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	\$135	\$59	2.30
12	\$125	\$59	2.13
13	\$75	\$59	1.28
14	\$105	\$59	1.79
15	N/A	N/A	N/A
16	\$630	\$59	10.74

Benefits: Long-term Systemwide Cost 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.

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.

2.5 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.

2.5.1 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 2.3.2, 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 31 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 4 for more details addressing energy equity and environmental justice.

Table 29: 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	0.01	0.00	0.01	1.09	\$1.50
2	1,861	0.01	0.00	0.02	1.49	\$2.12
3	3,035	0.18	0.06	0	0.58	\$1.48
4	2,689	0.21	0.06	0	0.65	\$1.57
5	616	0	0	0	0.37	\$0.54
6	1,685	0	0	0	0.40	\$0.55
7	1,832	-0.01	0	0.00	0.36	\$0.51
8	4,080	-0.05	0	0.01	0.93	\$1.20
9	4,200	-0.03	0	0.01	1.13	\$1.68
10	7,791	-0.05	0	0.03	2.28	\$3.31
11	5,840	0.01	0	0.04	3.98	\$5.61
12	14,542	-0.01	0.01	0.11	9.91	\$13.61
13	7,257	0.37	0.10	0	1.16	\$3.01
14	3,739	0.31	0.11	0	1.08	\$2.48
15	3,097	0.05	0	0	0.42	\$0.95
16	1,937	0	0	0.07	5.90	\$8.23
Total	64,559	1.01	0.34	0.31	31.72	\$48.35

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

Table 30: 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	0.07	\$0.09
2	425	0.00	0.000	0.00	0.33	\$0.45
3	1,556	-0.01	0.002	0.01	0.67	\$0.91
4	796	0.00	0.001	0.01	0.62	\$0.85
5	156	0.00	0.000	0.00	0.06	\$0.08
6	951	0.00	0.000	0.00	0.24	\$0.29
7	791	-0.01	0.000	0.00	0.17	\$0.17
8	1,482	-0.03	0.000	0.00	0.39	\$0.39
9	2,001	-0.03	0.001	0.01	0.63	\$0.70
10	1,708	-0.02	0.000	0.01	0.54	\$0.68
11	537	0.00	0.000	0.00	0.36	\$0.51
12	2,110	-0.01	0.002	0.02	1.48	\$1.90
13	1,016	0.01	0.000	0.01	0.54	\$0.79
14	397	0.00	0.000	0.00	0.30	\$0.42
15	284	0.01	0.000	0.00	0.05	\$0.10
16	157	0.00	0.000	0.00	0.17	\$0.23
Total	14,437	-0.10	0.008	0.07	6.62	\$8.56

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

Both Table 29 and Table 30 show negative electrical savings for some climates. The reasons for this are mentioned in Section 2.3.2 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, 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	1.01	0.34	0.31	31.72	\$48.34
Alterations	-0.10	0.01	0.07	6.62	\$8.56
Total	0.91	0.35	0.39	38.34	\$56.90

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

2.5.2 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).

The monetary value of avoided GHG emissions is based on a proxy for permit costs (not social costs).¹⁶ The Cost Effectiveness Analysis presented in Section 2.4 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 32Table 32 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 2,445 (metric tons CO₂e) would be avoided.

¹⁶ The permit cost of carbon is equivalent to the market value of a unit of GHG emissions in the California Cap-and-Trade program, while social cost of carbon is an estimate of the total economic value of damage done per unit of GHG emissions. Social costs tend to be greater than permit costs. See more on the Cap-and-Trade Program on the California Air Resources Board website: <https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program>.

Table 32: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings ^a (GWh/y)	Reduced GHG Emissions from Electricity Savings (Metric Tons CO ₂ e)	Natural Gas Savings ^a (Million Therms/y)	Reduced GHG Emissions from Natural Gas Savings (Metric Tons CO ₂ e)	Total Reduced GHG Emissions ^b (Metric Ton CO ₂ e)	Total Monetary Value of Reduced GHG Emissions ^c (\$)
TOTAL	1	197	0.38	2,259	2,456	\$302,448

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

2.5.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

2.5.4 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 stakeholder feedback. As discussed in section 2.2, 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 relative amount of products on the market which 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, embodied carbon as discussed in Appendix D is considered to be zero.

2.5.5 Other Non-Energy Impacts

The primary benefit of a high performance window is in energy savings and resulting cost savings. However, as with any measure that tightens the building envelope, the occupant may experience increased comfort as indoor temperatures are better regulated from thermal “leaks”, which the proposed window measures will help reduce. Improvements to the building envelope performance may also relieve strain on HVAC systems and building occupants during significant outdoor temperature swings.

3. Mandatory U-Factor Requirements for Framed Walls

3.1 Measure Description

3.1.1 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, as shown in 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 33.

Table 33: 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	Proposed Max. U-Factor	Proposed Corresponding Min. R-Value
2x4	U-0.102	R-13	U-0.095	R-15
2x6	U-0.071	R-20	U-0.069	R-21

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. Meaning, R-13 can be used, but only in combination with additional insulation, adding up to the total proposed U-factor.

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 minimum R-values.

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.

3.1.2 Justification and Background Information

3.1.2.1 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.¹⁷

3.1.2.2 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.

¹⁷ <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. 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.

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.¹⁸ See Section 5 of this report for detailed proposed revisions to code language.

3.1.3.1 Specific Purpose and Necessity of Proposed Code Changes

Each proposed change to language in Title 24, Part 1 and Part 6 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-0.905

¹⁸ Visit [EnergyCodeAce.com](https://www.energycodeace.com) for trainings, tools and resources to help people understand existing code requirements.

in 2x4 assemblies and U-0.069 in 2x6 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.

3.1.3.2 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.

3.1.3.3 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 3.1.3.1, 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.

3.1.3.4 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.

3.1.4 Regulatory Context

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

There are no relevant state or local laws or regulations.

3.1.4.2 Duplication or Conflicts with Federal Laws and Regulations

There are no relevant federal laws or regulations.

3.1.4.3 Difference From Existing Model Codes and Industry Standards

There are no relevant industry standards or model codes.

3.1.5 Compliance and Enforcement

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

3.2 Market Analysis

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard 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/>).

3.2.1 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.

3.2.2 Technical Feasibility and Market Availability

Exterior walls can be insulated with a variety of different 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. The percentage of installed R-18 cavity insulation is 22.5 percent, and 11.3 percent for R-19. R-20, which aligns with the 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.

3.2.3 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 3.4. Section 3.4 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.

3.2.4 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.

3.2.5 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.

3.3 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 envelope efficiency.

3.4 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 3.2.1, 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 3.2.1), 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 4. Most of the products are fiberglass insulation, representing the industry standard for wall cavity insulation.

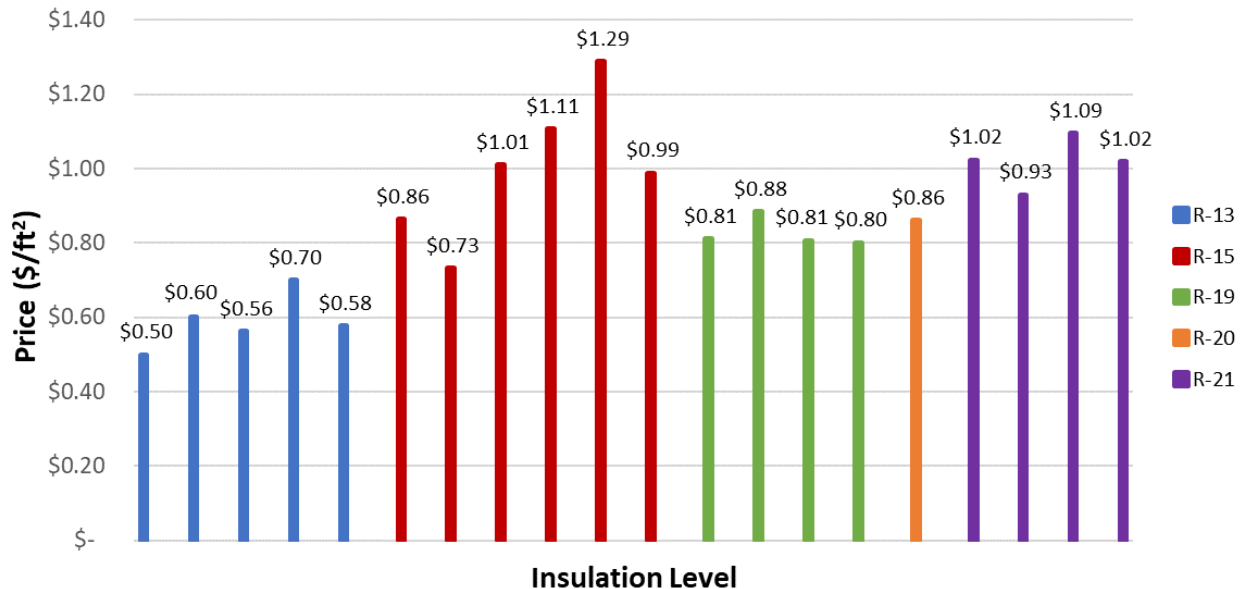


Figure 4: Price of cavity insulation. Products included are on rolls or packaged flat, faced and unfaced.

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

The data in Figure 4 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 4 does not include bulk prices, which is typically available for the most commonly used insulation products.

In Figure 4, 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 providing the same rate of insulation materials

according to a stakeholder, resulting in compressed insulation. If this material were not compressed, its R-value would be much higher.

For one specific manufacturer, the resulting incremental cost is \$0.36/ft² when going from R-13 to R-15, and \$0.16/ft² 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 34.

Table 34: Incremental cost for proposed increased mandatory wall insulation requirements.

Proposed Increase	One Story Single Family New Construction Prototype (2,100 ft²)	Two Story Single Family New Construction Prototype (2,700 ft²)
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.

3.5 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 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.

4. Addressing Energy Equity and Environmental Justice

This section covers all the window and wall code change proposals presented in this report.

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. DIPs refers to the areas 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. DIPs also incorporate race, class, and gender since these intersecting identity factors affect how people frame issues, interpret, and experience the world.¹⁹ 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).

Including impacted communities in the decision-making process, ensuring that the benefits and burdens of the energy sector are evenly distributed, and grappling with the unjust legacies of the past all serve as critical steps to achieving energy equity. Code change proposals must be developed and adopted with intentional screening for unintended consequences, otherwise they risk perpetuating systemic injustices and oppression.

The Statewide CASE Team assessed the potential impacts of the proposed measures, and based on a preliminary review, the measures are unlikely to have significant impacts on energy equity or environmental justice, therefore reducing the impacts of disparities in DIPs. The Statewide CASE Team does not recommend further research or action at this time. This research is still in process and more details will be available in the Final CASE Report.

¹⁹ 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.

4.1 Research Methods and Engagement

Stakeholder engagement is important because participatory approach allows individuals to address problems, develop innovative ideas, and bring forth a different perspective.

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.~~095402~~. In wood framed assemblies, compliance with this U-factor may be demonstrated by installing insulation between framing members with an R-value of 15 or greater.
Exception 1 to Section 150.0(c)1a: Existing walls 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 with insulation between framing members with an R-value of 13 or greater.
 - b. 2 × 6 inch or greater framing shall have an overall assembly U-factor not exceeding U-0.~~069074~~. In wood framed assemblies, compliance with this U-factor may be demonstrated by installing insulation between framing members with an R-value of 21 or greater.
Exception to Section 150.0(c)1b: Altered wood-framed walls where the existing siding is not being removed or replaced with insulation between framing members with an R-value of 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~~50~~.

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 0.450.

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 an area-weighted maximum 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 0.55 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 6 through 10 and 16 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

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	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	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 0.269 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	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	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	0.75	NR
	Fenestration	Maximum U-factor		0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	0.3028	
		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	0.23	NR
		Maximum Total Area		20%	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%	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	

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

(a) **Additions.** Additions to existing single-family residential buildings shall meet the requirements of Sections 110.0 through 110.9, Sections 150.0(a) through (n), (p), (q), and either Section 150.2(a)1 or 2.

1. **Prescriptive approach.** Additions to existing buildings shall meet the following additional requirements:

- A. Additions that are greater than 700 square feet shall meet the requirements of Section 150.1(c), with the following modifications:
 - i. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and shall install cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing.
 - ii. The maximum allowed fenestration area shall be the greater of 175 square feet or 20 percent of the addition floor area, and the maximum allowed west-facing fenestration area shall be the greater of 70 square feet or the requirements of Section 150.1(c).
 - iii. When existing siding of a wood-framed wall is not being removed or replaced, cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing shall be installed and continuous insulation is not required.
 - iv. Additions that consist of the conversion of existing spaces from unconditioned to conditioned space shall not be required to perform the following as part of QII:
 - a. Existing window and door headers shall not be required to be insulated.
 - b. Air sealing shall not be required when the existing air barrier is not being removed or replaced.
- B. Additions that are 700 square feet or less shall meet the requirements of Section 150.1(c), with the following modifications:
 - i. Roof and ceiling insulation in a ventilated attic shall meet one of the following requirements:
 - a. In Climate Zones 1, 2, 4, and 8 through 16, achieve an overall assembly U-factor not exceeding 0.025. In wood framed assemblies, compliance with U-factors may be demonstrated by installing insulation with an R-value of R-38 or greater.
 - b. In Climate Zones 3, and 5 through 7, achieve an overall assembly U-factor not exceeding 0.031. In wood framed assemblies, compliance with U-factors may be demonstrated by installing insulation with an R-value of R-30 or greater.
 - ii. Radiant barriers shall be installed in climate zones 2-15.
 - iii. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and shall install cavity insulation of R-15 in a 2x4 framing and R-21 in a 2x6 framing.
 - iv. In Climate Zones 2, 4 and 6- through 15; the maximum allowed west-facing

fenestration area shall not be greater than 60 square feet; and shall also comply with either a or b below:

- a. For additions that are 700 square feet or less but greater than 400 square feet, the maximum allowed fenestration area limit is the greater of 120 square feet or 25 percent of the conditioned floor area of the addition; or
- b. For additions that are 400 square feet or less, the maximum allowed fenestration area is the greater of 75 square feet or 30 percent of the conditioned floor area of the addition.
- v. Quality Insulation Installation (QII) requirements of Section 150.1(c)1E do not apply.
- vi. When existing siding of a wood-framed wall is not being removed or replaced, cavity insulation of R-15 in a 2×4 framing and R-21 in a 2×6 framing shall be installed and continuous insulation is not required.

Exception to Section 150.2(a)1B: Insulation in an enclosed rafter ceiling shall meet the requirements of Section 150.0.

(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, 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.

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 ~~at 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

2.5.6.3 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.

2.5.6 Exterior Surfaces

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 Section 110.6 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 Section 150.1(c) and Table 150.1-A, which is ~~0.30 U-factor in all climate zones~~ 0.28 in all Climate Zones. 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 acceptable range 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.

Specifically, the numeric references to be updated entail changing the maximum window U-factor from 0.30 to 0.28, and changing the maximum wall U-factors from 0.102 to 0.095 and from 0.071 to 0.069 (for 2 x 4 and 2 x 6 wall assemblies, respectively).

- 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 Ft² 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 2.3 and 2.4 results are presented for a weighted average of the 2,100 square foot and 2,700 square foot new construction prototypes since results for each of these two prototypes individually 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 35 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 building, 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 35: 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	100%	616	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		64,559	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 are summarized below.

- Reduce the prescriptive U-factor requirement for windows from 0.30 to 0.28 for all California Climate Zones.
- Reduce the mandatory window U-factor from 0.45 to 0.40.
- Reduce the mandatory 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 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 of 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 updated prescriptive window U-factor requirements in the Standard Design.

CBECC-Res would need to be updated 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 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 assembly details before the simulation proceeds.

The software would check that each wall 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

There is no need to verify this software change with CSE output variables.

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 will 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 Table 36 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 used entered SHGC minus 0.01.
- Add a new column #13 titled “Maximum SHGC”. This value will be reported as the used 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.

Table 36: Compliance Report Table of CF1R-PRF-01E.

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

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 2.1.5 and 3.1.5 and Appendix E for further details.

Testing and Confirming CBEC-Res Building Energy Modeling

Table 37 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 37: Proposed 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 2.1.5 and 3.1.5, could impact various market actors. Table 38 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 38 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 38 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 38: 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)	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Understand code requirement and confirm data on documents is compliant. • Confirm plans / specifications match data on compliance documents. • Provide correction comments if necessary. 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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 Draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost effectiveness, market barriers, technical barriers, compliance and enforcement challenges, or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

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

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team’s role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2025 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted one stakeholder meeting for Single-Family High-Performance Envelope via webinar described in Table 39. Please see below for dates and links to event pages on [Title24Stakeholders.com](https://www.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 39: 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 40.

Table 40: Engaged Stakeholders

Organization/Individual Name	Market Role
Harris & Sloan	HVAC Designer
CBIA	Builders/Developers & Industry Associations
Window & Door Manufacturers Association	Industry/Trade Associations
KB Homes	Builders/Developers & Industry Associations
Pella Windows	Manufacturers
Oak Ridge National Laboratory	National Laboratories
Department of Energy (DOE)	National Laboratories
Anderson Windows	Manufacturer
PGT Industries	Manufacturers
Northwest Energy Efficiency Alliance (NEEA)	Industry/Trade Associations
Lawrence Berkeley National Laboratory (LBNL)	National Laboratories
Jeld-Wen, Inc.	Manufacturers
Harris & Sloan	HVAC Designer
KB Homes	Builders/Developers & Industry Associations
Owens Corning	Manufacturers
Sika Corporation/Rmax	Manufacturers

Engagement with DIPs

TBD

Builder Survey

As part of the stakeholder outreach conducted by the Statewide CASE Team, a survey is underway to gather feedback from the building sector on numerous proposals. The survey is currently in development by the Statewide CASE Team with input from Evergreen Economics, who will administer the survey. The survey will be sent to members of the California Building Industry Association (CBIA) and results will be published in the final version of this CASE Report.

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 2.4 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 3.4 of this report). This appendix presents the same energy cost savings, but in nominal dollars, for high performance windows.

Table 41: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – 2100/2700 Weighted New Construction.

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	\$355	\$10,967	\$11,323
2	\$79	\$2,995	\$3,074
3	\$1,129	\$0	\$1,129
4	\$1,350	\$0	\$1,350
5	\$87	\$2,298	\$2,384
6	\$55	\$809	\$864
7	-\$32	\$781	\$749
8	-\$166	\$977	\$811
9	-\$55	\$1,135	\$1,079
10	-\$55	\$1,200	\$1,144
11	\$55	\$2,540	\$2,595
12	\$0	\$2,540	\$2,540
13	\$947	\$0	\$947
14	\$1,525	\$0	\$1,525
15	\$285	\$465	\$750
16	\$158	\$11,365	\$11,523

Table 42: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Home – New Construction and Additions – Small Home New Construction

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	\$45	\$1,533	\$1,578
2	\$11	\$400	\$411
3	\$158	\$0	\$158
4	\$192	\$0	\$192
5	\$0	\$120	\$120
6	-\$45	\$0	-\$45
7	-\$102	\$0	-\$102
8	-\$68	\$0	-\$68
9	-\$68	\$27	-\$41
10	-\$57	\$13	-\$43
11	\$0	\$360	\$360
12	-\$23	\$360	\$337
13	\$170	\$0	\$170
14	\$238	\$0	\$238
15	\$11	\$0	\$11
16	-\$91	\$1,785	\$1,695
13	\$151	\$1,908	\$2,059
14	\$38	\$2,751	\$2,789
15	\$302	\$577	\$878
16	-\$151	\$4,038	\$3,887

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 **Error! Reference source not found.** 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 43: 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. 85 percent of residential buildings use natural gas for space heating and 86 percent use natural gas for water heating (California Energy Commission, 2009).

Table 44 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 44: Alteration Prototype Baseline Assumptions

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)
Foundation Type & Insulation	Uninsulated slab	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission, 2014)
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)
Roofing Material & Color	Asphalt shingles, default values (0.10 reflectance, 0.85 emittance)	CBCEC-Res default
Radiant Barrier	No	2013 T24 Residential Vintage Table R3-50, default for 1992 to 1998 vintage. (California Energy Commission, 2014)
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.
Opaque Doors	0.50	CBCEC-Res default
Quality Insulation Inspection Credit (HERS)	No	CBCEC-Res default
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 CBCEC-Res default for multifamily
HVAC Equipment		
System Type & Description	Ducted FAU split system with gas furnace & A/C	Typical system for California homes

Building Component Efficiency Feature	Baseline Assumption	Reference
Heating Efficiency	0.78 AFUE	Federal minimum efficiency level in effect around 2015.
Cooling Efficiency	13 SEER 11 EER	Federal minimum efficiency level in effect around 2015 for SEER. EER estimated based on CBECC-Res equations.
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.
Mechanical Ventilation	None	CBECC-Res default
Verified Refrigerant Charge (HERS)	No	CBECC-Res default
Verified Cooling Airflow >= 350 cfm/ton (HERS)	No, 350 cfm/ton	CBECC-Res 45Table 454444,,,,,,,,,,,,,default
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 Heater Efficiency	0.575 EF	Federal minimum efficiency level in effect around 2015.
Water Heater Size (gal.)	40	Typical for residential storage gas water heaters.
Appliance & Lighting		
Lighting Type	per CBECC-Res	CBECC-Res default
Appliances	per CBECC-Res	CBECC-Res default
Cooking	Gas	Typical for mixed fuel home
Clothes Dryer	Gas	Typical for mixed fuel home