# Residential Energy Savings and Process Improvements for Additions and Alterations

2022-SF-EAA-D | Residential Envelope/HVAC/Water Heating | May 2020 DRAFT CASE REPORT

Frontier Energy, Resource Refocus

**Please submit comments to info@title24stakeholders.com by Friday June 12, 2020.**

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# 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 July 2020.*

*Email comments and suggestions to* info@title24stakeholders.com *by* ***Friday June 12, 2020.*** *Comments will not be released for public review or will be anonymized if shared with stakeholders.*

## Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Efficiency Building Standards (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 – Sacramento Municipal Utility District and Los Angeles Department of Water and Power (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 Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Building Energy Efficiency Standards website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this CASE Report is to present code change proposals for alterations and additions in residential buildings. The report contains pertinent information supporting the code change.

## Measure Description

### Background Information

By 2023 it is estimated that there will be over 13 million existing residential dwelling units in California (California Energy Commission 2019a). Almost 60 percent of these were built before the California Energy Code went into effect in 1978. The Energy Commission estimates that over the course of the 2023 code cycle, about 125,000 new dwelling units will be built each year. New construction has been the focus of recent Title 24, Part 6 code updates; however, existing buildings represent a significant savings opportunity and one that must be addressed in order to respond to statewide goals. Assembly Bill 3232, signed by Governor Brown in 2018, requires the Energy Commission to identify policies that reduces greenhouse gas emissions from the existing building stock by 40 percent below 1990 levels by 2030.

### Proposed Code Change

The code change proposals impact residential alterations and additions. They were originally developed based on the low-rise residential code, Section 150.2 of Title 24, Part 6, and have since been expanded to cover single family and all multifamily buildings. Most of the proposals revise prescriptive requirements in the California Energy Code. There are also proposals that add compliance options for alterations. The proposed submeasures are described below.

- Expand the climate zones where cool roofs are required for steep-slope and low-slope roof replacements.
- Add a roof deck insulation requirement for low-slope roofs at time of roof replacement in certain climate zones.
- Prohibit electric resistance space heating and water heating replacement equipment under certain conditions in most climate zones.
- Reduce the duct sealing target for altered duct and space conditioning systems in all climate zones for single family buildings.
- Increase the prescriptive duct insulation requirements in certain climate zones.
- Reduce the 40-foot trigger for prescriptive duct sealing and insulation requirements in all climate zones for systems serving existing zones and eliminate the trigger for systems serving additions.
- Add a prescriptive requirement for attic sealing and insulation for altered ceilings and when an entirely new or complete replacement duct system is installed in certain climate zones.
- Increase prescriptive attic insulation requirements for additions of 700 square feet or less in certain climate zones.

- Add three compliance options for alterations: revised blower door/air infiltration credit, fireplace removal credit, and quality insulation installation for alterations credit.

**Scope of Code Change Proposal**

Table 1 summarizes the scope of the proposed changes and which sections of Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents that would be modified as a result of the proposed change(s).

**Table 1: Scope of Code Change Proposal**

| **Measure Name** | **Type of Requirement** | **Modified Section(s) of Title 24, Part 6** | **Modified Title 24, Part 6 Appendices** | **Would Compliance Software Be Modified** (Revised ACM Reference Manual Sections) | **Modified Compliance Document(s)** |
|---|---|---|---|---|---|
| Cool roof for steep-slope roofs | Prescriptive | 150.2(b)1Ii | N/A | Yes (2.10.4.3) | CF1R-ALT-01-E CF1R-ALT-05-E |
| Cool roof for low-slope roof | Prescriptive | 150.2(b)1Iii | N/A | Yes (2.10.4.3) | CF1R-ALT-01-E CF1R-ALT-05-E |
| Roof deck insulation for low-slope roofs | Prescriptive | 150.2(b)1Iii | N/A | Yes (2.10.4.3) | CF1R-ALT-01-E CF1R-ALT-05-E CF2R-ALT-05-E CF2R-ENV-04-E |
| Electric resistance space heating | Prescriptive | 150.2(b)1C 150.2(b)1G | N/A | Yes (2.10.4.8) | CF1R-ALT-02-E |
| Electric resistance water heating | Prescriptive | 150.2(b)1Hiii | N/A | Yes (2.10.4.10) | CF1R-ALT-05-E |

| Measure Name | Type of Requirement | Modified Section(s) of Title 24, Part 6 | Modified Title 24, Part 6 Appendices | Would Compliance Software Be Modified (Revised ACM Reference Manual Sections) | Modified Compliance Document(s) |
|---|---|---|---|---|---|
| Prescriptive duct sealing | Prescriptive | 150.2(b)1D<br>150.2(b)1E | RA3.1.4.2 | Yes<br>(2.10.4.9) | N/A |
| Prescriptive duct insulation | Prescriptive | 150.2(b)1D | N/A | Yes<br>(2.10.4.9) | N/A |
| 40-ft trigger for prescriptive duct requirements | Prescriptive | 150.2(a)<br>150.2(b)1D | N/A | Yes<br>(2.10.4.9) | CF1R-ALT-02-E<br>CF2R-MCH-01-H |
| Prescriptive attic insulation for alterations | Prescriptive | 110.8(d)1<br>150.2(b)1A (new section)<br>150.2(b)1D | N/A | Yes<br>(2.10.4.3) | CF1R-ALT-05-E<br>CF1R-ALT-02-E<br>CF2R-ALT-05-E<br>CF2R-ENV-03-E |
| Prescriptive attic insulation for additions | Prescriptive | 150.2(a)1B | N/A | Yes<br>(2.10.4.3) | N/A |
| Compliance options for alterations | Compliance Option | N/A | RA3<br>RA4 | Yes<br>(2.10.4.1)<br>(2.10.4.7) | CF2R-ENV-03-E<br>CF2R-ENV-21-H<br>CF2R-ENV-22-H<br>CF3R-ENV-21-H<br>CF3R-ENV-22-H<br>CF3R-EXH-20-H |

## Market Analysis and Regulatory Assessment

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, market trends, and how the standard would affect individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors including roofing contractors, roofing industry representatives, manufacturers, and consultant. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

## Cost Effectiveness

The proposed prescriptive code changes were found to be cost effective for all climate zones where it would be required. The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 30-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost-effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratio for all the submeasures covered a broad range, from just cost effective with a B/C ratio just over 1.0 to a B/C ratio greater than 17. See Sections 2.4, 3.4, 4.4, and 5.4 for the methodology, assumptions, and results of the cost-effectiveness analysis.

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

Table 2 presents the estimated energy and demand impacts of the proposed code change that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (million therms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Sections 2.5, 3.5, 4.5, and 5.5 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Sections 2.3, 3.3, 4.3, and 5.3 contain details on the per-unit energy savings calculated by the Statewide CASE Team.

The compliance options submeasures do not modify the stringency of the California Energy Code and therefore do not have energy savings

**Table 2: First-Year Statewide Energy and Impacts**

| Measure | Electricity Savings (GWh/yr) | Peak Electrical Demand Reduction (MW) | Natural Gas Savings (million therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| Cool roof for steep-slope roofs | 10.0 | 6.19 | -0.04 | 534.3 |
| Cool roof for low-slope roof | 62.0 | 35.28 | -2.13 | 1,718.3 |
| Roof deck insulation for low-slope roofs | 82.8 | 25.03 | 3.74 | 4,847.1 |
| Electric resistance space heating | 9.3 | 0.07 | - | 282.0 |
| Electric resistance water heating | 61.5 | 6.54 | - | 1,589.3 |
| Prescriptive duct sealing | 3.8 | 2.32 | 0.26 | 319.8 |
| Prescriptive duct insulation | 0.2 | 0.13 | 0.01 | 17.5 |
| Prescriptive attic insulation for alterations | 9.0 | 4.11 | 0.50 | 573.1 |
| Prescriptive attic insulation for additions | 0.02 | 0.01 | 0.001 | 1.7 |

Table 3 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (Metric TonnesCO2e). Assumptions used in developing the GHG savings are provided in Sections 2.5.2, 3.5.2, 4.5.2, 5.5.2 and Appendix D of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

**Table 3: First-Year Statewide GHG Emissions Impacts**

| Measure | Avoided GHG Emissions (Metric TonnesCO2e/yr) | Monetary Value of Avoided GHG Emissions ($2023) |
|---|---|---|
| Cool roof for steep-slope roofs | 2,163 | $64,892 |
| Cool roof for low-slope roof | 3,307 | $99,220 |
| Roof deck insulation for low-slope roofs | 40,323 | $1,209,675 |

| Measure | Avoided GHG Emissions (Metric TonnesCO2e/yr) | Monetary Value of Avoided GHG Emissions ($2023) |
|---|---|---|
| Electric resistance space heating | 2,229 | $66,876 |
| Electric resistance water heating | 14,773 | $443,183 |
| Prescriptive duct sealing | 2,311 | $69,332 |
| Prescriptive duct insulation | 109 | $3,258 |
| Prescriptive attic insulation for alterations | 4,906 | $147,175 |
| Prescriptive attic insulation for additions | 9 | $284 |
| **Total** | **70,130** | **$2,103,895** |

**Water and Water Quality Impacts**

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

## Compliance and Enforcement

**Overview of Compliance Process**

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in the Compliance and Enforcement Sections. Impacts that the proposed measure would have on market actors is described in the Market Impacts and Economic Assessments Sections and Appendix F. The key issues related to compliance and enforcement are summarized below:

- Roof insulation for low-slope roofs at time of roof replacement is a new requirement for low-rise residential buildings. The documentation and inspections required for roof replacements vary widely jurisdiction to jurisdiction, which could result in inconsistencies in implementation. The code change proposal includes several detailed exceptions; when a project applies for an exception it's important that there is verification that the project qualifies. However, this would be an additional requirement on the building department which may be challenging based on available resources.
- With increased stringency in code requirements there is always concern that this may result in some alteration projects proceeding without applying for a permit. These code changes should be accompanied by education and outreach programs targeted at contractors, building departments, and building owners. Utility incentive programs throughout the 2019 Title 24, Part 6 code

cycle, and perhaps into the 2022 code cycle as well, can encourage early adopters and support a market transformation for improving existing homes. Local reach codes can also play a similar role.

### Field Verification and Diagnostic Testing

Field verification and testing by a HERS rater is required for air sealing component of the attic insulation for alterations submeasure, the prescriptive duct sealing submeasure and the performance approach compliance options. HERS verification of existing conditions is also required if one of the existing insulation R-value exceptions is used for the attic insulation for alterations submeasure. All other proposed measures rely on the building department permit review and onsite inspections to confirm compliance.

# 1. Introduction

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

The overall goal of this CASE Report is to present code change proposals for residential additions and alterations. The report contains pertinent information supporting the code changes.

When developing the code change proposals and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including roofing contractors, mechanical and plumbing contractors, building officials, manufacturers, designers, HERS Raters, Title 24 energy analysts, industry groups, and others involved in the code compliance process. The proposal incorporates feedback received during public stakeholder workshops that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

By 2023 it is estimated that there will be over 13 million existing residential dwelling units in California (California Energy Commission 2019a). Almost 60 percent of these were built before the California Energy Code went into effect in 1978. See Figure 1 for a breakdown of total single family and multifamily units statewide. The Energy Commission estimates that over the course of the 2023 code cycle, about 125,000 new dwelling units will be built each year. New construction has been the focus of recent Title 24, Part 6 code updates; however, existing buildings represent a significant savings opportunity and one that must be addressed in order to respond to statewide goals. Assembly Bill 3232, signed by Governor Brown in 2018, requires the Energy Commission to identify policies that reduce greenhouse gas emissions from the building stock by 40 percent below 1990 levels by 2030.

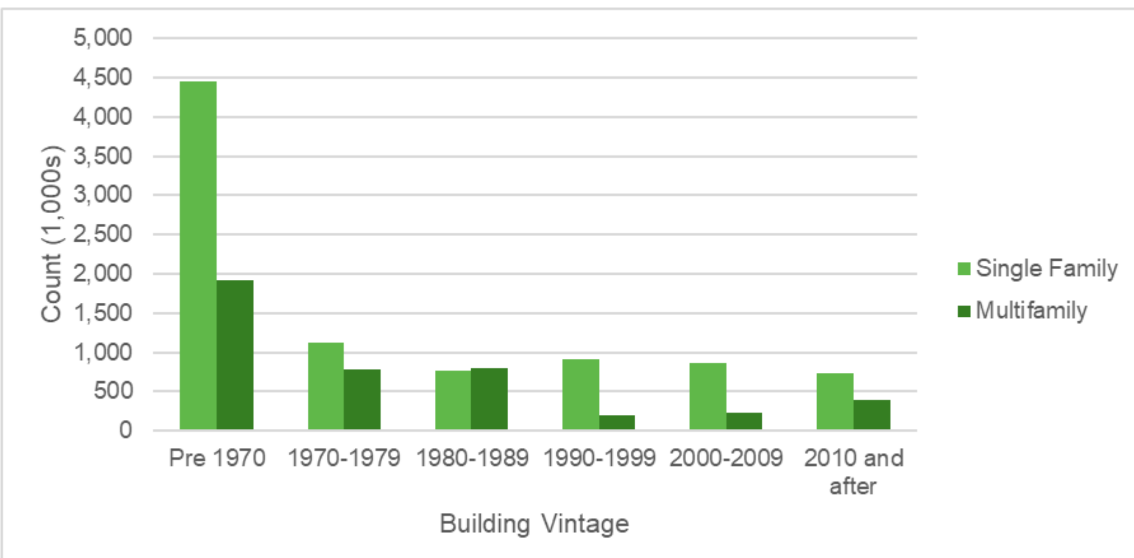


**Figure 1: Total number of residential single family and multifamily dwelling units in California.**

Source: Statewide construction forecasts provided by the Energy Commission (California Energy Commission 2019a).

These code change proposals have been developed based on the low-rise residential code, Section 150.2 of Title 24, Part 6, to cover low-rise single family and multifamily buildings. As part of the 2022 code cycle, the Statewide CASE Team and the Energy Commission are proposing to align the low-rise and high-rise multifamily requirements and reorganize the Standards so that all multifamily requirements are in a single section. In this report the Statewide CASE Team presents energy savings, cost effectiveness analysis, and proposed code change language for low-rise residential buildings. The Multifamily Restructuring CASE Report covers proposals related to multifamily restructuring and unification of low-rise residential and high-rise residential requirements beyond the scope of this CASE report.

This code change should be accompanied by education and outreach programs targeted at contractors, building departments, and building owners. Utility incentive programs throughout the 2019 Title 24, Part 6 code cycle, and perhaps into the 2022 code cycle as well, can encourage early adopters and support a market transformation for improving existing homes. Local reach codes can also play a similar role.

The following is a brief summary of the contents of this report. Each subsection is repeated for each of the five proposed submeasure groups. Each submeasure group includes two to three submeasures.

- Subsection 1 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Subsection 2 – In addition to the Market Analysis section, this section includes a review of the current market structure. Section 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.
- Subsection 3 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Subsection 4 –In addition to the Market Analysis section, this section includes a review of the current market structure. 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.
- Subsection 5 – First-Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the State of California. Statewide water consumption impacts are also reported in this section.
- Subsection 6 – Proposed Revisions to Code Language concludes the report with specific recommendations with strikeout (deletions) and underlined (additions)

language for the Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, Compliance Manual, and compliance documents.

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

The following is a brief summary of the Appendices included in this report.

- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Nominal Cost presents results energy cost savings results based on nominal costs.
- Appendix C: 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 D: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- Appendix E: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix F: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix G: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix H: Description of Prototypes describes the existing building prototypes used in the energy analysis.
- Appendix I: Additional Analysis provides additional analysis for select measures.

# 2. Roof Replacements, Cool Roofs & Insulation

## 2.1 Measure Description

### 2.1.1 Measure Overview

This section covers two prescriptive code change proposals: 1) cool roofs at steep-slope and low-slope roof replacement and 2) roof insulation at low-slope roof replacement. These submeasures would apply to all low-rise residential buildings, including single family and multifamily.

#### *2.1.1.1 Cool Roofs at Roof Replacement*

This submeasure expands the current cool roof requirements at time of roof replacement for steep-slope and low-slope roofs to additional climate zones and revises the existing exceptions. Table 4 describes the existing and proposed code requirements for minimum aged solar reflectance and minimum thermal emittance.

**Table 4: Summary of Existing and Proposed Cool Roof Requirements (Minimum Aged Solar Reflectance/Minimum Thermal Emittance)**

| Climate Zones | Steep-Slope | | | Low-Slope | | |
|---|---|---|---|---|---|---|
| | Existing | Proposed Single Family | Proposed Multifamily | Existing | Proposed Single Family | Proposed Multifamily |
| 1, 3, 5, 16 | N/A | N/A | N/A | N/A | N/A | N/A |
| 6-7 | N/A | N/A | N/A | N/A | 0.63/0.75 | 0.63/0.75 |
| 2 | N/A | N/A | 0.20/0.75 | N/A | N/A | 0.63/0.75 |
| 4, 8-9 | N/A | 0.20/0.75 | 0.20/0.75 | N/A | 0.63/0.75 | 0.63/0.75 |
| 10-12, 14 | 0.20/0.75 | 0.20/0.75 | 0.20/0.75 | N/A | 0.63/0.75 | 0.63/0.75 |
| 13, 15 | 0.20/0.75 | 0.20/0.75 | 0.20/0.75 | 0.63/0.75 | 0.63/0.75 | 0.63/0.75 |

Currently, a variety of exceptions are allowed for steep-slope roofs on low-rise residential buildings. This proposed change revises the existing exceptions and allows for the following alternative options.

a. Buildings with at least R-38 ceiling or roof insulation
b. Buildings with a radiant barrier in the attic where the radiant barrier is not installed directly over spaced sheathing
c. Buildings with R-2 or greater insulation above the roof deck
d. Buildings that have no ducts in the attic in Climate Zones 2, 4, 9, 10, 12, and 14

These four alternatives are estimated to result in similar or greater total savings than a roof with an aged solar reflectance of 0.20. The existing radiant barrier option is revised to not allow this alternative path if a radiant barrier is installed over spaced sheathing, which reduces the impact of the radiant barrier by almost half. The existing option for ducts located outside of the attic is revised to only allow this option in climate zones where the cool roof is not cost effective based on a building with ducts inside conditioned space. See Appendix I for analysis results with ducts in conditioned space.

Three of the existing exceptions are proposed to be removed, Table 5 provides details on the exceptions and the reasons for deleting them.

**Table 5: Exceptions to the Steep-Slope Cool Roof Requirements Proposed for Deletion**

| Existing Exception | Reason for Deletion |
|---|---|
| Air-space of 1.0 inch (25 mm) is provided between the top of the roof deck to the bottom of the roofing product. | Create consistency in the requirements applying equally to all roofs regardless of product types. |
| The installed roofing product has a profile ratio of rise to width of 1 to 5 for 50 percent or greater of the width of the roofing product. | Create consistency in the requirements applying equally to all roofs, regardless of product types. |
| Existing ducts in the attic are insulated and sealed according to Section 150.1(c)9. | This exception is no longer valid, Section 150.1(c)9 does not reference duct sealing requirements only duct insulation requirements. Duct sealing requirements have been moved from Section 150.1 to 150.0 and are now mandatory for new homes in addition to the prescriptive requirements for cool roofs. |

For low-slope roofs on low-rise buildings, the current Exception 1 exempts projects with no ducts in the attic. This exception is eliminated since most buildings with low-slope roofs do not have an attic space and the cost-effectiveness calculations conducted for this CASE Report are based on a building with ducts in conditioned space. The current Exception 2 allows for trade-offs between the aged solar reflectance and above roof deck insulation. Table 6 presents the revised trade-off values that reflect the new roof insulation requirements that are described in Section 2.1.1.2 for the climate zones where both a cool roof and roof insulation is prescriptively required. Equivalent combinations of solar reflectance and continuous insulation were determined based on results of energy simulations.

**Table 6: Aged Solar Reflectance Trade Off Table**

| Minimum Aged Solar Reflectance | Roof Deck Continuous Insulation R-value (Climate Zones 6-7) | Roof Deck Continuous Insulation R-value (Climate Zones 2, 4, 8-15) |
|---|---|---|
| 0.60 | R-2 | R-16 |
| 0.55 | R-4 | R-18 |
| 0.50 | R-6 | R-20 |
| 0.45 | R-8 | R-22 |
| No requirement | R-10 | R-24 |

#### 2.1.1.2 Roof Insulation at Low-Slope Roof Replacement

This submeasure adds a prescriptive requirement for above deck roof insulation at time of roof replacement for low-slope roofs. Currently, there is no requirement for low-rise residential buildings; there is an existing requirement for R-14 insulation for high-rise residential buildings. See Table 7 for a summary of existing and proposed low-rise residential requirements.

**Table 7: Summary of Existing and Proposed Insulation Requirements for Low-Slope Roofs at Time of Roof Replacement (Above Deck Continuous Insulation R-value)**

| Climate Zones | Existing | Proposed |
|---|---|---|
| 3, 5-7 | N/A | N/A |
| 1, 2, 4, 8-16 | N/A | R-14 |

The following summarizes the exceptions that are proposed for this code change. The first exception allows for projects that already have continuous insulation installed at a value of R-10, about 70 percent of the R-value of the R-14 requirement. Modeling showed that adding additional insulation when the base condition already has some minimum level of continuous insulation is not always cost effective. The last three exceptions have been developed based on the current exceptions for the insulation requirement for high-rise residential and nonresidential buildings in Section 141.0(b)2Biii; however, they have been revised to better low-rise residential roof reflect conditions. Item iii and iv allow for a lower level of continuous insulation thickness when certain conditions are met. Item iii qualifies this as R-4, which can be achieved with 1-inch or less of insulation.

i. Existing roofs with a minimum continuous insulation R-value of at least R-10 are not required to meet the R-value requirements.

ii. Existing roofs with a minimum cavity insulation R-value of at least R-19 in certain climate zones. This exception is based on cost effectiveness results using the existing building prototypes with R-19 roof insulation, see Appendix I for analysis results.

iii. Continuous insulation may be reduced to R-4 where:

    a. Mechanical equipment is located on the roof and adding insulation would reduce the base flashing height to less than that allowable by the California Residential Code.

    b. The roof has sidewall or parapet walls and adding insulation would reduce the base flashing height to less than that allowed by the California Residential Code.

iv. Where adding insulation would result in the necessity to move existing exterior windows or doors, increased thickness may be reduced.

v. Allowance to use tapered insulation provided that the average thermal resistance equals or exceeds the required value.

### 2.1.2 Measure History

#### *2.1.2.1 Cool Roofs at Roof Replacement*

A cool roof is a roofing product that provides higher solar reflectance and thermal emittance than a standard roofing product. When solar radiation hits a roof surface, a portion of the visible, infrared, and ultraviolet energy is absorbed, and a portion is reflected. Thermal emittance describes the ability of the roof surface to radiate energy once absorbed. The “cooler” the roof, the more energy the roof surface reflects and the better it is at emitting absorbed energy. A roof with a solar reflectance and thermal emittance of 0 is not reflective or emissive at all. A solar reflectance of 1 indicates complete reflectivity. A thermal emittance of 1 indicates complete emissivity. Cool roofs with very high solar reflectance values, such as those that meet the low-slope requirements of 0.63 solar reflectance, are typically very light or white in color. However, there are many cool roof products that use darker colored pigments and meet the steep-slope requirements of 0.20 solar reflectance.

Cool roof requirements for roof replacements in low-rise residential buildings were introduced in the 2008 Title 24, Part 6 code. The requirements have not changed significantly since that time. In the 2008 Standards, the low-rise requirements were for a minimum 0.20 aged solar reflectance and 0.75 thermal emittance roof for steep-slope roofs in Climate Zones 10 through 15, and a minimum 0.55 aged solar reflectance roof 0.75 thermal emittance for low-slope roofs in Climate Zones 13 and 15. The current requirements are identical except that the aged solar reflectance for low-slope roofs increased to 0.63, which happened in the 2013 code cycle, and the exceptions have been slightly revised over time.

#### 2.1.2.2 Roof Insulation at Low-Slope Roof Replacement

Roof insulation is the application of continuous insulation above the roof deck and below the exterior roofing material. This submeasure has not been considered for low-rise residential buildings in past code cycles. The current requirement for high-rise residential buildings has been in place since the 2008 Title 24, Part 6 code. There have been no changes since 2008 except for minor revisions to the allowable exceptions.

### 2.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed changes and covers both the cool roof and roof insulation submeasures. See Section 2.6 of this report for detailed proposed revisions to code language.

#### 2.1.3.1 Summary of Changes to the Standards

The two submeasures would modify the following sections of the California Energy Code as shown below. See Section 2.6.2 of this report for marked-up code language.

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

**Section 150.2(b)1Ii:** Revise to reflect the additional climate zones where the cool roof requirements would apply and the proposed changes to the exceptions.

**Section 150.2(b)1Iii:** Add subsections a and b. Locate the existing cool roof requirements under subsection a and revise to reflect the additional climate zones where cool roofs are proposed. Revise the exceptions including TABLE 150.2-B AGED SOLAR REFLECTANCE TRADE OFF TABLE. Add the requirement for continuous insulation in new subsection b.

#### 2.1.3.2 Summary of Changes to the Reference Appendices

The two proposed submeasures would not modify the Reference Appendices.

#### 2.1.3.3 Summary of Changes to the Residential ACM Reference Manual

The two submeasures would modify the following sections of the Residential ACM Reference Manual as shown below. See Section 2.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

**SECTION 2.10 Additions/Alterations**

**Section 2.10.4.3 Roof/Ceilings:** Update Table 26 to reflect a change to the basis of the Standard Design for altered roofing surfaces for both steep-slope and low-slope roofs. Add a row for low-slope roof deck insulation and add the insulation requirements based on the proposal.

#### 2.1.3.4 Summary of Changes to the Residential Compliance Manual

The two submeasures would modify the following section of the Residential Compliance Manual:

- Section 9.2 What's New in the 2019 Energy Standards
- Section 9.4.4 Envelope Alterations

See Section 2.6.5 of this report for further details.

#### 2.1.3.5 Summary of Changes to Compliance Documents

The two submeasures would modify the compliance documents listed below. Further details are presented in Section 2.6.6.

- CF1R-ALT-01-E – Repurpose subsection E for steep-slope roof replacements and create a new subsection for low-slope roof replacements. Provided that the exceptions for the low-slope roof insulation requirements are detailed for this submeasure, the Statewide CASE Team recommends that additional documentation be required by the installing contractor if applying for one of the exceptions to verify that the project meets the qualifications for the exception.
- CF1R-ALT-05-E – Repurpose subsection C for steep-slope roof replacements and create a new subsection for low-slope roof replacements. Provided that the exceptions for the low-slope roof insulation requirements are detailed for this submeasure, the Statewide CASE Team recommends that additional documentation be required by the installing contractor if applying for one of the exceptions to verify that the project meets the qualifications for the exception.
- CF2R-ALT-05-E – Revise subsection B to add a section for above deck insulation.
- CF2R-ENV-04-E – Revise the form to add a section for above deck insulation.

### 2.1.4 Regulatory Context

#### 2.1.4.1 Existing Requirements in the California Energy Code

**Cool Roofs at Roof Replacement**

There are existing requirements for cool roofs in certain climate zones at time of roof replacement for both steep-slope and low-slope roofs. The requirements are in Section 150.2(b)1I for low-rise residential buildings. Table 8 describes the existing code requirements for minimum aged solar reflectance and minimum thermal emittance.

**Table 8: Summary of Existing Cool Roof Requirements (Minimum Aged Solar Reflectance/Minimum Thermal Emittance)**

| Climate Zones | Steep-Slope | Low-Slope |
|---|---|---|
| 1-9, 16 | N/A | N/A |
| 10-12, 14 | 0.20/0.75 | N/A |
| 13, 15 | 0.20/0.75 | 0.63/0.75 |

A variety of exceptions currently exist for steep-slope roofs on low-rise residential buildings. These exceptions are listed below.

- Air-space of 1.0 inch (25 mm) is provided between the top of the roof deck to the bottom of the roofing product; or
- The installed roofing product has a profile ratio of rise to width of 1 to 5 for 50 percent or greater of the width of the roofing product; or
- Existing ducts in the attic are insulated and sealed according to Section 150.1(c)9; or
- Buildings with at least R-38 ceiling insulation; or
- Buildings with a radiant barrier in the attic meeting the requirements of Section 150.1(c)2; or
- Buildings that have no ducts in the attic; or
- In Climate Zones 10-15, R-2 or greater insulation above the roof deck.

For low-slope roofs on low-rise buildings, there is currently an exception if there are no ducts located in an attic, as well as a trade-off table that allows for lower aged solar reflectance when roof deck insulation is installed.

There is another code change proposal under consideration for the 2022 code cycle that would make changes to the cool roof requirements for nonresidential buildings for new construction and at time of roof replacement.[1]

### Roof Insulation at Low-Slope Roof Replacement

There are no relevant existing requirements in the California Energy Code for low-rise buildings. There is a requirement for high-rise multifamily buildings in Section 141.0(b)2Biii which requires that R-14 continuous above roof deck insulation is installed at time of roof replacement in all climate zones. There are exceptions that allow for a lower R-value to be installed under certain conditions. Section 141.0(b)2Biii also includes requirements for non-residential buildings.

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[1] More information on the code change proposals is available here: https://title24stakeholders.com/measures/cycle-2022/nonresidential-high-performance-envelope/

There is another code change proposal under consideration for the 2022 code cycle that, if adopted, would increase the roof insulation requirements for nonresidential buildings at time of roof replacement to match new construction standards.[1]

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

There are no relevant requirements in other parts of the California Building Code for either of the two submeasures.

#### 2.1.4.3 Relationship to Local, State, or Federal Laws

**Cool Roofs at Roof Replacement**

There are three local reach codes in place throughout California under the 2016 Standards that impose a mandatory requirement for cool roofs. As of January 28, 2020, the jurisdictions have not filed an application with the Energy Commission for a similar ordinance under the 2019 Standards. Table 9 describes the reach code requirements by building type for each jurisdiction.

**Table 9: Summary of Reach Code Requirements for Cool Roofs (Minimum Aged Solar Reflectance/Minimum Thermal Emittance)**

| Jurisdiction | Steep-Slope | | | Low-Slope | | |
|---|---|---|---|---|---|---|
| | Low-Rise Residential | High-Rise Residential | Nonresidential | Low-Rise Residential | High-Rise Residential | Nonresidential |
| LA County[a] CZs 6, 8, 9 New construction & alterations | 0.25/0.85 | 0.25/0.75 | 0.28/0.85 | 0.65/0.85 | 0.65/0.77 | 0.68/0.85 |
| Brisbane[b] CZ 3 New construction | N/A | N/A | N/A | 0.70/0.85 | 0.70/0.85 | 0.70/0.85 |
| San Mateo[c] CZ 3 New construction & alterations | N/A | N/A | N/A | 0.70/0.85 | 0.70/0.85 | 0.70/0.85 |

a. https://ww2.energy.ca.gov/title24/2016standards/ordinances/losangeles/approved_LA_2016.zip

b. https://ww2.energy.ca.gov/title24/2016standards/ordinances/brisbane/City_of_Brisbane_2017-07-12.zip

c. https://ww2.energy.ca.gov/title24/2016standards/ordinances/sanmateo/2016-09-14_Item_6b_San_Mateo.zip

Assembly Bill 660: Building Energy Efficiency Standards: Solar Reflectance of Roofs (AB 660), authored by Assemblymember Marc Levine, was passed by the State Assembly in May of 2019 and is now under consideration by the Senate. AB 660 would require that the State Energy Resources Conservation and Development Commission consider amendments to the Title 24, Part 6 code for existing low-rise residential buildings with steep-sloped roofs with the goal of increasing the value of minimum aged solar reflectance up to 0.40 in the 2031 standard and the goal of expanding the range of climate zones in which minimum aged solar reflectance values are prescribed for those alterations.

**Roof Insulation at Low-Slope Roof Replacement**

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

#### *2.1.4.4 Relationship to Industry Standards*

No relevant industry standards for either of the two submeasures were identified while preparing this proposal.

### 2.1.5 Compliance and Enforcement

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

This discussion relates to both the cool roof and roof insulation submeasures. The activities that need to occur during each phase of the project are described below:

- **Design Phase:** In most instances roof replacements are completed as isolated retrofits rather than part of a larger remodel. In this case the roofing contractor corresponds directly with the building owner, recommends the replacement material, and needs to be aware of Title 24, Part 6 requirements related to the scope of work. Depending on the project, the contractor recommends options to the owner for compliance by installing a cool roof and/or roof insulation or meeting one of the alternative paths.
- **Permit Application Phase:** The roofing contractor submits the project for permit and completes the necessary Certificate of Compliance documents. A roof replacement does not trigger HERS testing and the prescriptive forms would be completed outside of the HERS registry. The Statewide CASE Team has heard that permit requirements vary by jurisdiction and some may not require Certificate of Compliance documents for a roof replacement project.
- **Construction Phase:** The roofing contractor installs the roofing system.

- **Inspection Phase:** Typically, the roofing contractor completes the Certificate of Installation (CF2R-ALT-05-E) and a building inspector conducts a final inspection. However, inspection processes vary by jurisdiction with some requiring an onsite inspection and others not requiring visual inspection for a roof replacement project.

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

The roof insulation proposal would require additional scope of work during each of the project phases. During design, the contractor would need to evaluate the site-specific conditions of the roof and determine how to address details for adding thickness in the form of insulation to the existing roof. The contractor would then conclude whether the project can comply with the required R-value or take one of the exceptions. There would be additional steps for plan review and inspection in the permit application phase and the inspection phase. However, this added requirement for above deck insulation fits within the existing permitting process and is not expected to add substantial burden to building departments. This requirement is similar to what is currently in Title 24, Part 6 for nonresidential and high-rise residential buildings, therefore there is familiarity with this process for both the contractors and the building departments.

It is possible that the added requirements may result in projects being completed without applying for a permit. Multiple stakeholders have indicated that in some jurisdictions, the percent of residential roof alteration projects that apply for a permit is low. This is likely more of a problem with single family homes where smaller roof areas allow for roof replacements to be completed over the weekend. More low-slope roofs are on multifamily buildings where larger roof areas make this more challenging. However, this is highly dependent on local enforcement. This code change should be supported by education and outreach programs designed for contractors, building departments, and building owners. Utility incentive programs throughout the 2019 Title 24, Part 6 code cycle, and perhaps into the 2022 code cycle, can encourage early adopters and support a market transformation for cool roofs and roof deck insulation. Local reach codes would play a similar role.

## 2.2 Market Analysis

### 2.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, market trends, and how the standard would affect individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors including roofing contractors, roofing industry representatives, manufacturers, and consultant. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

The residential roofing market is comprised of buildings with both low-slope and steep-slope roofs. Single family homes are primarily steep-slope. The type of roofing used in multifamily buildings is dependent on the building type and height; both steep-slope and low-slope roofs are typical with low-rise buildings. The 2009 Residential Appliance Saturation Study (California Energy Commission 2009) estimates that 77 percent of single family homes and 31 percent of multifamily homes have insulated attics, which can be used as a surrogate to indicate steep-slope roofs. Of the performance-based alteration projects with new or altered roofs registered with CalCERTS under the 2013 and 2016 code cycles 78 percent of single family and 47 percent of low-rise multifamily projects were steep-slope roofs (CalCERTS 2020).

Steep-slope existing residential roofs are predominantly asphalt shingles with tile and metal products filling most of the remainder. A 2015 study by the National Roofing Contractor's Association estimated that the largest segments of the low-slope roofing market were represented by thermoplastic polyolefin, or TPO, at 30 percent, EPDM rubber at 25 percent, modified bitumen at 12 percent, and built up roofing at 7 percent (Klutz, Dutton and Davis 2018).

Insulating the roof deck of low-slope roofs is typically accomplished with rigid foam insulation board or spray foam insulation. There are three major types of rigid foam insulation that are most commonly applied in roof systems. These are expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate (polyiso). Spray polyurethane foam integrates the insulation into the waterproofing system and is self-flashing. When the roof deck does not provide adequate slope for drainage a tapered insulation system may be used.

There are many manufacturers that produce low-slope and steep-slope roofing system components and various trade associations that represent the industry. Trade associations include the National Roofing Contractors Association (NRCA), Asphalt Roofing Manufacturers Association (ARMA), Roofing Contractors Association of California (RCAC), Associated Roofing Contractors of the Bay Area Counties (ARCBAC), Cool Roof Rating Council (CRRC), and Cool Metal Roofing Coalition (CMRC), among others.

There are over 13 million existing residential dwelling units in California (see Appendix A). It is estimated that 7 percent of residential buildings undergo a roof replacement each year (Roofing Contractor 2013). This results in new roofs for 920,000 residential dwelling units in California annually.

Roofing contractors are the primary market actors involved with implementing these code change proposals. They typically correspond directly with the building owner, who is the primary decision maker, and make recommendations for specifications on replacement roofing systems. Other market actors include manufactures, plans examiners, and building inspectors.

### 2.2.2 Technical Feasibility, Market Availability, and Current Practices

#### *2.2.2.1 Cool Roofs at Roof Replacement*

The Statewide CASE Team conducted a stakeholder outreach to roofing contractors, manufacturers, and roofing industry representatives. Trade associations interviewed include ARMA, RCAC, and ARCBAC. In general, there was support for expanding the current requirements to additional climates zones, not increasing the stringency of the solar reflectance requirements at this time and maintaining exceptions in the code that allow for flexibility. Industry representatives voiced concern about the high number of residential roof replacements that are not permitted and a lack of enforcement statewide. While the cool roof market in California is larger than in other areas of the country, it has not grown as much as expected, which may partially be a result of lack of enforcement for roof replacements. Expanding the climate zones where cool roofs are required can support market growth.

The Cool Roof Rating Council (CRRC) is a non-profit educational organization incorporated "to implement and communicate accurate radiative energy performance rating systems for roof surfaces, support research, and serve as an educational resource for information on roofing" (Cool Roof Rating Council n.d.). Roofing manufacturers register their products with the CRRC, which verifies that testing methodologies and reporting standards are consistent for all products. The CRRC database of products is updated daily. As of December 12, 2019, there were 2,962 products registered in the CRRC database. Of these, 2,636 (89 percent) products meet Title 24, Part 6 cool roof requirements for low-or steep-slope roofing. 183 manufacturers are represented in the CRRC database, which encompasses almost all major roofing product manufacturers. The distribution of compliant products is shown in Figure 2.

Of the 2,636 products that meet the prescriptive cool roof requirements, 768 products meet requirements for low-slope roofing and 2,465 products meet requirements for steep-slope roofing. 62 percent of products are listed as appropriate for both low-slope and steep-slope installations. These include single-ply, fluid applied membrane, asphaltic membrane, and metal coating products, which are the products most commonly installed on low-slope roofs.

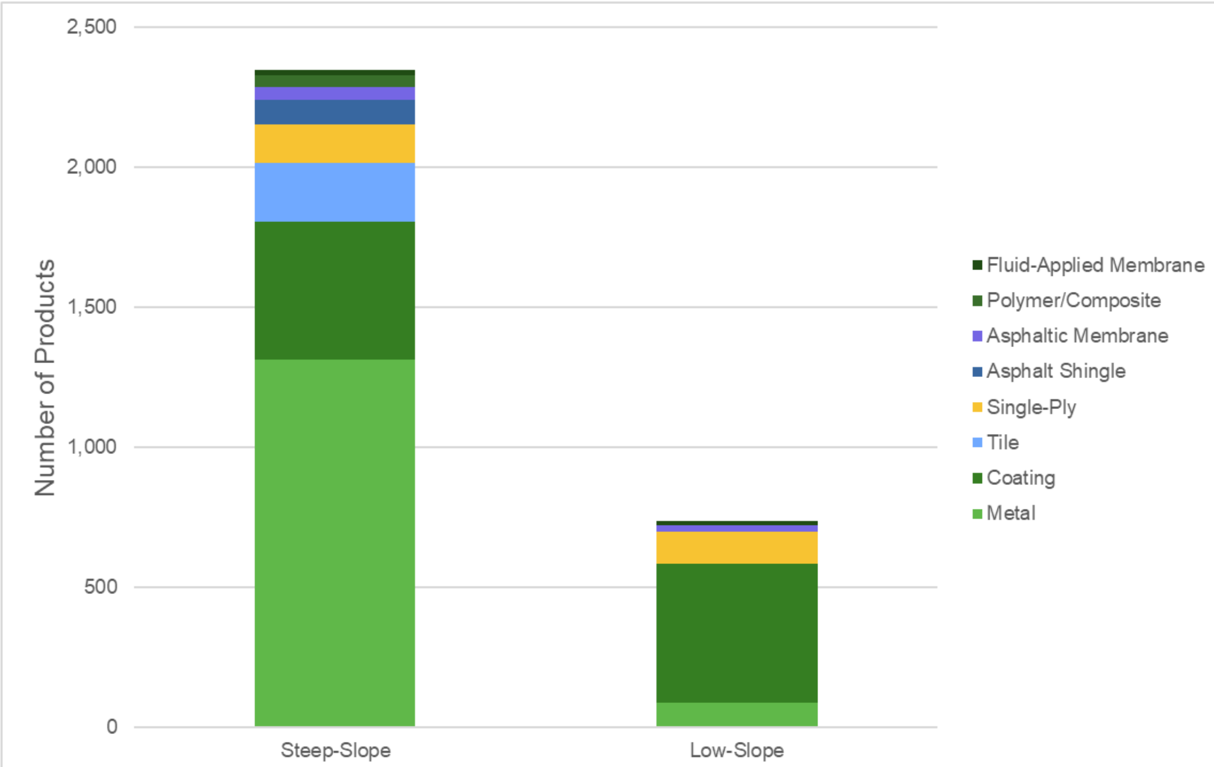


**Figure 2: Number of CRRC-registered products that meet current Title 24, Part 6 minimum criteria for aged solar reflectance and thermal emittance.**

Source: Cool Roof Rating Council

Figure 3 and Figure 4 show data from CalCERTS on alteration only or alteration and addition projects that complied with Title 24, Part 6 using the performance path. The figures show the percentage of new or altered roofs in these projects that meet the current prescriptive requirements for aged solar reflectance. The data is presented separately for steep-slope and low-slope roofs and the 2013 and 2016 code cycles (CalCERTS 2020). Both figures show a trend from the 2013 to 2016 code cycles of an increasing percentage of projects installing cool roofs. Most roof replacements are completed prescriptively and would not be registered with a HERS registry; however, this data is not available on a statewide basis.

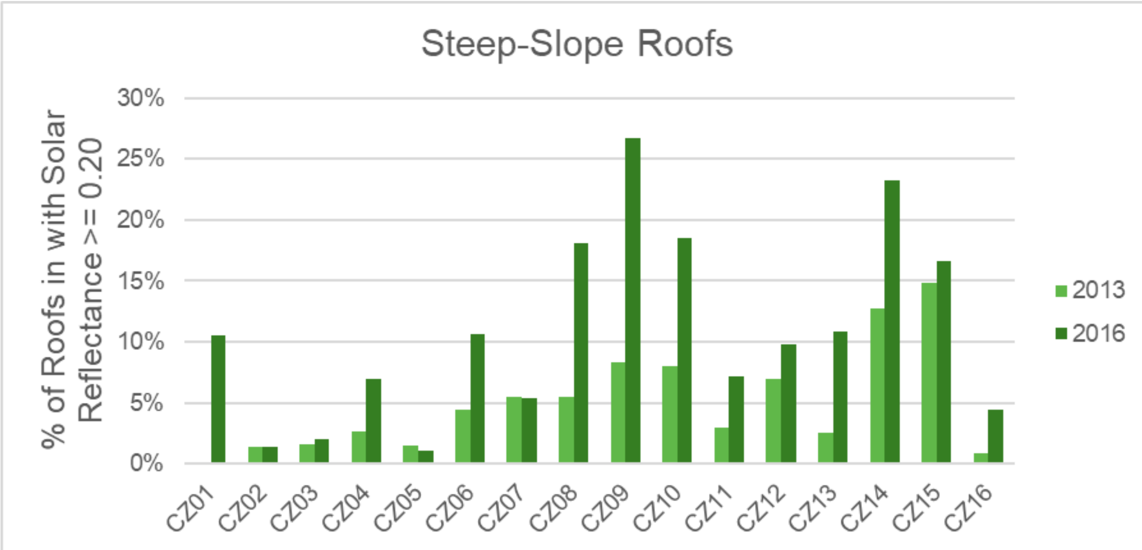


**Figure 3: Percent of altered or new steep-slope roofs in existing plus addition plus alteration project registered with CalCERTS in the 2013 & 2016 code cycles that meet the current prescriptive requirement for aged solar reflectance.**

Source: CalCERTS (CalCERTS 2020)

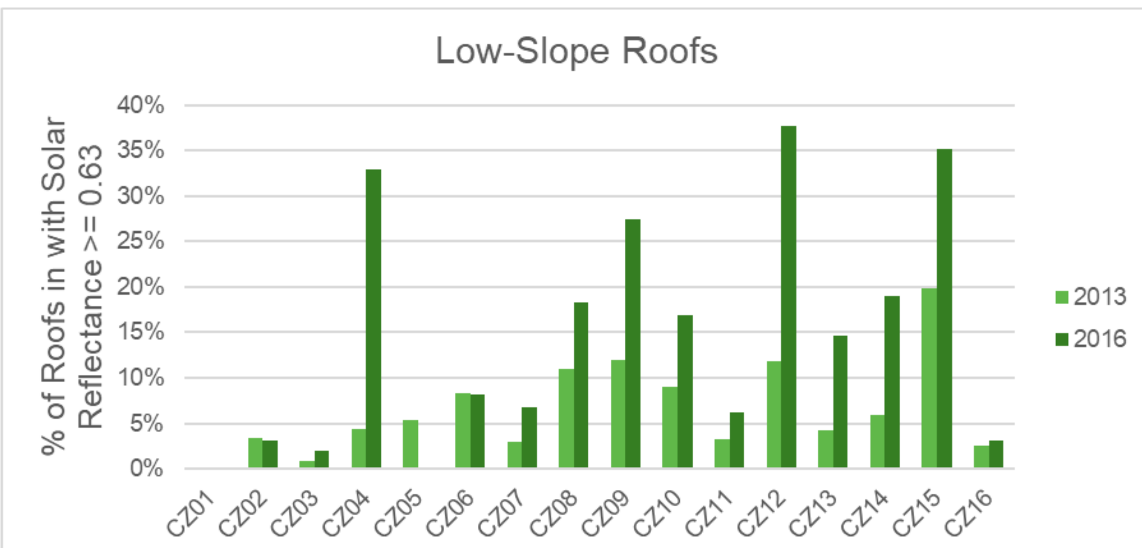


**Figure 4: Percent of altered or new low-slope roofs in existing plus addition plus alteration project registered with CalCERTS in the 2013 & 2016 code cycles that meet the current prescriptive requirement for aged solar reflectance.**

Source: CalCERTS (CalCERTS 2020)

Stakeholders provided feedback that there are few issues with availability of low-slope roofing products that meet the Title 24, Part 6 aged solar reflectance requirements. If a project is installing a single-ply membrane roof it's highly likely that any roof that is specified would meet the cool roof requirements. If installing a modified bitumen roof, a cool roof-rated cap sheet is applied.

For steep-slope roofs there are more tile and metal roofing products available than asphalt shingle products. Stakeholders provided feedback that selecting asphalt shingle products that meet customer needs can be challenging in certain locations. While there are many products available (127 products certified on the CRRC identified as steep-slope asphalt shingle products that meet the cool roof requirements), options are not always available based on customer color preference or geographic locations (mostly distributor reach).

#### 2.2.2.2 Roof Insulation at Low-Slope Roof Replacement

The Statewide CASE Team conducted a stakeholder outreach to roofing contractors and roofing industry representatives. In general, there was support for applying the current requirements for high-rise residential insulation requirements to low-rise buildings as long as exceptions similar to the existing exceptions were also allowed. There are technical considerations when increasing the thickness of an existing roof with added insulation. These include adjustments to flashing around rooftop equipment, skylights, penthouse and parapet walls, and roof penetrations. On roofs without parapet walls, the fascia also needs to be re-built.

The nonresidential roofing industry is familiar with this requirement because it has been in Title 24, Part 6 since the 2008 code cycle. The industry has developed a knowledge base for how to detail the technical considerations discussed above. There are many insulation products available that are used both on new construction roofs and for roof replacements.

The Statewide CASE Team is proposing a number of exceptions to the insulation requirements that are similar to the existing requirements for high-rise residential and nonresidential buildings. One primary change is to eliminate the reference to a specific minimum base flashing height of eight inches and instead use language that allows for an exception if the available base flashing height does not comply with California Building Code requirements. California Building Code requires specific base flashing heights in certain conditions, but mostly references manufacturers installation procedures. This change allows for flexibility if language in the building code changes or manufacturer installation procedures and best practices change over time. This requires that the contractor conduct due diligence on the product to be installed and provide appropriate justification to the building department if an exception is requested. Various stakeholders indicated that a base flashing height of eight inches is often not available on existing residential roofs, but that even so it is usually possible to add a minimum amount of insulation, typically up to one inch. This informed the other primary change relative to the existing exceptions for high-rise residential and non-residential buildings. Instead of waiving the roof insulation requirements in cases where minimum base flashing heights are not met, the proposal is to reduce the requirement to R-4.

### 2.2.3 Market Impacts and Economic Assessments

#### *2.2.3.1 Impact on Builders*

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 10).[2] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector, while another 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

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

**Table 10: California Construction Industry, Establishments, Employment, and Payroll, 2018**

| Construction Sectors | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| **Residential** | **59,287** | **420,216** | **$23.3** |
| Residential Building Construction Contractors | 22,676 | 115,777 | $7.4 |
| Foundation, Structure, & Building Exterior | 6,623 | 75,220 | $3.6 |
| Building Equipment Contractors | 14,444 | 105,441 | $6.0 |
| Building Finishing Contractors | 15,544 | 123,778 | $6.2 |
| **Commercial** | **17,273** | **343,513** | **$27.8** |
| Commercial Building Construction | 4,508 | 75,558 | $6.9 |
| Foundation, Structure, & Building Exterior | 2,153 | 53,531 | $3.7 |
| Building Equipment Contractors | 6,015 | 128,812 | $10.9 |
| Building Finishing Contractors | 4,597 | 85,612 | $6.2 |
| **Industrial, Utilities, Infrastructure, & Other** | **4,103** | **96,550** | **$9.2** |
| Industrial Building Construction | 299 | 5,864 | $0.5 |
| Utility System Construction | 1,643 | 47,619 | $4.3 |
| Land Subdivision | 952 | 7,584 | $0.9 |
| Highway, Street, and Bridge Construction | 770 | 25,477 | $2.4 |
| Other Heavy Construction | 439 | 10,006 | $1.0 |

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

The proposed change to require cool roofs and roof insulation at roof replacement would likely affect residential builders but would not impact commercial builders or firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 11 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Because the proposed code requirements come only into play at roof replacement, they are expected to impact roofing contractors primarily and residential remodelers to the extent that they work on projects with roof replacements. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 2.2.4 Economic Impacts.

**Table 11: Size of the California Residential Building Industry by Subsector, 2018**

| Residential Building Subsector | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| Residential Remodelers | 11,122 | 52,133 | $2,973,873,865 |
| Residential Roofing Contractors | 2,208 | 16,814 | $813,935,273 |

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

#### *2.2.3.2 Impact on Building Designers and Energy Consultants*

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Energy Code) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 12 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code change would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for the residential roof replacement submeasures to affect firms that focus on single family and low-rise multifamily construction.

There is not a North American Industry Classification System (NAICS)[3] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[4] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy

[3] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

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

efficiency consulting. The information shown in Table 12 provides an upper bound indication of the size of this sector in California.

**Table 12: California Building Designer and Energy Consultant Sectors, 2018**

| Sector | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|
| Architectural Services[a] | 3,704 | 29,611 | $2,906.7 |
| Building Inspection Services[b] | 824 | 3,145 | $223.9 |

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

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

#### *2.2.3.3 Impact on Occupational Safety and Health*

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

#### *2.2.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)*

According to data from the U.S. Census, American Community Survey (ACS), there were nearly 14.3 million housing units in California in 2018 and nearly 13.1 million were occupied (see Table 13). Most housing units (nearly 9.2 million) were single family homes (either detached or attached), while about 2 million homes were in buildings containing two to nine units and 2.5 million were in multifamily building containing 10 or more units. The U.S. Census reported that 59,200 single family and 50,700 multifamily homes were constructed in 2019.

**Table 13: California Housing Characteristics, 2018**

| **Housing Measure** | **Estimate** |
|---|---|
| Total housing units | 14,277,867 |
| Occupied housing units | 13,072,122 |
| Vacant housing units | 1,205,745 |
| Homeowner vacancy rate | 1.2% |
| Rental vacancy rate | 4.0% |
| **Units in Structure** | **Estimate** |
| 1-unit, detached | 8,177,141 |
| 1-unit, attached | 1,014,941 |
| 2 units | 358,619 |
| 3 or 4 units | 783,963 |
| 5 to 9 units | 874,649 |
| 10 to 19 units | 742,139 |
| 20 or more units | 1,787,812 |
| Mobile home, RV, etc. | 538,603 |

Source: (2018 American Community Survey n.d.)

Table 14 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59% 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 (California Energy Commission 2019).

**Table 14: Distribution of California Housing by Vintage, 2018**

| Home Vintage | Units | Percent | Cumulative Percent |
|---|---|---|---|
| Built 2014 or later | 343,448 | 2.4% | 2.4% |
| Built 2010 to 2013 | 248,659 | 1.7% | 4.1% |
| Built 2000 to 2009 | 1,553,769 | 10.9% | 15.0% |
| Built 1990 to 1999 | 1,561,579 | 10.9% | 26.0% |
| Built 1980 to 1989 | 2,118,545 | 14.8% | 40.8% |
| Built 1970 to 1979 | 2,512,178 | 17.6% | 58.4% |
| Built 1960 to 1969 | 1,925,945 | 13.5% | 71.9% |
| Built 1950 to 1959 | 1,896,629 | 13.3% | 85.2% |
| Built 1940 to 1949 | 817,270 | 5.7% | 90.9% |
| Built 1939 or earlier | 1,299,845 | 9.1% | 100.0% |
| **Total housing units** | **14,277,867** | **100%** | |

Source: (2018 American Community Survey n.d.)

Table 15 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 income below $50,000 is only 37 percent, whereas the owner occupancy rate is 72 percent for households earning $100,000 or more.

**Table 15: Owner- and Renter-Occupied Housing Units in California by Income, 2018**

| Household Income | Total | Owner Occupied | Renter Occupied |
|---|---|---|---|
| Less than $5,000 | 391,235 | 129,078 | 262,157 |
| $5,000 to $9,999 | 279,442 | 86,334 | 193,108 |
| $10,000 to $14,999 | 515,804 | 143,001 | 372,803 |
| $15,000 to $19,999 | 456,076 | 156,790 | 299,286 |
| $20,000 to $24,999 | 520,133 | 187,578 | 332,555 |
| $25,000 to $34,999 | 943,783 | 370,939 | 572,844 |
| $35,000 to $49,999 | 1,362,459 | 590,325 | 772,134 |
| $50,000 to $74,999 | 2,044,663 | 1,018,107 | 1,026,556 |
| $75,000 to $99,999 | 1,601,641 | 922,609 | 679,032 |
| $100,000 to $149,999 | 2,176,125 | 1,429,227 | 746,898 |
| $150,000 or more | 2,780,761 | 2,131,676 | 649,085 |
| **Total Housing Units** | **13,072,122** | **7,165,664** | **5,906,458** |
| **Median household income** | **$75,277** | **$99,245** | **$52,348** |

Source: (2018 American Community Survey n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 13 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 14 and Table 15.

For California residents, the code changes that the Statewide CASE Team is proposing for the 2022 code cycle regulation would result in lower energy bills. When homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors 2011).]

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

The Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers apart from a slight increase in economic activity for manufacturers of cool roof and insulation products due to increased demand.

#### 2.2.3.6 Impact on Building Inspectors

Table 16 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

**Table 16: Employment in California State and Government Agencies with Building Inspectors, 2018**

| Sector | Govt. | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|---|
| Administration of Housing Programs[a] | State | 17 | 283 | $29.0 |
| | Local | 36 | 2,882 | $205.7 |
| Urban and Rural Development Admin[b] | State | 35 | 552 | $48.2 |
| | Local | 52 | 2,446 | $186.6 |

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

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

#### *2.2.3.7 Impact on Statewide Employment*

As described in Sections 2.2.3.1 through 2.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 2.2.4, the Statewide CASE Team estimated how the proposed change in cool roof and insulation requirements at roof replacement 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 cool roof and insulation requirements at roof replacement would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

### 2.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes. [5] While this is the first code cycle in which the CASE team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By

[5] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the residential building and remodeling industry 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. There may also be some non-residential 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 or have measurable economic impacts. Table 17, Table 18, and Table 19 demonstrate economic impacts based on the estimated additional spending from the proposed submeasures. These figures assume that there would be no reduction in the number of homes completing relevant projects as a direct result of these proposed code changes. Estimated impacts to the residential construction sector and on discretionary spending by residents is based on the incremental cost and energy savings presented in this report for each submeasure. Estimated impacts to building inspectors are based on an increase of additional time required for plan review and inspection of 15 minutes per single family or multifamily building.

**Table 17: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Cool Roof Requirements for Steep-Slope Roofs | Direct Effects (Additional spending by Residential Builders) | 400.6 | $25,677,314 | $43,275,601 | $70,272,563 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 154.6 | $9,910,118 | $15,446,893 | $27,431,106 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 189.7 | $10,578,832 | $18,930,656 | $30,902,430 |
| | **Total Submeasure Impacts** | **744.9** | **$46,166,263** | **$77,653,150** | **$128,606,099** |
| Cool Roof Requirements for Low-Slope Roofs | Direct Effects (Additional spending by Residential Builders) | 900.9 | $57,754,187 | $97,336,785 | $158,059,165 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 347.7 | $22,290,136 | $34,743,617 | $61,698,869 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 426.8 | $23,794,227 | $42,579,400 | $69,506,676 |
| | **Total Submeasure Impacts** | **1,675.4** | **$103,838,549** | **$174,659,803** | **$289,264,710** |
| Roof Insulation Requirements for Low- | Direct Effects (Additional spending by Residential Builders) | 3,244.9 | $208,015,363 | $350,581,454 | $569,287,467 |
| | Indirect Effect (Additional spending | 1,252.4 | $80,283,196 | $125,137,355 | $222,223,071 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Slope Roofs | by firms supporting Residential Builders) | | | | |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 1,537.1 | $85,700,535 | $153,359,781 | $250,344,733 |
| | **Total Submeasure Impacts** | **6,034.4** | **$373,999,094** | **$629,078,591** | **$1,041,855,270** |
| **Total Economic Impacts** | | **8,454.70** | **$524,003,906** | **$881,391,544** | **$1,459,726,079** |

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

**Table 18: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Cool Roof Requirements for Steep-Slope Roofs | Direct Effects (Additional spending by Building Inspectors) | 9.1 | $914,414 | $1,081,315 | $1,292,510 |
| | Indirect Effect (Additional spending by firms supporting Building Inspectors) | 1.0 | $72,601 | $116,975 | $202,923 |
| | Induced Effect (Spending by employees of Building Inspection Bureaus and Departments) | 5.3 | $296,639 | $530,689 | $866,560 |
| | **Total Submeasure Impacts** | **15.4** | **$1,283,653** | **$1,728,979** | **$2,361,993** |
| Cool Roof Requirements for Low-Slope Roofs | Direct Effects (Additional spending by Building Inspectors) | 5.9 | $593,792 | $702,173 | $839,316 |
| | Indirect Effect (Additional spending | 0.6 | $47,145 | $75,960 | $131,772 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | by firms supporting Building Inspectors) | | | | |
| | Induced Effect (Spending by employees of Building Inspection Bureaus and Departments) | 3.4 | $192,628 | $344,613 | $562,718 |
| | **Total Submeasure Impacts** | **10.0** | **$833,565** | **$1,122,746** | **$1,533,806** |
| Roof Insulation Requirements for Low-Slope Roofs | Direct Effects (Additional spending by Building Inspectors) | 5.4 | $538,576 | $636,878 | $761,269 |
| | Indirect Effect (Additional spending by firms supporting Building Inspectors) | 0.6 | $42,761 | $68,897 | $119,519 |
| | Induced Effect (Spending by employees of Building Inspection Bureaus and Departments) | 3.1 | $174,716 | $312,568 | $510,391 |
| | **Total Submeasure Impacts** | **9.0** | **$756,053** | **$1,018,343** | **$1,391,179** |
| **Total Economic Impacts** | | **34.40** | **$2,873,271** | **$3,870,068** | **$5,286,978** |

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

**Table 19: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Cool Roof Requirements for Steep-Slope Roofs | Direct Effects (Additional spending by households) | 300.5 | $15,550,550 | $28,602,065 | $46,080,654 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 106.9 | $7,333,723 | $12,178,542 | $20,489,847 |
| | Induced Effect (Spending by employees of businesses experiencing "indirect" effects) | 122.2 | $6,828,480 | $12,218,256 | $19,947,236 |
| | **Total Submeasure Impacts** | **529.6** | **$29,712,753** | **$52,998,863** | **$86,517,737** |
| Cool Roof Requirements for Low-Slope Roofs | Direct Effects (Additional spending by households) | 1,527.1 | $79,029,260 | $145,358,209 | $234,185,931 |
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 543.1 | $37,270,627 | $61,892,420 | $104,131,204 |
| | Induced Effect (Spending by employees of businesses experiencing "indirect" effects) | 621.2 | $34,702,937 | $62,094,252 | $101,373,605 |
| | **Total Submeasure Impacts** | **2,691.4** | **$151,002,823** | **$269,344,880** | **$439,690,739** |
| | Direct Effects (Additional spending by households) | 3,235.2 | $167,425,381 | $307,944,850 | $496,128,509 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Roof Insulation Requirements for Low-Slope Roofs | Indirect Effect (Purchases by businesses to meet additional household spending) | 1,150.6 | $78,958,717 | $131,120,575 | $220,604,451 |
| | Induced Effect (Spending by employees of businesses experiencing “indirect” effects) | 1,316.0 | $73,519,003 | $131,548,162 | $214,762,412 |
| | **Total Submeasure Impacts** | **5,701.8** | **$319,903,101** | **$570,613,586** | **$931,495,372** |
| **Total Economic Impacts** | | **8,922.80** | **$500,618,677** | **$892,957,329** | **$1,457,703,848** |

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

#### 2.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 2.2.4 would lead to modest changes in employment of existing jobs.

#### 2.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 2.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to cool roof and insulation requirements at roof replacement, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes to the California Energy Code.

### *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.[6] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

### *2.2.4.4 Increase or Decrease of Investments in the State of California*

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[7] As Table 20 shows between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, and the average was 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

**Table 20: Net Domestic Private Investment and Corporate Profits, U.S.**

| Year | Net Domestic Private Investment by Businesses, Billions of Dollars | Corporate Profits After Taxes, Billions of Dollars | Ratio of Net Private Investment to Corporate Profits |
|---|---|---|---|
| 2015 | 609.245 | 1,740.349 | 35% |
| 2016 | 455.980 | 1,739.838 | 26% |
| 2017 | 509.276 | 1,813.552 | 28% |
| 2018 | 618.247 | 1,843.713 | 34% |
| 2019 | 580.849 | 1,826.971 | 32% |
| | | **5-Year Average** | **31%** |

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

The estimated increase in investment in California is $52.7 million. The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed

[6] 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.

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

measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 17 through Table 19 above by 31 percent.

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

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

**Cost of Enforcement**

*Cost to the State*

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. Because the proposed code change applies to residential buildings alone, impact to state buildings is not expected.

*Cost to Local Governments*

All revisions to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 2.1.5 and Appendix F, 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.

#### 2.2.4.6 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code changes may result in unintended consequences. The Statewide CASE Team does not expect that the proposed submeasures would result in negative impacts on specific persons.

## 2.3 Energy Savings

As of the Draft CASE Report's date of publication, the Energy Commission has not released the final 2022 TDV factors that are used to evaluate TDV energy savings and cost effectiveness. The energy and cost analysis presented in this report used the TDV factors that were released in the 2022 CBECC-Res research version that was released in December 2019. These TDV factors were consistent with the TDV factors that the Energy Commission presented during their public workshop on compliance metrics held October 17, 2019 (California Energy Commission 2019). The electricity TDV factors did not include the 15 percent retail adder and the natural gas TDV factors did not include the impact of methane leakage on the building site, updates that the Energy Commission presented during their workshop on March 27, 2020. Presentations from Bruce Wilcox and NORESCO during the March 27, 2020 workshop indicated that the 15 percent retail adder and methane leakage would result in most energy efficiency measures having slightly higher TDV energy and energy cost savings than using the TDV factors without these refinements. As a result, the TDV energy savings presented in this report are lower than the values that would have been obtained using TDV with the 15 percent retail adder and methane leakage, and the proposed code changes would be more cost effective using the revised TDV. The Energy Commission notified the Statewide CASE Team on April 21, 2020 that they were investigating further refinements to TDV factors using 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. It is anticipated that the 20-year GWP values may increase the TDV factors slightly making proposed changes that improve energy efficiency more cost effective. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

When the Energy Commission releases the final TDV factors, the Statewide CASE Team will consider the need to re-evaluate energy savings and cost-effectiveness analyses using the final TDV factors for the results that will be presented in the Final CASE Report.

The Energy Commission is developing a source energy metric (energy design rating or EDR 1) for the 2022 code cycle. As of the date this Draft CASE Report was published, the source energy metric has not been finalized and the Energy Commission has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

### 2.3.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relies on results of California Building Energy Code Compliance (CBECC) software simulations to estimate energy use for single family and multifamily prototype buildings. Various scenarios were evaluated comparing different aged solar reflectance values and roof insulation values against a range of basecase conditions (attic and roof insulation level, duct location, and heating, ventilation, and air conditioning (HVAC) system efficiency). The prototypes evaluated use natural gas for space heating, water heating, cooking, and clothes drying, and represent the majority of the existing residential buildings in California (see Appendix H for further details). All sixteen climate zones were evaluated though ultimately, each submeasure is recommended only in a subset of climate zones based on the cost effectiveness results.

### 2.3.2 Energy Savings Methodology

#### *2.3.2.1 Energy Savings Methodology per Prototypical Building*

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. These prototypes represent new construction buildings and therefore in some cases, the prototypes were revised to better reflect the existing building stock relative to new construction. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 21. Refer to Appendix H for further details on the prototypes.

These proposals impact single family and multifamily buildings. In addition to the single family alteration prototype, the measures were evaluated for the low-rise garden prototype. The low-rise loaded corridor prototype was not evaluated because the energy savings and cost effectiveness are expected to be very similar to the low-rise garden prototype.

**Table 21: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis**

| Prototype Name | Number of Stories | Floor Area (square feet) | Description | Measures evaluated |
|---|---|---|---|---|
| Single Family Alteration | 1 | 1,665 | Single story house. 8-ft ceilings. 2 variations: steep-slope roof above attic with ducts in attic; low-slope roof with ducts in | Steep-slope cool roof, Low-slope cool roof, Low-slope insulation |

| Prototype Name | Number of Stories | Floor Area (square feet) | Description | Measures evaluated |
|---|---|---|---|---|
| | | | conditioned space. | |
| Low-Rise Garden Multifamily | 2 | 6,960 | 2-story, 8-unit apartment building. Average dwelling unit size: 870 ft2. Individual HVAC & DHW systems. 2 variations: steep-slope roof above attic with ducts in attic; low-slope roof with ducts in conditioned space. | Steep-slope cool roof, Low-slope cool roof, Low-slope insulation |

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of the CBECC software for residential buildings (CBECC-Res for low-rise residential (California Energy Commission 2019c).

CBECC-Res generates two models based on user inputs: the Standard Design and the Proposed Design.[8] The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Residential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building.

There is an existing Title 24, Part 6 requirement that covers the building system in question, so the Standard Design is minimally compliant with the 2019 Title 24

[8] 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.

requirements with two exceptions for alterations. For single family buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. The existing condition building infiltration assigned to the existing home (10 ACH50) is not reflected in the CBECC-Res Standard Design calculation per the ACM rules. For multifamily buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. Ductwork was located within the vented attic, which is common for this building type, while the CBECC-Res Standard Design for multifamily buildings assumes that ductwork is located within conditioned space. Therefore, two simulations were conducted for each submeasure: one to represent the revised Standard Design and another to represent the Proposed Design. Refer to Appendix H for additional details.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 22 and Table 23 present precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume a new roof with a thermal emittance of 0.75 and a solar reflectance of 0.20 for steep-slope roofs and 0.65 for low-slope roofs. For the roof insulation measure the proposed conditions assume R-14 continuous insulation at the roof deck and the roof reflectivity and emittance remain the same across the Standard and Proposed Design.

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

**Table 22: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Cool Roofs**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration & Low-Rise Garden Multifamily: Steep-Slope | All | Attic: Sol. Reflectance | 0.10 | 0.20 |
| | | Attic: IR Emittance | 0.85 | 0.75 |
| Single Family Alteration & Low-Rise Garden Multifamily: Low-Slope | All | Cathedral Ceiling: Solar Reflectance | 0.10 | 0.65 |
| | | Cathedral Ceiling: IR Emittance | 0.85 | 0.75 |

**Table 23: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Roof Insulation**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration & Low-Rise Garden Multifamily: Low-Slope | All | Construction Assembly (Cathedral Ceilings): Above Deck Insulation | No insulation | R14 Sheathing |
| | | Attic: Sol. Reflectance | 0.10 | 0.10 |
| | | Attic: IR Emittance | 0.85 | 0.85 |

CBECC-Res calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). CBECC-Res also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars.

The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

Per unit energy impacts for single family buildings are presented in savings per prototype building. Per-unit energy impacts for multifamily buildings are presented in savings per dwelling unit. Annual energy and peak demand impacts for each prototype building were translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building.

#### *2.3.2.2 Statewide Energy Savings Methodology*

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2019d). The Statewide Construction Forecasts estimate the size of the total existing building stock by building type and climate zone in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. In order to translate per unit savings to statewide energy impacts, The Statewide CASE Team conducted research to determine appropriate weighting factors for each submeasure. Table 24 through Table 26 present the prototypical buildings and weighting factors used for the cool roof and roof insulation submeasures. The percent of building type represented by prototype is 100 percent for single family since there is only a single prototype. The portion of multifamily impacted  is based on the portion of total California multifamily dwelling units in buildings three stories or less, according to the CoStar database (CoStar 2018). The percent of prototype impacted by the proposed code change is estimated based on the 2009 Residential Appliance Saturation Study (California Energy Commission 2009) to determine the breakdown between steep-slope and low-slope roofs and assuming 7 percent of roofs are replaced annually (Roofing Contractor 2013). Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

**Table 24: Residential Building Types and Associated Prototype Weighting for the Steep-Slope Cool Roof Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 1.58% | 1.58% |
| Multifamily | Low-Rise Garden | 84% | 1.24% | 1.04% |

**Table 25: Residential Building Types and Associated Prototype Weighting for the Low-Slope Cool Roof Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.91% | 0.91% |
| Multifamily | Low-Rise Garden | 84% | 3.19% | 2.68% |

**Table 26: Residential Building Types and Associated Prototype Weighting for the Low-Slope Roof Insulation Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.83% | 0.83% |
| Multifamily | Low-Rise Garden | 84% | 2.76% | 2.32% |

### 2.3.3 Per-Unit Energy Impacts Results

#### 2.3.3.1 Cool Roofs at Roof Replacement

Energy savings and peak demand reductions per unit are presented in Table 27 through Table 30. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Positive values indicate energy savings while negative values indicate an increase in energy use. For the single family prototype per-unit electricity savings for the first year for steep-slope roofs are expected to range from -4 (an increase in electricity use) to 68 kWh/yr depending upon climate zone. Natural gas use increases from 0 to 5 therms/yr depending on climate zone. Peak demand reductions are expected to range between 0 kW and 0.051 kW depending on climate zone.

Per-unit electricity savings for the first year for single family low-slope roofs are expected to range from -66 (an increase in electricity use) to 706 kWh/yr depending upon climate zone. Natural gas use increases from 12 to 81 therms/yr depending on climate zone. Peak demand reductions are expected to range between 0 kW and 0.383 kW depending on climate zone.

Since this submeasure reduces heat gain through the roofing surface and into the building, heating energy use increases, which is why there is an increase in natural gas use in all climate zones. There is also an increase in electricity use in Climate Zone 1, which is due to an increase in heating fan energy use.

These savings figures are relative to an existing building with R-19 attic or roof insulation and ducts in the attic. As is discussed in Appendix H, these measures were evaluated against a base case with both R-11 and R-19 insulation.

**Table 27: Steep-Slope Cool Roof First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | -4 | 0.000 | -4.6 | -1,532 |
| 2 | 28 | 0.017 | -1.1 | 1,615 |
| 3 | 3 | 0.008 | -1.5 | 499 |
| 4 | 55 | 0.051 | -0.9 | 2,747 |
| 5 | 2 | 0.000 | -1.5 | -283 |
| 6 | 43 | 0.034 | -0.5 | 1,632 |
| 7 | 38 | 0.029 | -0.4 | 1,315 |
| 8 | 68 | 0.027 | -0.1 | 3,596 |
| 9 | 63 | 0.044 | -0.2 | 3,546 |
| 10 | N/A | N/A | N/A | N/A |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 11 | N/A | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A |
| 16 | 28 | 0.026 | -1.7 | 216 |

**Table 28: Steep-Slope Cool Roof First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 0 | 0.000 | -0.6 | -200 |
| 2 | 15 | 0.005 | -0.1 | 948 |
| 3 | 4 | 0.003 | -0.2 | 261 |
| 4 | 22 | 0.013 | -0.1 | 1,488 |
| 5 | 3 | 0.001 | -0.2 | 78 |
| 6 | 18 | 0.010 | -0.1 | 618 |
| 7 | 18 | 0.005 | 0.0 | 505 |
| 8 | 28 | 0.003 | 0.0 | 1,618 |
| 9 | 27 | 0.020 | 0.0 | 1,114 |
| 10 | N/A | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A |
| 16 | 13 | 0.004 | -0.3 | 209 |

**Table 29: Low-Slope Cool Roof First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | -66 | -0.001 | -81.2 | -27,989 |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 2 | 228 | 0.164 | -42.1 | 3,413 |
| 3 | 18 | 0.043 | -31.8 | -2,631 |
| 4 | 470 | 0.378 | -25.8 | 12,920 |
| 5 | -2 | 0.002 | -37.8 | -11,622 |
| 6 | 365 | 0.255 | -14.0 | 10,023 |
| 7 | 330 | 0.270 | -11.6 | 8,558 |
| 8 | 636 | 0.315 | -17.4 | 22,378 |
| 9 | 563 | 0.383 | -21.8 | 14,868 |
| 10 | 701 | 0.275 | -22.6 | 16,966 |
| 11 | 706 | 0.340 | -28.7 | 17,882 |
| 12 | 529 | 0.368 | -31.0 | 13,203 |
| 13 | N/A | N/A | N/A | N/A |
| 14 | 644 | 0.350 | -41.9 | 13,886 |
| 15 | N/A | N/A | N/A | N/A |
| 16 | 244 | 0.262 | -63.2 | -14,902 |

**Table 30: Low-Slope Cool Roof First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | -7 | 0.001 | -15.3 | -5,229 |
| 2 | 107 | 0.052 | -8.0 | 2,175 |
| 3 | 28 | 0.022 | -5.5 | 244 |
| 4 | 135 | 0.088 | -4.7 | 3,097 |
| 5 | 27 | 0.020 | -6.5 | -1,027 |
| 6 | 126 | 0.063 | -2.2 | 3,228 |
| 7 | 121 | 0.070 | -1.5 | 3,228 |
| 8 | 194 | 0.073 | -3.2 | 5,916 |
| 9 | 174 | 0.089 | -4.0 | 4,550 |
| 10 | 204 | 0.058 | -4.6 | 4,750 |
| 11 | 185 | 0.066 | -5.9 | 4,594 |
| 12 | 157 | 0.092 | -6.3 | 4,159 |
| 13 | N/A | N/A | N/A | N/A |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 14 | 174 | 0.045 | -8.8 | 3,950 |
| 15 | N/A | N/A | N/A | N/A |
| 16 | 99 | 0.060 | -12.5 | -1,862 |

#### *2.3.3.2 Roof Insulation at Low-Slope Roof Replacement*

Energy savings and peak demand reductions per unit are presented in Table 31 through Table 32. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Single family prototype per-unit savings for the first year are expected to range from 88 to 2,078 kWh/yr and 15 to 128 therms/yr depending upon climate zone. Demand reductions are expected to range between 0.002 kW and 0.462 kW depending on climate zone.

These savings figures are relative to an existing building with R-11 attic or roof insulation. As is discussed in Appendix H, these measures were evaluated against a baseline with both R-11 and R-19 insulation. The results from the R-11 baseline analysis were used to define the climate zones where the proposed code change applies; results from the R-19 baseline were used to qualify some of the allowable exceptions. Additional analysis results can be found in Appendix I.

**Table 31: Low-Slope Roof Insulation First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 88 | 0.002 | 99.0 | 36,697 |
| 2 | 451 | 0.177 | 64.9 | 48,635 |
| 3 | 112 | 0.059 | 50.4 | 28,888 |
| 4 | 626 | 0.295 | 45.9 | 44,272 |
| 5 | 91 | 0.012 | 48.8 | 20,929 |
| 6 | 446 | 0.133 | 20.6 | 22,661 |
| 7 | 408 | 0.117 | 16.1 | 16,983 |
| 8 | 805 | 0.132 | 22.5 | 47,519 |
| 9 | 746 | 0.357 | 28.5 | 42,591 |
| 10 | 969 | 0.136 | 34.0 | 47,286 |
| 11 | 1,106 | 0.288 | 67.0 | 68,898 |
| 12 | 823 | 0.359 | 61.8 | 58,791 |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 13 | 1,389 | 0.462 | 45.7 | 72,261 |
| 14 | 1,006 | 0.321 | 68.2 | 68,864 |
| 15 | 2,078 | 0.233 | 14.6 | 75,524 |
| 16 | 445 | 0.164 | 127.8 | 56,310 |

**Table 32: Low-Slope Roof Insulation First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 18 | 0.001 | 26.4 | 9,527 |
| 2 | 143 | 0.040 | 16.4 | 12,119 |
| 3 | 41 | 0.018 | 12.2 | 6,490 |
| 4 | 155 | 0.044 | 11.3 | 10,118 |
| 5 | 42 | 0.015 | 12.0 | 5,429 |
| 6 | 124 | 0.009 | 4.6 | 5,107 |
| 7 | 110 | 0.010 | 3.1 | 3,358 |
| 8 | 216 | 0.009 | 5.4 | 11,458 |
| 9 | 198 | 0.079 | 7.0 | 10,022 |
| 10 | 258 | 0.004 | 8.5 | 11,736 |
| 11 | 273 | 0.053 | 17.1 | 16,721 |
| 12 | 216 | 0.079 | 15.8 | 14,538 |
| 13 | 352 | 0.073 | 11.8 | 17,618 |
| 14 | 254 | 0.020 | 17.5 | 16,922 |
| 15 | 510 | 0.045 | 3.6 | 17,826 |
| 16 | 117 | 0.017 | 32.7 | 14,007 |

## 2.4 Cost and Cost Effectiveness

### 2.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 2.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures). The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 30 years. TDV energy cost factors of 0.173 2023 PV$/kBtu and 0.173 Nominal$/kBtu were applied.

### 2.4.2 Energy Cost Savings Results

#### *2.4.2.1 Cool Roofs at Roof Replacement*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 33 through Table 36. Positive values indicate cost savings while negative values indicate an increase in cost. Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

**Table 33: Steep-Slope Cool Roof 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | -$17 | -$248 | -$265 |
| 2 | $343 | -$63 | $279 |
| 3 | $176 | -$89 | $86 |
| 4 | $527 | -$52 | $475 |
| 5 | $35 | -$84 | -$49 |
| 6 | $314 | -$32 | $282 |
| 7 | $251 | -$23 | $228 |
| 8 | $631 | -$9 | $622 |
| 9 | $625 | -$12 | $614 |
| 10 | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | $127 | -$89 | $37 |

**Table 34: Steep-Slope Cool Roof 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | -$2 | -$33 | -$35 |
| 2 | $169 | -$5 | $164 |
| 3 | $57 | -$12 | $45 |
| 4 | $262 | -$5 | $257 |
| 5 | $24 | -$11 | $14 |
| 6 | $111 | -$5 | $107 |
| 7 | $90 | -$3 | $87 |
| 8 | $280 | $0 | $280 |
| 9 | $193 | $0 | $193 |
| 10 | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | $50 | -$14 | $36 |

**Table 35: Low-Slope Cool Roof 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | -$317 | -$4,525 | -$4,842 |
| 2 | $3,065 | -$2,474 | $590 |
| 3 | $1,420 | -$1,875 | -$455 |
| 4 | $3,773 | -$1,538 | $2,235 |
| 5 | $199 | -$2,209 | -$2,011 |
| 6 | $2,587 | -$853 | $1,734 |
| 7 | $2,195 | -$714 | $1,481 |
| 8 | $4,928 | -$1,057 | $3,871 |
| 9 | $3,889 | -$1,316 | $2,572 |
| 10 | $4,309 | -$1,374 | $2,935 |

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 11 | $4,790 | -$1,697 | $3,094 |
| 12 | $4,116 | -$1,832 | $2,284 |
| 13 | N/A | N/A | N/A |
| 14 | $4,923 | -$2,520 | $2,402 |
| 15 | N/A | N/A | N/A |
| 16 | $1,080 | -$3,658 | -$2,578 |

**Table 36: Low-Slope Cool Roof 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | -$48 | -$856 | -$905 |
| 2 | $850 | -$474 | $376 |
| 3 | $370 | -$328 | $42 |
| 4 | $819 | -$283 | $536 |
| 5 | $203 | -$381 | -$178 |
| 6 | $694 | -$135 | $558 |
| 7 | $653 | -$95 | $558 |
| 8 | $1,218 | -$194 | $1,023 |
| 9 | $1,028 | -$241 | $787 |
| 10 | $1,103 | -$281 | $822 |
| 11 | $1,145 | -$351 | $795 |
| 12 | $1,096 | -$376 | $719 |
| 13 | N/A | N/A | N/A |
| 14 | $1,215 | -$531 | $683 |
| 15 | N/A | N/A | N/A |
| 16 | $403 | -$725 | -$322 |

#### *2.4.2.2 Roof Insulation at Low-Slope Roof Replacement*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 37 through Table 38. Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

These savings figures are relative to an existing building with R-11 attic or roof insulation. As is discussed in Appendix H, these measures were evaluated against a baseline with both R-11 and R-19 insulation. Additional analysis results can be found in Appendix I.

**Table 37: Low-Slope Roof Insulation 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $495 | $5,853 | $6,349 |
| 2 | $4,491 | $3,923 | $8,414 |
| 3 | $1,953 | $3,045 | $4,998 |
| 4 | $4,871 | $2,788 | $7,659 |
| 5 | $677 | $2,944 | $3,621 |
| 6 | $2,659 | $1,262 | $3,920 |
| 7 | $1,947 | $991 | $2,938 |
| 8 | $6,844 | $1,377 | $8,221 |
| 9 | $5,628 | $1,740 | $7,368 |
| 10 | $6,104 | $2,077 | $8,180 |
| 11 | $7,849 | $4,070 | $11,919 |
| 12 | $6,421 | $3,750 | $10,171 |
| 13 | $9,713 | $2,788 | $12,501 |
| 14 | $7,763 | $4,151 | $11,914 |
| 15 | $12,173 | $893 | $13,066 |
| 16 | $2,085 | $7,656 | $9,742 |

**Table 38: Low-Slope Roof Insulation 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $95 | $1,553 | $1,648 |
| 2 | $1,105 | $992 | $2,097 |
| 3 | $382 | $741 | $1,123 |
| 4 | $1,066 | $685 | $1,750 |
| 5 | $218 | $721 | $939 |
| 6 | $604 | $280 | $883 |

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 7 | $391 | $190 | $581 |
| 8 | $1,651 | $331 | $1,982 |
| 9 | $1,308 | $426 | $1,734 |
| 10 | $1,508 | $522 | $2,030 |
| 11 | $1,851 | $1,042 | $2,893 |
| 12 | $1,558 | $957 | $2,515 |
| 13 | $2,328 | $719 | $3,048 |
| 14 | $1,862 | $1,066 | $2,927 |
| 15 | $2,863 | $221 | $3,084 |
| 16 | $471 | $1,952 | $2,423 |

### 2.4.3 Incremental First Cost

#### *2.4.3.1 Cool Roofs at Roof Replacement*

Incremental costs for this measure reflect the difference between replacing a standard roof that does not meet the prescriptive minimum aged solar reflectance and thermal emissivity values with one that does. For steep-slope roofs, the costs are based on asphalt shingles, which are used on approximately 80 percent of homes in the U.S (Levinson, et al. 2016). Estimated costs were collected from previous research reports including recent reach code analysis ( (TRC 2016a) (TRC 2016b) (Statewide Reach Code Team 2019)) and the 2013 residential cool roof CASE Report (Statewide CASE Team 2011a), one roofing contractor during stakeholder interviews, and online product research. Incremental costs for cool roofing products ranged from $0 to $0.55 per square foot of roof relative to non-cool products. The high end of this range, $0.55 per square foot, was a cost point in Climate Zone 3 where costs are substantially higher than the rest of the state. The estimated incremental cost used in this analysis is $0.19 per square foot of roof. This is based on an average of all the cost points for a 0.20 solar reflectance product obtained from the Statewide CASE Team's research and normalized to the regions where this measure is proposed, specifically Climate Zones 4, 8 and 9. This covers material costs only; there is no incremental labor cost for this measure.

For low-slope roofs the costs are based on an asphalt-based modified bitumen roofing product. A 2015 study by the National Roofing Contractor's Association estimated that the largest segments of the low-slope roofing market were represented by thermoplastic polyolefin, or TPO, at 30 percent, EPDM rubber at 25 percent, modified bitumen at 12 percent, and built up roofing at 7 percent (Klutz, Dutton and Davis 2018). A TPO or

EPDM membrane type roof is generally more expensive than asphalt; however, there is no incremental cost for a membrane cool roof as most of the products available meet the minimum 0.63 aged solar reflectance cool. While data shows that a modified bitumen roof may not be the most common roofing product, assuming this roof type for purposes of cost estimates provides a more conservative basis when demonstrating cost effectiveness. Estimated costs were collected from previous research reports including recent reach code analysis (TRC 2016b),the 2013 nonresidential cool roof CASE Report (Statewide CASE Team 2011b), and one roofing contractor during stakeholder interviews. Costs ranged from $0.17 to $0.84 per square foot of roof. The estimated incremental cost used in this analysis is $0.53 per square foot of roof, which is the estimate provided by the roofing contractor for an asphalt-based cap sheet product. This covers material costs; there is no incremental labor cost for this measure.

Table 39 summarizes the total cost for the single family and low-rise multifamily prototypes for both the steep-slope and low-slope cool roof measures and the assumptions for roof area. Roof area for the steep-slope prototypes is based on a 5:12 pitch roof.

**Table 39: First Cost Summary for Cool Roofs**

| | Steep-Slope | | Low-Slope | |
|---|---|---|---|---|
| | **Single Family** | **Multifamily (building)** | **Single Family** | **Multifamily (building)** |
| Incremental cost per square foot of roof area | $0.189 | $0.189 | $0.525 | $0.525 |
| Square foot of roof area | 1,804 | 4,176 | 1,665 | 3,480 |
| ***Total Incremental First Cost*** | ***$341*** | ***$790*** | ***$874*** | ***$1,827*** |

#### *2.4.3.2 Roof Insulation at Low-Slope Roof Replacement*

Incremental costs for this measure reflect the difference between installing a new roof on an existing low-slope roof with and without above roof deck insulation. Cost estimates were obtained from online product research and interviews with stakeholders. The estimated incremental cost used in this analysis is $3.41 per square foot of roof. Material costs of $2.12 per square foot of roof are based on cost data found online. The labor cost of $1.29 per square foot of roof is extrapolated based on costs provided by roofing contractors for installation of above roof deck insulation on steep-slope roofs. The steep- slope labor costs were roughly doubled to be conservative and arrive at the $1.29 figure.

Table 40 summarizes the total cost for the single family and low-rise multifamily prototypes for the low-slope roof insulation measure and the assumptions for roof area.

Table 40: First Cost Summary for Low-Slope Roof Insulation

| | Low-Slope | |
|---|---|---|
| | Single Family | Multifamily(building) |
| Incremental cost per square foot of roof area | $3.406 | $3.406 |
| Square foot of roof area | 1,665 | 3,480 |
| ***Total Incremental First Cost*** | ***$5,671*** | ***$11,853*** |

### 2.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the $n^{th}$ year is calculated as follows:

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

#### *2.4.4.1 Cool Roofs at Roof Replacement*

Research, based on conversations with stakeholders, industry data, and manufacturer warranties, shows that asphalt shingles have a typical lifetime of 15 years to 30 years. Lifetime depends on the installation quality as well as the grade of roofing product. For this analysis an average lifetime of 20 year is assumed for an asphalt shingle roof. The present values of the replacement costs at year 20 are calculated and based on the incremental installed cost of $0.19 per square foot. At the end of the 30 year analysis period the roof replaced at year 20 has a remaining life of 10 years. The remaining value of this roof is calculated and subtracted from the total incremental cost. The total present value of the incremental cost for this code change proposal is $0.26 per square foot, see Table 41 for details.

Table 41: Steep-Slope Cool Roof Summary of Replacement Cost

| | Steep-Slope Asphalt Shingle Cool Roof |
|---|---|
| Incremental First Cost | $0.189 / square foot |
| Present Value of Replacement Cost at Year 20 | $0.105 / square foot |
| Present Value of Remaining Useful Life at Year 30 | -$0.039 / square foot |
| ***Total Present Value of Incremental Cost*** | ***$0.255 / square foot*** |

For the low-slope cool roof submeasure, research and interviews with stakeholders indicated that the life of a low-slope roof is dependent on the installation quality. Various sources referenced lifetimes of up to 20 years for both modified bitumen and membrane roofs; an expected useful life of 15 years is used for this analysis. The present values of the replacement costs at year 15 are calculated and based on the incremental installed cost of $0.53 square foot. The total present value of the incremental cost for this code change proposal is $0.86 per square foot, see Table 42 for details.

**Table 42: Low-Slope Cool Roof Summary of Replacement Cost**

| | **Low-Slope Modified Bitumen Cool Roof** |
|---|---|
| Incremental First Cost | $0.525 / square foot |
| Present Value of Replacement Cost at Year 15 | $0.337 / square foot |
| ***Total Present Value of Incremental Cost*** | ***$0.862 / square foot*** |

##### *2.4.4.2 Roof Insulation at Low-Slope Roof Replacement*

There are no incremental maintenance or replacement costs associated with this measure. Insulation has an expected useful life of 30 years or greater.

### 2.4.5 Cost Effectiveness

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

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the 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 2023 PV costs and cost savings.

#### *2.4.5.1 Cool Roofs at Roof Replacement*

Results of the per-unit cost-effectiveness analyses are presented in Table 43 through Table 48.

For the single family prototype, the proposed steep-slope cool roof submeasure saves money over the 30-year period of analysis relative to the existing conditions in Climate Zones 4, 8, and 9 for single family buildings and 2, 4, 8, and 9 for multifamily buildings. The low-slope submeasure saves money over the 30-year period of analysis relative to the existing conditions in Climate Zones 4, 6 through 12, and 14 for single family buildings and 2, 4, 6 through 12 and 14 for multifamily buildings.

**Table 43: Steep-Slope Cool Roof 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $(265) | $460 | (0.58) |
| 2 | $279 | $460 | 0.61 |
| 3 | $86 | $460 | 0.19 |
| 4 | $475 | $460 | 1.03 |
| 5 | $(49) | $460 | (0.11) |
| 6 | $282 | $460 | 0.61 |
| 7 | $228 | $460 | 0.49 |
| 8 | $622 | $460 | 1.35 |
| 9 | $614 | $460 | 1.33 |
| 10 | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | $37 | $460 | 0.08 |

a. Benefits: TDV Energy Cost Savings + Other PV Savings: Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. Costs: Total Incremental Present Valued Costs: Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 44: Steep-Slope Cool Roof 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $(35) | $133 | (0.26) |
| 2 | $164 | $133 | 1.23 |
| 3 | $45 | $133 | 0.34 |
| 4 | $257 | $133 | 1.93 |
| 5 | $14 | $133 | 0.10 |
| 6 | $107 | $133 | 0.80 |
| 7 | $87 | $133 | 0.66 |
| 8 | $280 | $133 | 2.10 |
| 9 | $193 | $133 | 1.45 |
| 10 | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | $36 | $133 | 0.27 |

a. Benefits: TDV Energy Cost Savings + Other PV Savings: Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. Costs: Total Incremental Present Valued Costs: Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

**Table 45: Low-Slope Cool Roof 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $(4,842) | $1,435 | (3.37) |
| 2 | $590 | $1,435 | 0.41 |

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 3 | $(455) | $1,435 | (0.32) |
| 4 | $2,235 | $1,435 | 1.56 |
| 5 | $(2,011) | $1,435 | (1.40) |
| 6 | $1,734 | $1,435 | 1.21 |
| 7 | $1,481 | $1,435 | 1.03 |
| 8 | $3,871 | $1,435 | 2.70 |
| 9 | $2,572 | $1,435 | 1.79 |
| 10 | $2,935 | $1,435 | 2.05 |
| 11 | $3,094 | $1,435 | 2.16 |
| 12 | $2,284 | $1,435 | 1.59 |
| 13 | N/A | N/A | N/A |
| 14 | $2,402 | $1,435 | 1.67 |
| 15 | N/A | N/A | N/A |
| 16 | $(2,578) | $1,435 | (1.80) |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 46: Low-Slope Cool Roof 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $(905) | $375 | (2.41) |
| 2 | $376 | $375 | 1.00 |
| 3 | $42 | $375 | 0.11 |
| 4 | $536 | $375 | 1.43 |
| 5 | $(178) | $375 | (0.47) |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 6 | $558 | $375 | 1.49 |
| 7 | $558 | $375 | 1.49 |
| 8 | $1,023 | $375 | 2.73 |
| 9 | $787 | $375 | 2.10 |
| 10 | $822 | $375 | 2.19 |
| 11 | $795 | $375 | 2.12 |
| 12 | $719 | $375 | 1.92 |
| 13 | N/A | N/A | N/A |
| 14 | $683 | $375 | 1.82 |
| 15 | N/A | N/A | N/A |
| 16 | $(322) | $375 | (0.86) |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

#### *2.4.5.2 Roof Insulation at Low-Slope Roof Replacement*

Results of the per-unit cost-effectiveness analyses are presented in Table 47 through Table 48. These savings figures are relative to an existing building with R-11 attic or roof insulation. As is discussed in Appendix H, these measures were evaluated against a baseline with both R-11 and R-19 insulation. Additional analysis results can be found in Appendix I.

For the single family and multifamily prototype the proposed submeasure saves money over the 30-year period of analysis relative to the existing conditions in Climate Zones 1, 2, 4, and 8 through 16.

### Table 47: Low-Slope Roof Insulation 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $6,349 | $5,671 | 1.12 |
| 2 | $8,414 | $5,671 | 1.48 |
| 3 | $4,998 | $5,671 | 0.88 |
| 4 | $7,659 | $5,671 | 1.35 |
| 5 | $3,621 | $5,671 | 0.64 |
| 6 | $3,920 | $5,671 | 0.69 |
| 7 | $2,938 | $5,671 | 0.52 |
| 8 | $8,221 | $5,671 | 1.45 |
| 9 | $7,368 | $5,671 | 1.30 |
| 10 | $8,180 | $5,671 | 1.44 |
| 11 | $11,919 | $5,671 | 2.10 |
| 12 | $10,171 | $5,671 | 1.79 |
| 13 | $12,501 | $5,671 | 2.20 |
| 14 | $11,914 | $5,671 | 2.10 |
| 15 | $13,066 | $5,671 | 2.30 |
| 16 | $9,742 | $5,671 | 1.72 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 48: Low-Slope Roof Insulation 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,648 | $1,481 | 1.11 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 2 | $2,097 | $1,481 | 1.42 |
| 3 | $1,123 | $1,481 | 0.76 |
| 4 | $1,750 | $1,481 | 1.18 |
| 5 | $939 | $1,481 | 0.63 |
| 6 | $883 | $1,481 | 0.60 |
| 7 | $581 | $1,481 | 0.39 |
| 8 | $1,982 | $1,481 | 1.34 |
| 9 | $1,734 | $1,481 | 1.17 |
| 10 | $2,030 | $1,481 | 1.37 |
| 11 | $2,893 | $1,481 | 1.95 |
| 12 | $2,515 | $1,481 | 1.70 |
| 13 | $3,048 | $1,481 | 2.06 |
| 14 | $2,927 | $1,481 | 1.98 |
| 15 | $3,084 | $1,481 | 2.08 |
| 16 | $2,423 | $1,481 | 1.64 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

## 2.5 First-Year Statewide Impacts

### 2.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 2.3.3, by assumptions about the percentage of existing buildings that would be impacted by the proposed code. The statewide existing building forecast for 2023 is presented in Appendix A, as are the Statewide CASE Team's assumptions about the percentage of existing buildings that would be impacted by the proposal (by climate zone and building type).

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

Table 49 through Table 51 present the first-year statewide energy and energy cost savings by climate zone.

**Table 49: Steep-Slope Cool Roof Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | N/A | N/A | N/A | N/A | N/A |
| 2 | 2,801 | 0.04 | 0.01 | (0.00) | $0.46 |
| 3 | N/A | N/A | N/A | N/A | N/A |
| 4 | 36,942 | 1.72 | 1.55 | (0.03) | $15.57 |
| 5 | N/A | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 57,230 | 3.46 | 1.30 | (0.01) | $31.75 |
| 9 | 87,547 | 4.77 | 3.33 | (0.01) | $44.64 |
| 10 | N/A | N/A | N/A | N/A | N/A |
| 11 | N/A | N/A | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A | N/A |
| **TOTAL** | **184,519** | **10.00** | **6.19** | **(0.04)** | **$92.43** |

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

**Table 50: Low-Slope Cool Roof Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | N/A | N/A | N/A | N/A | N/A |
| 2 | 3,181 | 0.34 | 0.17 | (0.03) | $1.20 |
| 3 | N/A | N/A | N/A | N/A | N/A |
| 4 | 13,684 | 3.99 | 3.06 | (0.20) | $18.22 |
| 5 | N/A | N/A | N/A | N/A | N/A |
| 6 | 22,861 | 5.30 | 3.39 | (0.17) | $24.70 |
| 7 | 16,397 | 3.50 | 2.59 | (0.10) | $15.82 |
| 8 | 35,508 | 14.84 | 6.95 | (0.37) | $87.59 |
| 9 | 62,985 | 18.98 | 11.70 | (0.62) | $86.43 |
| 10 | 15,617 | 6.51 | 2.36 | (0.19) | $26.95 |
| 11 | 3,669 | 1.26 | 0.55 | (0.05) | $5.48 |
| 12 | 17,057 | 5.55 | 3.69 | (0.30) | $24.34 |
| 13 | N/A | N/A | N/A | N/A | N/A |
| 14 | 4,396 | 1.73 | 0.82 | (0.11) | $6.53 |
| 15 | N/A | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A | N/A |
| **TOTAL** | **195,355** | **62.00** | **35.28** | **(2.13)** | **$297.27** |

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

**Table 51: Low-Slope Roof Insulation Cool Roof Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: buildings) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | 780 | 0.03 | 0.00 | 0.04 | $2.65 |
| 2 | 5,708 | 1.59 | 0.57 | 0.22 | $27.93 |

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: buildings) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 3 | N/A | N/A | N/A | N/A | N/A |
| 4 | 13,684 | 5.14 | 2.21 | 0.38 | $61.82 |
| 5 | N/A | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 35,508 | 18.27 | 2.53 | 0.50 | $182.66 |
| 9 | 62,985 | 23.78 | 10.73 | 0.88 | $225.51 |
| 10 | 15,617 | 8.77 | 0.94 | 0.30 | $72.80 |
| 11 | 3,669 | 1.93 | 0.46 | 0.12 | $20.70 |
| 12 | 17,057 | 8.36 | 3.51 | 0.62 | $101.96 |
| 13 | 9,894 | 9.33 | 2.92 | 0.31 | $83.50 |
| 14 | 4,396 | 2.66 | 0.71 | 0.18 | $31.31 |
| 15 | 1,691 | 2.31 | 0.25 | 0.02 | $14.42 |
| 16 | 1,978 | 0.61 | 0.20 | 0.18 | $13.29 |
| **TOTAL** | **172,966** | **82.80** | **25.03** | **3.74** | **$838.55** |

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

### 2.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard goal of 33 percent renewable electricity generation by 2020.[9] Avoided GHG emissions from natural

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[9] When evaluating the impact of increasing the Renewable Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020, the California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix D for additional details on the methodology used to calculate GHG emissions.

Table 52 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 45,793 metric tons of carbon dioxide equivalents (Metric TonnesCO2e) would be avoided.

**Table 52: First-Year Statewide GHG Emissions Impacts**

| Measure | Electricity Savings[a] (GWh/yr) | Reduced GHG Emissions from Electricity Savings[a] (Metric Tonnes CO2e) | Natural Gas Savings[a] (million therms/yr) | Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tonnes CO2e) | Total Reduced $CO_2e$ Emissions[a,b] (Metric Tones CO2e) |
|---|---|---|---|---|---|
| Cool Roof, Steep-Slope | 10.00 | 2,403 | -0.04 | -240 | 2,163 |
| Cool Roof, Low-Slope | 62.00 | 14,902 | -2.13 | -11,595 | 3,307 |
| Roof Insulation, Low-Slope | 82.80 | 19,903 | 3.74 | 20,420 | 40,323 |

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

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

### 2.5.3 Statewide Water Use Impacts

The proposed submeasures would not result in water savings.

### 2.5.4 Statewide Material Impacts

The proposed submeasures would not result in impacts on the use of toxic or energy intensive materials.

### 2.5.5 Other Non-Energy Impacts

#### *2.5.5.1 Cool Roofs at Roof Replacement*

The U.S. EPA recognizes cool roofs as an important component in mitigating the urban heat island effect (United States Environmental Protection Agency 2019b). As a result, cool roofs help to reduce the health and equity issues created by urban heat islands. The urban heat island effect refers to the tendency of heavily developed urban environments to experience higher temperatures than nearby rural areas. The heat island effect can cause daytime temperatures in urban areas to increase by 4°C and nighttime temperatures by as much as 2.5°C relative to surrounding rural areas (Hibbard, et al. 2017). These higher temperatures, "…modify local microclimates, with implications for regional and global climate change. Urban systems affect various climate attributes, including temperature, rainfall intensity and frequency, winter precipitation (snowfall) and flooding" (Hibbard, et al. 2017). Additionally, heat islands are directly associated with impacts to human health, with vulnerable populations such as the elderly, infirm, and economically disadvantaged facing disproportionately high levels of risk from heat islands compared to the general population (United States Environmental Protection Agency 2019a). These risks include prolonged exposure to high temperatures and air pollution, especially ground-level ozone, which can cause or exacerbate asthma (United States Environmental Protection Agency 2019a).

In addition to the mitigation of urban heat islands, cool roofing can reduce radiative forcing associated with global warming. Shortwave solar radiation is absorbed or reflected by the surfaces that it comes into contact with. Shortwave energy that is absorbed is converted to heat and released back into the atmosphere as longwave radiation, where it can be absorbed by atmospheric GHG emissions such as carbon dioxide, resulting in atmospheric forcing (warming) and higher temperatures at the Earth's surface. Shortwave energy that is reflected by a surface passes through the Earth's atmosphere with minimal absorption and is released into space, resulting in little atmospheric forcing (North Carolina Climate Office 2019). By reflecting shortwave radiation from a roof's surface, cool roofing is responsible for lower levels of atmospheric forcing than non-cool roofing counterparts.

#### *2.5.5.2 Roof Insulation at Low-Slope Roof Replacement*

Adding roof insulation, especially to uninsulated or minimally insulated existing roofs can greatly increase occupant comfort during both the summer and winter. Mean radiant temperature (MRT) is the "temperature of an imaginary isothermal black enclosure in which an occupant would exchange the same amount of heat by radiation as in the actual non-uniform environment" (ASHRAE 2015). MRT is a key indicator of thermal comfort in a building and expresses the effect of surface temperatures on occupant comfort. On a hot day, surfaces of uninsulated or minimally insulated building assemblies would have a higher surface temperature than a highly insulated surface, contributing to a higher MRT of the space. Even though the cooling system may be operating as expected and the indoor air temperature in the space is acceptable, the occupant may still be uncomfortable as a result of the higher MRT. When all building assemblies in a space are well insulated, the MRT is more in line with the interior air temperature resulting in greater occupant comfort.

## 2.6 Proposed Revisions to Code Language

### 2.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

### 2.6.2 Standards

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

(b) **Alterations.** Alterations to existing low-rise residential buildings or alterations in conjunction with a change in building occupancy to a low-rise 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 Section 150.0(a) through (l); 150.0(m)1 through 150.0 (m)10, Section 150.0(o) through (q); and

**I. Roofs.** Replacements of the exterior surface of existing roofs, including adding a new surface layer on top of the existing exterior surface, shall meet the requirements of Section 110.8 and the applicable requirements of Subsections i and ii where more than 50 percent of the roof is being replaced.

i. Low-rise residential buildings with steep-sloped roofs shall meet the following:

New roofing products in Climate Zones 4 and 8~~10~~ through 15 for single family buildings and Climate Zones 2, 4, and 8 through 15 for multifamily buildings shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

**EXCEPTION 1 TO 150.2(b)1Ii:** The following shall be considered equivalent to Subsection i:

~~a. Air-space of 1.0 inch (25 mm) is provided between the top of the roof deck to the bottom of the roofing product; or~~

~~b. The installed roofing product has a profile ratio of rise to width of 1 to 5 for 50 percent or greater of the width of the roofing product; or~~

~~c. Existing ducts in the attic are insulated and sealed according to Section 150.1(c)9; or~~

a~~d~~. Buildings with ceiling assemblies with a U-factor lower than or equal to 0.025 or that are insulated with at least R-38 ceiling insulation in an attic; or be. Buildings with a radiant barrier in the attic, where the radiant barrier is not installed directly above spaced sheathing, meeting the requirements of Section 150.1(c)2; or

cf. Buildings that have no ducts in the attic in Climate Zones 2, 4, 9, 10, 12, and 14; or

dg. In Climate Zones 10-15, Buildings with R-2 or greater continuous insulation above or below the roof deck.

**EXCEPTION 2 to Section 150.2(b)1Ii:** Roof area covered by building integrated photovoltaic panels or building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

ii. Low-rise residential buildings with low-sloped roofs shall meet the following:

a. New roofing products Low-sloped roofs in Climate Zones 4, and 613 and through 15 in single family buildings and Climate Zones 2, 4, and 6 through 15 in multifamily buildings shall have a 3-year aged solar reflectance equal or greater than 0.63 and a thermal emittance equal or greater than 0.75, or a minimum SRI of 75.

**EXCEPTION 1 to Section 150.2(b)1Iii:** Buildings with no ducts in the attic.

**EXCEPTION 12 to Section 150.2(b)1Iiia:** The aged solar reflectance can be met by using insulation at the roof deck specified in TABLE 150.2-B.

*TABLE 150.2-B AGED SOLAR REFLECTANCE INSULATION TRADE OFF TABLE*

| Minimum Aged Solar Reflectance | Roof Deck Continuous Insulation R-value (Climate Zones 6-7) | Aged Solar Reflectance | Roof Deck Continuous Insulation R-value (Climate Zones 2, 4, 8-15) |
|---|---|---|---|
| 0.62 0.60 | 2 | 0.44 0.40 | 1216 |
| 0.59 0.55 | 4 | 0.39 0.35 | 1618 |
| 0.54 0.50 | 6 | 0.34 0.30 | 20 |
| 0.49 0.45 | 8 | 0.29 0.25 | 2422 |
| No requirement | 10 | | 24 |

**EXCEPTION 2 to Section 150.2(b)1Iiia:** Roof area covered by building integrated photovoltaic panels or building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

b. Roofs shall be insulated to the levels specified in TABLE 150.2-C.

*TABLE 150.2-C* INSULATION REQUIREMENTS FOR ROOF ALTERATIONS

| **Climate Zone** | **Continuous Insulation R-value** | **Roof Assembly U-factor** |
|---|---|---|
| 3, 5-7 | NR | NR |
| 1, 2, 4, 8-16 | R-14 | 0.039 |

**EXCEPTION to Section 150.2(b)1Iiib:**

i. Existing roofs with R-10 or greater continuous insulation above or below the roof deck; or

ii. Existing roofs with an assembly U-factor lower than or equal to 0.056 or that are insulated with at least R-19 insulation in the roof cavity in Climate Zones 1, 2, 4, and 8 through 10 for single family buildings and Climate Zones 1, 2, 4, 8 through 10, and 16 for multifamily buildings; or

iii. The continuous insulation requirements per Table 150.2-C may be reduced to R-4 where the following conditions are met:

1. Mechanical equipment is located on the roof and will not be temporarily disconnected and lifted as part of the roof replacement and the addition of insulation required by Table 150.2-C would reduce the height from the roof surface to the top of the base flashing to less than that allowed by the California Residential Code Section R900; or

2. Replaced roofing abuts sidewall or parapet walls and the addition of insulation required by Table 150.2-C would reduce the height from the roof surface to the top of the base flashing to less than that allowed by the California Residential Code Section R900, provided that the following conditions apply:

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

    b. The sidewall or parapet walls have exterior cladding material that must be removed to install the new roof covering membrane to maintain the minimum base flashing height; and

    c. The ratio of the replaced roof area to the linear dimension of affected sidewall or parapet walls is less than 25 square feet per linear foot; or

iv. Where increasing the thickness of above deck insulation would result in existing exterior wall openings becoming less compliant with the California Residential Code, increased insulation to the maximum extent feasible shall be considered in compliance with this Section; or

v. Tapered insulation may be used which has a thermal resistance less than that prescribed at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds the required value.

### 2.6.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

### 2.6.4 ACM Reference Manual

**2 Proposed, Standard, and Reference Design**

Table 26 in Section 2.10.4.3 would need to be revised to reflect the new requirements for cool roof and low-slope roof insulation. Revised language is also included for Roof Deck Insulation (below-deck, where required) for alterations to correct for a discrepancy between Table 26 and Table 150.2-C in the Standards. See Appendix E for further details.

2.10 Additions/Alterations

*2.10.4.3 Roof/Ceilings*

**Table 26: ~~Addition~~ Standard Design for Roofs/Ceilings**

| Proposed Design Roof/Ceiling Types | Standard Design Based on Proposed Duct System Status | | | | |
|---|---|---|---|---|---|
| | Add ≤ 300 ft2 | Add > 300 ft2 and ≤ 700 ft | Addition > 700 ft2 | Altered | Verified Altered |
| Roof Deck Insulation (below-deck, where required) | NR | NR | CZ 4, 8-16 = R-19 (single-family)<br>CZ 8, 9, 11-15 = R19, CZ 10, 16 = R13 (multifamily) | NR<br>~~CZ 4, 8-16 = R-19 (single-family)~~<br>~~CZ 8, 9, 11-15 = R19, CZ 10, 16 = R13 (multifamily)~~ | Existing |
| Roofing Surface (Cool Roof) Steep- Slope | NR | CZ 10-15 ~~>~~0.20 Reflectance, ~~>~~0.75 Emittance | CZ 10-15 ~~>~~0.20 Reflectance, ~~>~~0.75 Emittance | CZ 4, 8-15~~10-15~~ (single family)<br>CZ 2, 4, 8-15 (multifamily)<br>~~>~~0.20 Reflectance<br>~~>~~0.75 Emittance | Existing |
| Roofing Surface (Cool Roof) Low- Slope | NR | CZ 13, 15 ~~>~~ 0.63 Reflectance, ~~>~~0.75 Emittance | CZ 13, 15 ~~>~~ 0.63 Reflectance, ~~>~~0.75 Emittance | CZ 4, 6-15~~13, 15~~ (single family)<br>CZ 2, 4, 8-15 (multifamily)<br>~~>~~ 0.63 Reflectance<br>~~>~~0.75 Emittance | Existing |
| Above Deck Insulation, Low-Slope | NR | NR | NR | CZ 1, 2, 4, 8-16<br>R-14 continuous | Existing |

The following language in subsection 2.6.6.1 specific to radiant barrier installations over spaced sheathing is not implemented in CBECC-Res.

*Radiant barriers are used to reduce heat flow at the bottom of the roof deck in the attic. A 0.05 emittance is modeled at the bottom surface of the roof deck if radiant barriers are used. If no radiant barrier is used, the value modeled is 0.9. If radiant barrier is installed over existing skip sheathing in a reroofing application, 0.5 is modeled.*

The Statewide CASE Team is not recommending any changes to the ACM Reference Manual language related to radiant barriers but does recommend that a checkbox be added to the Construction Assembly for Attic Roofs that allows the user to indicate if the radiant barrier is installed over existing spaced sheathing. When the checkbox is checked the radiant barrier would be modeled with a 0.5 emittance value instead of 0.05.

### 2.6.5 Compliance Manuals

Chapter 9 of the Residential Compliance Manual would need to be revised. Section 9.2 What's New in the 2019 Energy Standards and Section 9.4.4 Envelope Alterations would need to be updated to describe the proposed code changes.

### 2.6.6 Compliance Documents

Compliance documents CF1R-ALT-01-E, CF1R-ALT-05-E, CF2R-ALT-05-E, and CF2R-ENV-04-E would need to be revised. No new compliance documents are being proposed. It's proposed that on the CF1R forms there be two subsections for roof replacements, one for steep-slope roofs and another for low-slope roofs. Subsection E of CF1R-ALT-01-E and subsection C of CF1R-ALT-05-E can be repurposed for steep-slope roof replacements and updated to reflect the changes to climate zones and the exceptions. A new subsection can be dedicated to low-slope roof requirements and request the same details as on the steep-slope subsections about roof reflectance, emittance, and SRI, in addition to proposed and minimum required values for roof insulation. Subsection B of CF2R-ALT-05-E should be revised to add a column for "Above Deck Insulation R-value". CF2R-ENV-04-E should either be revised to add a section for above deck insulation, or CF2R-ENV-03-E must be required in addition to CF2R-ENV-04-E for roof replacements with above deck insulation.

Provided that the exceptions are detailed for the low-slope roof insulation submeasure, the Statewide CASE Team recommends that additional documentation be required by the installing contractor on the CF1R if applying for one of the exceptions to verify that the project meets the qualifications for the exception. This could be documenting the details relevant for the exception within the CF1R form itself or on a drawing. Another option to consider is to require that photographs be presented to the plans examiner.

# 3. Electric Equipment Replacements

## 3.1 Measure Description

### 3.1.1 Measure Overview

This section of the CASE Report covers two prescriptive code change proposals: 1) requiring heat pumps when electric equipment space heating equipment is replaced and 2) requiring heat pump water heaters when electric resistance water heaters are replaced.

The submeasures apply to all residential single family and multifamily buildings with individual space heating or water heating equipment. They do not apply to central space or water heating systems. Both submeasures would require updates to the compliance software for existing plus addition plus alteration analysis.

Specifically, the two submeasures proposed are described as follows.

#### *3.1.1.1 Electric Space Heating Equipment*

Currently, Section 150.2(b)1G of Title 24, Part 6 limits prescriptive replacement heating equipment to natural gas, liquefied petroleum gas, the existing fuel type, or a heat pump. This language allows for new electric resistance heating equipment when the existing equipment is electric. The code change proposal prescriptively prohibits electric resistance replacement space heating equipment based on certain existing and upgrade conditions. Specifically, it's prohibited when the replacement heating system is part of a new or replacement ducted cooling system. This existing condition represents a straightforward and cost-effective upgrade to a heat pump because the air conditioning and electrical infrastructure is already in place. The proposal does not cover non-ducted electric resistance heating systems or systems without central air conditioning, although these scenarios may be considered in future code cycles. Single family buildings in Climate Zones 7 and 15 and multifamily buildings in Climate Zones 6 through 8 and 15 are exempt from the proposed code change because low heating loads did not justify the incremental cost of the heat pump.

#### *3.1.1.2 Electric Water Heating Equipment*

Currently, Section 150.2(b)1Hiiid of Title 24, Part 6 limits prescriptive replacement water heating equipment to natural gas, propane, heat pump water heaters (in most climate zones under certain conditions) or a consumer electric water heater where no natural gas is connected to the existing water heater location. This language allows for electric resistance water heaters when no natural gas is connected to the existing water heater location. The code change proposal prohibits electric resistance replacement water heating equipment in most cases. Exceptions include when the existing electric resistance water heater is located within conditioned space, which adds complications that are further discussed in Section 3.2.2, or in spaces such as closets that are not large enough to accommodate a heat pump water heater. Electric resistance replacement water heaters in other locations would still be allowed if they are combined with a solar water heating system. Multifamily buildings with water heaters located outdoors or in exterior closets are exempt as a result of the cost effectiveness analysis.

### 3.1.2 Measure History

Electric resistance heating relies on an electric resister as the heating element. Electric current is passed through the resister converting the electrical energy into heat energy. Electric resistance heating is essentially 100 percent efficient in the sense that all the electrical energy is converted into heat. An electric resistance furnace is a ducted system with a fan that forces air over the electric resistance heating element, delivering heated air to the house through supply ducts. This is very similar to a ducted gas furnace, which is common in California homes, except an electric heat exchanger is used in place of a gas heat exchanger. Electric resistance storage water heaters have one or multiple electric heating elements submerged in a storage tank. Electric resistance tankless water heaters have a much higher capacity than storage systems because the heating element must heat the water to an acceptable temperature as it passes through the heat exchanger.

Heat pumps are also an electric heating device but use a compressor to drive a refrigeration cycle. They transfer heat energy from one source to another. They operate at efficiencies three to five times greater than electric resistance heaters. Ducted split heat pumps have an indoor coil located in an air handler or fan coil unit, an outdoor coil and compressor unit, and a supply and return duct distribution system. Heat pumps function similarly to air conditioners, except that they have a reversing valve which reverses the direction of flow of the refrigerant converting the indoor coil from a cooling coil into a heating coil. Most residential heat pump water heaters are packaged units with the heat pump unit located directly on top of a storage tank. Heat is transferred from the surrounding air to the water in the tank via a refrigerant to a water heating coil submerged towards the bottom of the tank. There are also split heat pump water heaters where the heat pump unit is external from the storage tank and refrigerant lines are run between the storage tank and the heat pump.

As heat pump performance, product availability, and market share have improved over the years, allowance for electric resistance equipment has slowly been phased out of the Title 24, Part 6 code. While electric resistance heating is not prohibited in new residential construction, it is not allowed prescriptively, and it is very challenging to design a compliant system with electric resistance heat under the performance approach. The 2019 Title 24, Part 6 code saw revisions for space heating and water heating replacements, which expressly allows heat pumps to replace either electric resistance or gas water heating systems. The one scenario where electric resistance equipment continues to be allowed prescriptively is when replacing existing electric resistance equipment.

Heat pumps save energy and peak demand relative to electric resistance technology in all cases. However, this code change proposal is not prohibiting electric resistance heating in all existing conditions, but instead has identified those instances where it is most justified. For space heating, homes that have central electric resistance furnaces with central air conditioning represent a prime opportunity for an upgrade to a central heat pump due to electrical and condensate infrastructure already being in place, and there is no incremental labor for this upgrade. Homes with electric resistance equipment that is ductless or not coupled with central air conditioning may still replace like-for-like. While there are good solutions for these homes, such as ductless mini-split heat pumps, this is a much costlier upgrade and, in some cases, would add an air conditioning load where there was none previously.

An upgrade from an electric resistance water heater to a heat pump water heater comes with additional considerations, such as ensuring that there is adequate ventilation and installation of condensate lines. These are much easier dealt with in certain locations of a home than in others. This proposal exempts homes with electric resistance equipment within conditioned space, in which case they may still replace like-for-like.

### 3.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 3.6 of this report for detailed proposed revisions to code language.

#### *3.1.3.1 Summary of Changes to the Standards*

This proposal would modify the following sections of the California Energy Code as shown below. See Section 3.6.2 of this report for marked-up code language.

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

**Section 150.2(b)1C:** Revise the language in this section to improve clarity and readability.

**Section 150.2(b)1G:** Revise the language to only allow electric resistance heating under the proposed conditions.

**Section 150.2(b)1Hiiid:** Revise the language to only allow electric resistance heating under the proposed conditions.

#### 3.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

#### 3.1.3.3 Summary of Changes to the Residential ACM Reference Manual

This proposal would modify the following sections of the Residential ACM Reference Manual as shown below. See Section 3.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

**SECTION 2.4 Building Mechanical Systems**

**Section 2.4.1 Heating Subsystems:** Update Table 6 to consolidate standard heating subsystem options.

**SECTION 2.10 Additions/Alterations**

**Section 2.10.4.10 Water Heating System:** Update Table 34 to reflect a change to the basis of the Standard Design for altered water heating systems where the existing system is an electric resistance water heater. In this case the Standard Design would reflect a heat pump water heater.

#### 3.1.3.4 Summary of Changes to the Residential Compliance Manual

The proposed code change would modify the following section of the Residential Compliance Manual:

- Section 9.2 What's New in the 2019 Energy Standards
- Section 9.4.5 Water Heating Alterations
- Section 9.4.6 HVAC System Alterations

See Section 3.6.5 of this report for further details.

#### 3.1.3.5 Summary of Changes to Compliance Documents

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

- CF1R-ALT-02-E – Revise subsections D, E & F to reflect requirements for space conditioning heat pumps under certain conditions.
- CF1R-ALT-05-E – Revise subsection H to reflect requirements for heat pump water heaters under certain conditions.

### 3.1.4 Regulatory Context

#### *3.1.4.1 Existing Requirements in the California Energy Code*

#### *3.1.4.2 Electric Heating Equipment*

Currently, Section 150.2(b)1G of Title 24, Part 6 limits prescriptive replacement heating equipment to natural gas, liquefied petroleum gas, the existing fuel type, or a heat pump. This allows for electric resistance heating equipment when the existing equipment is electric.

There are no other code change proposals under consideration for the 2022 code cycle that overlap with the recommendations in this report.

There are no federal preemption concerns with this submeasure since it would not require efficiencies greater than the minimum required by federal regulations.

#### *3.1.4.3 Electric Water Heating Equipment*

Currently, Section 150.2(b)1Hiiid of Title 24, Part 6 limits prescriptive replacement water heating equipment to natural gas, propane, heat pump water heaters (in most climate zones under certain conditions) or a consumer electric water heater where no natural gas is connected to the existing water heater location. This allows for electric resistance water heaters when the existing equipment is electric with no natural gas connection.

There are no other code change proposals under consideration for the 2022 code cycle that overlap with the recommendations in this report.

There are no federal preemption concerns with this submeasure since it would not require efficiencies greater than the minimum required by federal regulations.

#### *3.1.4.4 Relationship to Requirements in Other Parts of the California Building Code*

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

#### *3.1.4.5 Relationship to Local, State, or Federal Laws*

Space conditioning heat pumps, electric furnaces, electric resistance water heaters, and heat pump water heaters are subject to federal regulations as covered products. Table 53 and Table 54 show the minimum efficiencies required by federal regulations for the space heating and water heating equipment covered in these two submeasures. Federal regulations require a uniform energy factor (UEF) greater than one for water heaters larger than 55 gallons, which can only be met by a heat pump water heater.

**Table 53: Minimum Efficiency for Federally Covered Space Heating Equipment**

| Product Class | Minimum Heating Efficiency |
|---|---|
| Electrical furnace | 78 AFUE |
| Split systems heat pump | 8.2 HSPF |
| Single package heat pump | 8.0 HSPF |

Source: California Code of Regulations Title 20, Tables C-3 & E-6 (California Energy Commission 2019a).

**Table 54: Minimum Efficiency for Federally Covered Water Heating Equipment**

| Product Class | Draw Pattern | Minimum Uniform Energy Factor | Minimum Uniform Energy Factor 40gal & 60gal |
|---|---|---|---|
| Electric Storage Water Heater ≥ 20 gallons and ≤ 55 gallons | Very small | 0.8808 − (0.0008 × Vr) | 0.8488 |
| | Low | 0.9254 − (0.0003 × Vr) | 0.9134 |
| | Medium | 0.9307 − (0.0002 × Vr) | 0.9227 |
| | High | 0.9349 − (0.0001 × Vr) | 0.9309 |
| Electric Storage Water Heater > 55 gallons and ≤ 120 gallons | Very small | 1.9236 − (0.0011 × Vr) | 1.8576 |
| | Low | 2.0440 − (0.0011 × Vr) | 1.978 |
| | Medium | 2.1171 − (0.0011 × Vr) | 2.0511 |
| | High | 2.2418 − (0.0011 × Vr) | 2.1758 |

Source: California Code of Regulations Title 20, Table F-2 (California Energy Commission 2019a).

#### *3.1.4.6 Relationship to Industry Standards*

There are no relevant industry standards.

### 3.1.5 Compliance and Enforcement

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

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

- **Design Phase:** In many instances HVAC and water heating system replacements are completed as isolated retrofits rather than part of a larger remodel. In these cases, the mechanical or plumbing contractor corresponds directly with the building owner, recommends the replacement equipment and needs to be aware of Title 24, Part 6 requirements related to the scope of work.

- **Permit Application Phase:** The mechanical or plumbing contractor submits the project for permit and completes the necessary Certificate of Compliance documents. For space heating replacements HERS duct testing would be triggered and the residential CF-1Rs would be registered with a HERS registry. For water heating replacements HERS testing is usually not triggered, and the prescriptive forms would be completed outside of the HERS registry.
- **Construction Phase:** The mechanical or plumbing contractor installs the equipment.
- **Inspection Phase:** For space heating replacements the mechanical contractor would complete the CF-2R. HERS duct testing would be triggered and a HERS Rater would conduct verification testing and complete the CF-3R. A building inspector would conduct a final inspection. For water heating replacements the plumbing contractor would complete the CF-2R. HERS verifications are not typically required. A building inspector would conduct a final inspection.

The compliance process described above does not differ from the existing compliance process for any phase. There are no challenges related to feasibility of compliance and enforcement in any of the phases. However, it is possible that the added requirements may result in projects being completed without applying for a permit in order to continue to install electric resistance equipment when it is prohibited. The value proposition to the occupant or whoever pays the utility bills is significant for this proposal; the utility cost savings for switching from electric resistance to heat pump heating are high. This speaks to the need for education to the HVAC and water heating contractor community so that they can inform their clients on why it is in their best interest to follow the code requirements. This may be most challenging for multifamily buildings where the building owner would be investing in the upgrade, but the tenant would reap the benefits of the reduced utility bills.

## 3.2 Market Analysis

### 3.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

There are various manufacturers that produce furnaces, heat pumps, and water heaters. Manufacturers often sell their products directly to distributors, who in turn work directly with mechanical and plumbing service companies. The mechanical and plumbing service companies range from large companies with hundreds of employees servicing broad regions of the state to independent contractors. Mechanical and plumbing contractors are the primary market actors involved with implementing these code change proposals. They typically correspond directly with the building owner, who is the primary decision maker, and make recommendations for replacement equipment. Many equipment replacements are done at time of failure of the existing equipment. In these cases, the building owner is often in a hurry for the project to be completed so that they can heat their home or have access to hot water. The decision on replacement equipment can be driven by the products that the contractor has readily available; if a product needs to be specially ordered the owner would likely not want to wait the extra time. Other market actors include plans examiners and building inspectors.

Most existing homes in California (about 90 percent of single family buildings and 70 to 80 percent of multifamily buildings) are heated with natural gas. Of those buildings that are electrically heated, 60,000 residential homes or 1 percent of the total building stock (0.3 percent for single family to 2.1 percent for townhouses or duplexes) are represented by forced air electric furnaces with central air conditioning. See Table 55 and Figure 5 for market share details.

**Table 55: Market Overview of Space Heating System Types in Existing Buildings**

| Space Heating System | Single Family (6.2 million) | Townhouse, Duplex (0.7 million) | Apt Condo 2-4 Units (0.8 million) | Apt Condo 5+ Units (1.7 million) |
|---|---|---|---|---|
| **Electric** | 2.0% | 5.9% | 8.3% | 17.2% |
| Forced Air Electric Furnace (+ Central A/C) | 0.3% | 2.1% | 0.3% | 1.5% |
| Other Electric Resistance | 1.1% | 3.2% | 6.5% | 11.6% |
| Heat Pump | 0.6% | 0.7% | 1.5% | 4.2% |
| **Natural Gas** | 89.0% | 90.6% | 81.1% | 71.6% |
| **Other** | 9.0% | 3.5% | 10.6% | 11.1% |

Source: 2009 Residential Appliance Saturation Study (California Energy Commission 2009). “No response” and “N/A” responses removed from dataset when calculating percentages.

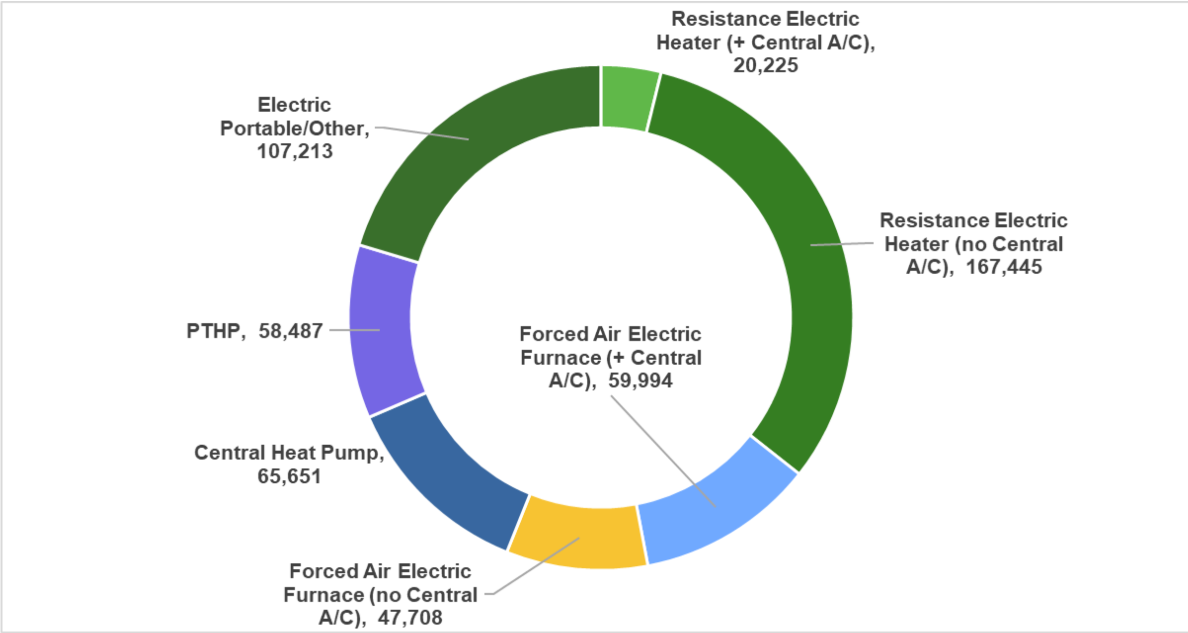


**Figure 5: Breakdown of all residential homes with electric space heating.**
Source: 2009 Residential Appliance Saturation Study (California Energy Commission 2009).

Most existing homes in California also use natural gas for water heating. However, the number of homes that would be impacted by the water heating code change proposal is much higher than for space heating. There are about 870,000 existing homes with a primary water heater that is electric, or 10 percent of the total building sock (6.8 percent for single family to 25.4 percent for apartment buildings with five units or more). The majority of these are standard tank water heaters. See Table 56 for market share details.

"No response" and "N/A" responses removed from dataset when calculating percentages.

**Table 56: Market Overview of Water Heating System Types in Existing Buildings**

| Water Heating System | Single Family (6.2 million) | Townhouse, Duplex (0.7 million) | Apt Condo 2-4 Units (0.6 million) | Apt Condo 5+ Units (1.0 million) |
|---|---|---|---|---|
| **Electric** | 6.8% | 10.5% | 18.6% | 25.4% |
| Standard Tank | 6.1% | 9.6% | 16.9% | 22.6% |
| Tankless | 0.3% | 0.7% | 0.7% | 1.8% |
| HPWH | 0.2% | 0.3% | 0.9% | 0.8% |
| Point of Use Tankless | 0.2% | 0.0% | 0.1% | 0.2% |
| **Natural Gas** | 88.1% | 87.8% | 79.5% | 72.4% |

| Water Heating System | Single Family (6.2 million) | Townhouse, Duplex (0.7 million) | Apt Condo 2-4 Units (0.6 million) | Apt Condo 5+ Units (1.0 million) |
|---|---|---|---|---|
| **Other** | 5.1% | 1.7% | 1.9% | 2.2% |

Source: 2009 Residential Appliance Saturation Study (California Energy Commission 2009). “No response” and “N/A” responses removed from dataset when calculating percentages.

### 3.2.2 Technical Feasibility, Market Availability, and Current Practices

The Statewide CASE Team conducted stakeholder outreach to mechanical and plumbing contractor professionals who predominantly work in residential retrofits in Climate Zones 3, 11 and 12. The contractors averaged 380 HVAC and 150 water heating replacements annually. The majority of equipment replacements are like-for-like gas equipment replacements. Heat pump upgrades are predominantly for customers converting from gas to electric.

More than one contractor working in the Sacramento region stated that single family homes built in the mid to late 1970s have more existing electric resistance or heat pump HVAC systems than in other vintage and California regions. Contractors attributed this to builders in these areas developing all-electric projects during this time. The Statewide CASE Team also heard that 15 percent of homes in SMUD territory have electric resistance water heating. This points to the likelihood that these code change proposals would impact different regions of California distinctly, depending on the makeup of the existing building stock.

Drivers for customers in selecting the type of equipment to replace existing electric heating systems include upfront costs, comfort, reliability, and utility costs. Based on stakeholder feedback, upfront costs are often the single most critical driver, along with timing in the case of failed equipment. Maintenance is also a concern for multifamily building owners. Maintaining electric resistance equipment is very affordable with parts readily available and easy to repair.

There are various incentive programs in California offered by the IOUs, as well as municipal utilities for both space heating and water heating heat pumps. Recently, several programs are encouraging the replacement of electric resistance water heaters, with SMUD, PG&E, SCE, SDG&E, and the City of Palo Alto offering incentives from $300 to $1,000 per system. Incentives can play a critical role in influencing a building owner on product selection. If these code change proposals are adopted, utility incentives may play a role in encouraging projects to apply for a permit and comply with local and state regulations. One contractor working in SMUD territory experienced a shift in their business once SMUD opened an incentive program for space heating conversion from gas to heat pumps. Although this code change proposal does not relate to fuel switching, this example highlights the impacts of incentives and the potential role they may have with supporting implementation of this code change proposal. Prior to the incentive, 100 percent of the contractor's HVAC changeouts were like-for-like gas heating systems. After the incentive, their customer base shifted to a 60 percent or greater portion of their customers looking to convert their HVAC from gas to heat pumps. This also speaks to the market shift increasing product acceptance and contractor familiarity with heat pump technology.

The space heating code change proposal does not present many technical challenges. In almost all cases the upgrade from a central electric resistance furnace with air conditioning to a heat pump is straightforward. The air handler for the heat pump would be a similar size as the electric furnace and can be located in the same place. The electrical capacity for a heat pump is lower than for an electric furnace so no electrical upgrade required. The refrigerant lines and condensate lines already exist if there is an existing central air conditioner. One consideration that was raised by a contractor was that there would be some homes where the outdoor compressor is not in a suitable location for space heating operation. It may be outside of a bedroom window where there are noise concerns with operation during the middle of the night in the winter. Or it may be sited where the condensate during defrost mode cannot be easily dealt with.

While mechanical contractors are typically comfortable working with space heating heat pumps because of how similar they are to air conditioners, there is a greater learning curve for plumbing contractors with heat pump water heaters. Technical considerations include ensuring that the space has adequate ventilation for the heat pump water heater to operate efficiently. This is not a problem with garage installations but needs to be considered for water heaters located in closets. Since heat pump water heaters extract heat from the air and transfer it to water in the storage tank, they need to be supplied a sufficient volume of air to operate properly. Otherwise the space would be cooled down over time, which would impact the operating efficiency of the heat pump water heater. Efficiencies are also more closely tied to the temperature of the space in which they are located. In addition to heat loss from the tank, heat pump water heater performance is directly impacted by the temperature of the supply air to the evaporator coil, with performance declining at lower temperatures.

The condensate off the evaporator coil needs to be properly disposed of and can typically be gravity drained easily in garage and exterior closet located water heaters. When the water heater is within conditioned space there would be additional considerations and a condensate pump may be required. Additionally, there are potential noise and comfort concerns with packaged heat pump water heaters. Ducting the inlet and exhaust air resolves comfort concerns but adds costs and complexity in some cases. Split heat pump water heaters also address these concerns, but currently there are limited products on the market and there is a cost premium relative to the packaged products.

As a result of these variables the Statewide CASE Team is proposing that water heaters located in conditioned spaces are exempt from the requirement. If an electric resistance water heater is exempt under these conditions and has a storage volume of 40 gallons or greater, the replacement electric water heater must include CTA-2045 communications interface to facilitate demand response and load-shifting capabilities. The CTA-2045 interface provides for a standardized physical port but allows for communication to occur in a wide range of demand response application languages including OpenADR2.0 and BACnet. This requirement builds on prior activities in the Pacific Northwest and legislation in Washington state requiring electric water heaters sold in the state to have a CTA-2045 communications interface beginning in 2021. Similar legislation is being considered in Oregon. There is also a California Energy Code proposal that would require HPWHs that receive a load shifting compliance credit to have a CTA-2045 communications interface.

Alternative paths for the water heating code change proposal provide flexibility for projects in how they meet the new requirements, including an option to couple an electric resistance water heater with solar thermal water heating system that results in equivalent annual energy use as a heat pump water heater.

### 3.2.3 Market Impacts and Economic Assessments

#### *3.2.3.1 Impact on Builders*

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California’s construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 57).[10] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector, while another 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

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

**Table 57: California Construction Industry, Establishments, Employment, and Payroll, 2018**

| Construction Sectors | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| **Residential** | **59,287** | **420,216** | **$23.3** |
| Residential Building Construction Contractors | 22,676 | 115,777 | $7.4 |
| Foundation, Structure, & Building Exterior | 6,623 | 75,220 | $3.6 |
| Building Equipment Contractors | 14,444 | 105,441 | $6.0 |
| Building Finishing Contractors | 15,544 | 123,778 | $6.2 |
| **Commercial** | **17,273** | **343,513** | **$27.8** |
| Commercial Building Construction | 4,508 | 75,558 | $6.9 |
| Foundation, Structure, & Building Exterior | 2,153 | 53,531 | $3.7 |
| Building Equipment Contractors | 6,015 | 128,812 | $10.9 |
| Building Finishing Contractors | 4,597 | 85,612 | $6.2 |
| **Industrial, Utilities, Infrastructure, & Other** | **4,103** | **96,550** | **$9.2** |
| Industrial Building Construction | 299 | 5,864 | $0.5 |
| Utility System Construction | 1,643 | 47,619 | $4.3 |
| Land Subdivision | 952 | 7,584 | $0.9 |
| Highway, Street, and Bridge Construction | 770 | 25,477 | $2.4 |
| Other Heavy Construction | 439 | 10,006 | $1.0 |

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

The proposed change to require heat pump equipment in certain cases at HVAC and water heating replacement would likely affect residential builders but would not impact commercial builders or firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 69 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Because the proposed code requirements come only into play at HVAC and water heater replacement, they are expected to impact mechanical and plumbing contractors primarily and residential remodelers to the extent that they work on these types of projects. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.2.4 Economic Impacts.

**Table 58: Size of the California Residential Building Industry by Subsector, 2018**

| Residential Building Subsector | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| Residential plumbing and HVAC contractors | 8,086 | 66,177 | $3,778,328,951 |

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

#### *3.2.3.2 Impact on Building Designers and Energy Consultants*

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Energy Code) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 59 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The code change proposals the Statewide CASE Team is proposing for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for the residential electric equipment replacement submeasures to affect firms that focus on single family and low-rise multifamily construction.

There is not a North American Industry Classification System (NAICS)[11] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[12] It is not possible to determine which business

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[11] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

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

establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 59 provides an upper bound indication of the size of this sector in California.

**Table 59: California Building Designer and Energy Consultant Sectors, 2018**

| Sector | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|
| Architectural Services [a] | 3,704 | 29,611 | $2,906.7 |
| Building Inspection Services [b] | 824 | 3,145 | $223.9 |

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

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

#### *3.2.3.3 Impact on Occupational Safety and Health*

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

#### *3.2.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)*

According to data from the U.S. Census, American Community Survey (ACS), there were nearly 14.3 million housing units in California in 2018 and nearly 13.1 million were occupied (see Table 60). Most housing units (nearly 9.2 million) were single family homes (either detached or attached), while about 2 million homes were in buildings containing two to nine units and 2.5 million were in multifamily building containing 10 or more units. The U.S. Census reported that 59,200 single family and 50,700 multifamily homes were constructed in 2019.

**Table 60: California Housing Characteristics, 2018**

| Housing Measure | Estimate |
|---|---|
| Total housing units | 14,277,867 |
| Occupied housing units | 13,072,122 |
| Vacant housing units | 1,205,745 |

| | |
|---|---|
| Homeowner vacancy rate | 1.2% |
| Rental vacancy rate | 4.0% |
| **Units in Structure** | **Estimate** |
| 1-unit, detached | 8,177,141 |
| 1-unit, attached | 1,014,941 |
| 2 units | 358,619 |
| 3 or 4 units | 783,963 |
| 5 to 9 units | 874,649 |
| 10 to 19 units | 742,139 |
| 20 or more units | 1,787,812 |
| Mobile home, RV, etc. | 538,603 |

Source: (2018 American Community Survey n.d.)

Table 61 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59% 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 (California Energy Commission 2019).

**Table 61: Distribution of California Housing by Vintage, 2018**

| Home Vintage | Units | Percent | Cumulative Percent |
|---|---|---|---|
| Built 2014 or later | 343,448 | 2.4% | 2.4% |
| Built 2010 to 2013 | 248,659 | 1.7% | 4.1% |
| Built 2000 to 2009 | 1,553,769 | 10.9% | 15.0% |
| Built 1990 to 1999 | 1,561,579 | 10.9% | 26.0% |
| Built 1980 to 1989 | 2,118,545 | 14.8% | 40.8% |
| Built 1970 to 1979 | 2,512,178 | 17.6% | 58.4% |
| Built 1960 to 1969 | 1,925,945 | 13.5% | 71.9% |
| Built 1950 to 1959 | 1,896,629 | 13.3% | 85.2% |
| Built 1940 to 1949 | 817,270 | 5.7% | 90.9% |
| Built 1939 or earlier | 1,299,845 | 9.1% | 100.0% |
| **Total housing units** | **14,277,867** | **100%** | |

Source: (2018 American Community Survey n.d.)

Table 62 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 income below $50,000 is only 37 percent, whereas the owner occupancy rate is 72 percent for households earning $100,000 or more.

**Table 62: Owner- and Renter-Occupied Housing Units in California by Income, 2018**

| Household Income | Total | Owner Occupied | Renter Occupied |
|---|---|---|---|
| Less than $5,000 | 391,235 | 129,078 | 262,157 |
| $5,000 to $9,999 | 279,442 | 86,334 | 193,108 |
| $10,000 to $14,999 | 515,804 | 143,001 | 372,803 |
| $15,000 to $19,999 | 456,076 | 156,790 | 299,286 |
| $20,000 to $24,999 | 520,133 | 187,578 | 332,555 |
| $25,000 to $34,999 | 943,783 | 370,939 | 572,844 |
| $35,000 to $49,999 | 1,362,459 | 590,325 | 772,134 |
| $50,000 to $74,999 | 2,044,663 | 1,018,107 | 1,026,556 |
| $75,000 to $99,999 | 1,601,641 | 922,609 | 679,032 |
| $100,000 to $149,999 | 2,176,125 | 1,429,227 | 746,898 |
| $150,000 or more | 2,780,761 | 2,131,676 | 649,085 |
| **Total Housing Units** | **13,072,122** | **7,165,664** | **5,906,458** |
| **Median household income** | **$75,277** | **$99,245** | **$52,348** |

Source: (2018 American Community Survey n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 60 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 61 and Table 62.

For California residents, the code changes that the Statewide CASE Team is proposing for the 2022 code cycle regulation would result in lower energy bills. When homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors 2011).

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

The Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers apart from a slight increase in economic activity for manufacturers of heat pump products due to increased demand.

#### 3.2.3.6 Impact on Building Inspectors

Table 63 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

**Table 63: Employment in California State and Government Agencies with Building Inspectors, 2018**

| Sector | Govt. | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|---|
| Administration of Housing Programs[a] | State | 17 | 283 | $29.0 |
| | Local | 36 | 2,882 | $205.7 |
| Urban and Rural Development Admin[b] | State | 35 | 552 | $48.2 |
| | Local | 52 | 2,446 | $186.6 |

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

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

#### 3.2.3.7 Impact on Statewide Employment

As described in Sections 3.2.3.1 through 3.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.2.4, the Statewide CASE Team estimated how the proposed changes for electric HVAC and water heater replacement equipment 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 changes for electric HVAC and water heater replacement equipment requirements would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

### 3.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes. [13] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations  as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the residential building and remodeling industry 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. There may also be some non-residential 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 or have measurable economic impacts. Table 64, Table 65, and Table 66 demonstrate economic impacts based on the estimated additional spending from the proposed submeasures. These figures assume that there would be no reduction in the number of homes completing relevant projects as a direct result of these proposed code changes. Estimated impacts to the residential construction sector and on discretionary spending by residents is based on the incremental cost and energy savings presented in this report for each submeasure. Estimated impacts to building inspectors are based on an increase of additional time

[13] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

required for plan review and inspection of 15 minutes per single family or multifamily building.

**Table 64: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Electric Space Heating | Direct Effects (Additional spending by Residential Builders) | 83.3 | $5,342,641 | $9,004,292 | $14,621,511 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 32.2 | $2,061,984 | $3,214,013 | $5,707,551 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 39.5 | $2,201,122 | $3,938,874 | $6,429,824 |
| | **Total Submeasure Impacts** | **155.0** | **$9,605,748** | **$16,157,179** | **$26,758,885** |
| Electric Water Heating | Direct Effects (Additional spending by Residential Builders) | 1,083.2 | $69,437,364 | $117,027,183 | $190,033,180 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 418.1 | $26,799,239 | $41,771,953 | $74,180,022 |
| | Induced Effect (Spending by employees of | 513.1 | $28,607,595 | $51,192,848 | $83,567,281 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | firms experiencing “direct” or “indirect” effects) | | | | |
| | **Total Submeasure Impacts** | **2,014.4** | **$124,844,198** | **$209,991,985** | **$347,780,483** |
| **Total Economic Impacts** | | **2,169.3** | **$134,449,945** | **$226,149,163** | **$374,539,368** |

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

### Table 65: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Electric Space Heating | Direct Effects (Additional spending by Residential Builders) | 0.2 | $22,353 | $26,432 | $31,595 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 0.0 | $1,775 | $2,859 | $4,960 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 0.1 | $7,251 | $12,973 | $21,183 |
| | **Total Submeasure Impacts** | **0.4** | **$31,379** | **$42,264** | **$57,738** |
| Electric Water Heating | Direct Effects (Additional spending by Residential Builders) | 1.7 | $166,853 | $197,307 | $235,844 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 0.2 | $13,247 | $21,344 | $37,027 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 1.0 | $54,128 | $96,835 | $158,121 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | **Total Submeasure Impacts** | **2.8** | **$234,228** | **$315,486** | **$430,992** |
| **Total Economic Impacts** | | **3.2** | **265,606.4** | **357,750.7** | **488,730.4** |

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

### Table 66: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Electric Space Heating | Direct Effects (Additional spending by households) | 539.7 | $27,932,441 | $51,376,029 | $82,771,681 |
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 192.0 | $13,173,091 | $21,875,523 | $36,804,580 |
| | Induced Effect (Spending by employees of businesses experiencing “indirect” effects) | 219.6 | $12,265,555 | $21,946,859 | $35,829,922 |
| | **Total Submeasure Impacts** | **951.3** | **$53,371,086** | **$95,198,411** | **$155,406,183** |
| Electric Water Heating | Direct Effects (Additional spending by households) | 1,896.6 | $98,150,498 | $180,527,828 | $290,847,541 |
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 674.5 | $46,288,307 | $76,867,376 | $129,325,892 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | Induced Effect (Spending by employees of businesses experiencing "indirect" effects) | 771.5 | $43,099,360 | $77,118,042 | $125,901,089 |
| | **Total Submeasure Impacts** | **3,342.6** | **$187,538,165** | **$334,513,247** | **$546,074,522** |
| **Total Economic Impacts** | | **4,293.9** | **240,909,251** | **429,711,658** | **701,480,704** |

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

#### 3.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.2.4 would lead to modest changes in employment of existing jobs.

#### 3.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to electric equipment requirements at time of HVAC and water heater replacement, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes to the California Energy Code.

#### 3.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The code changes the Statewide CASE Team is proposing for the 2022 code cycle would apply to all businesses operating in California, regardless of whether the business is located inside or outside of the state.[14] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

#### 3.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[15] As Table 67 shows between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, and the average was 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

**Table 67: Net Domestic Private Investment and Corporate Profits, U.S.**

| Year | Net Domestic Private Investment by Businesses, Billions of Dollars | Corporate Profits After Taxes, Billions of Dollars | Ratio of Net Private Investment to Corporate Profits |
|---|---:|---:|---:|
| 2015 | 609.245 | 1,740.349 | 35% |
| 2016 | 455.980 | 1,739.838 | 26% |
| 2017 | 509.276 | 1,813.552 | 28% |
| 2018 | 618.247 | 1,843.713 | 34% |
| 2019 | 580.849 | 1,826.971 | 32% |
| | | **5-Year Average** | **31%** |

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

The estimated increase in investment in California is $18.6 million. The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in

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[14] 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.

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

investment by California businesses by multiplying the sum of Business Income estimated in Table 64 through Table 66 above by 31 percent.

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

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

**Cost of Enforcement**

*Cost to the State*

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. Because the proposed code change applies to residential buildings alone, impact to state buildings is not expected.

*Cost to Local Governments*

All revisions to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 3.1.5 and Appendix F, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

#### 3.2.4.6 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team does not expect that the proposed submeasures would result in negative impacts on specific persons.

## 3.3 Energy Savings

As of the Draft CASE Report's date of publication, the Energy Commission has not released the final 2022 TDV factors that are used to evaluate TDV energy savings and cost effectiveness. The energy and cost analysis presented in this report used the TDV factors that were released in the 2022 CBECC-Res research version that was released in December 2019. These TDV factors were consistent with the TDV factors that the Energy Commission presented during their public workshop on compliance metrics held October 17, 2019 (California Energy Commission 2019). The electricity TDV factors did not include the 15 percent retail adder and the natural gas TDV factors did not include the impact of methane leakage on the building site, updates that the Energy Commission presented during their workshop on March 27, 2020. Presentations from Bruce Wilcox and NORESCO during the March 27, 2020 workshop indicated that the 15 percent retail adder and methane leakage would result in most energy efficiency measures having slightly higher TDV energy and energy cost savings than using the TDV factors without these refinements. As a result, the TDV energy savings presented in this report are lower than the values that would have been obtained using TDV with the 15 percent retail adder and methane leakage, and the proposed code changes would be more cost effective using the revised TDV. The Energy Commission notified the Statewide CASE Team on April 21, 2020 that they were investigating further refinements to TDV factors using 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. It is anticipated that the 20-year GWP values may increase the TDV factors slightly making proposed changes that improve energy efficiency more cost effective. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

When the Energy Commission releases the final TDV factors, the Statewide CASE Team will consider the need to re-evaluate energy savings and cost-effectiveness analyses using the final TDV factors for the results that will be presented in the Final CASE Report.

The Energy Commission is developing a source energy metric (energy design rating or EDR 1) for the 2022 code cycle. As of the date this Draft CASE Report was published, the source energy metric has not been finalized and the Energy Commission has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

### 3.3.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relies on results of California Building Energy Code Compliance (CBECC) software simulations to estimate energy use for single family and multifamily prototype buildings. Various scenarios were evaluated comparing electric heat pump with electric resistance technology against a range of basecase conditions (i.e. water heater location). The prototypes evaluated all use electricity for both space heating and water heating. All sixteen climate zones were evaluated.

### 3.3.2 Energy Savings Methodology

#### *3.3.2.1 Energy Savings Methodology per Prototypical Building*

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. These prototypes represent new construction buildings and therefore in some cases the prototypes were revised to better reflect the existing building stock relative to new construction. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 68. Refer to Appendix H for further details on the prototypes.

These proposals impact single family and multifamily buildings with individual space heating and water heating systems and were evaluated for the single family alteration prototype and the low-rise garden prototype. The low-rise loaded corridor prototype was not evaluated because the energy savings and cost effectiveness are expected to be very similar to the low-rise garden prototype.

**Table 68: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis**

| Prototype Name | Number of Stories | Floor Area (square feet) | Description | Measures evaluated |
|---|---|---|---|---|
| Single Family Alteration | 1 | 1,665 | Single story house with attached garage. 8-ft ceilings. Steep-slope roof above attic with ducts in attic. | Space heating, Water heating |
| Low-Rise Garden Multifamily | 2 | 6,960 | 2-story, 8-unit apartment building. Average dwelling unit size: 870 ft2. Individual HVAC & DHW systems. Steep-slope roof above attic with ducts in attic. | Space heating, Water heating |

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of the CBECC software for residential buildings (CBECC-Res for low-rise residential (California Energy Commission 2019c)).

CBECC-Res generates two models based on user inputs: the Standard Design and the Proposed Design.[16] The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Residential ACM Reference Manual for low-rise residential buildings. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building.

There is an existing Title 24, Part 6 requirement that covers the building system in question, so the Standard Design is minimally compliant with the 2019 Title 24 requirements with two exceptions for alterations. For single family buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. The existing condition building infiltration assigned to the existing home (10 ACH50) is not reflected in the CBECC-Res Standard Design calculation per the ACM Reference Manual rules. For multifamily buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. Ductwork was located within the vented attic, which is common for this building type, while the CBECC-Res Standard Design for multifamily buildings assumes that ductwork is located within conditioned space. Therefore, two simulations were conducted for each submeasure: one to represent the revised Standard Design and another to represent the Proposed Design. Refer to Appendix H for additional details.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 69 through Table 70 present precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume a heat pump space heating or water heating system in place of an electric resistance heating system. The water heating system was located in an attached garage for single family and an exterior closet for low-rise multifamily.

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[16] 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.

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

**Table 69: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Electric Space Heating Equipment Replacements**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration & Low-Rise Garden Multifamily | All | HVAC System: System Type | Other Heating and Cooling System | Heat Pump Heating and Cooling System |
| | | Heating System: Type | Electric – All electric heating systems other than heat pump | N/A |
| | | Heat Pump System: Type | N/A | SplitHeatPump – Central split heat pump |
| | | Heat Pump System: HSPF | N/A | 8.2 |

**Table 70: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Electric Water Heating Equipment Replacements**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration & Low-Rise Garden Multifamily | All | Water Heater: Heater Type | Electric Resistance | Heat Pump |
| | | Water Heater: Tank Type | Consumer Storage (UEF) | N/A |
| | | Water Heater: Uniform Energy Factor | 0.92 | N/A |
| | | Water Heater: NEEA Rated | N/A | Yes (Generic) |
| | | Water Heater: Model | N/A | UEF 2 (50 gallons) |

CBECC-Res calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). CBECC-Res also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars.

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

Per unit energy impacts for single family buildings are presented in savings per prototype building. Per-unit energy impacts for multifamily buildings are presented in savings per dwelling unit. Annual energy and peak demand impacts for each prototype building were translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building.

#### *3.3.2.2 Statewide Energy Savings Methodology*

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2019d). The Statewide Construction Forecasts estimate the size of the total existing building stock by building type and climate zone in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. In order to translate per unit savings to statewide energy impacts, The Statewide CASE Team conducted research to determine appropriate weighting factors for each submeasure. Table 71 and Table 72 present the prototypical buildings and weighting factors used for the electric space heating and water heating submeasures. The percent of building type represented by prototype is 100 percent for single family since there is only a single prototype. The portion of multifamily impacted is based on the portion of total California multifamily dwelling units in buildings three stories or less, according to the CoStar database (CoStar 2018). The percent of prototype impacted by the proposed code change is estimated based on the 2009 Residential Appliance Saturation Study (California Energy Commission 2009) and CalCERTS data ( (CalCERTS 2020). Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

**Table 71: Residential Building Types and Associated Prototype Weighting for the Electric Space Heating Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.03% | 0.03% |
| Multifamily | Low-Rise Garden | 84% | 0.10% | 0.09% |

**Table 72: Residential Building Types and Associated Prototype Weighting for the Electric Water Heating Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.26% | 0.26% |
| Multifamily | Low-Rise Garden | 84% | 0.78% | 0.65% |

### 3.3.3 Per-Unit Energy Impacts Results

#### *3.3.3.1 Electric Space Heating Equipment*

Energy savings and peak demand reductions per unit are presented in Table 73 through Table 74 for the single family and multifamily prototypes. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For the single family prototype per-unit savings for the first year are expected to range from 326 to 6,604 kWh/yr depending upon climate zone. There are no natural gas savings or demand reductions for this submeasure.

**Table 73: Electric Space Heating Replacements First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 6,365 | 0.000 | 0.0 | 191,408 |
| 2 | 3,068 | 0.000 | 0.0 | 88,012 |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 3 | 2,355 | 0.000 | 0.0 | 70,779 |
| 4 | 1,774 | 0.000 | 0.0 | 54,229 |
| 5 | 1,624 | 0.000 | 0.0 | 52,131 |
| 6 | 525 | 0.000 | 0.0 | 16,500 |
| 7 | 332 | 0.000 | 0.0 | 9,441 |
| 8 | 735 | 0.000 | 0.0 | 22,378 |
| 9 | 1,093 | 0.000 | 0.0 | 32,801 |
| 10 | 1,432 | 0.000 | 0.0 | 42,291 |
| 11 | 3,716 | 0.000 | 0.0 | 105,811 |
| 12 | 3,408 | 0.000 | 0.0 | 99,301 |
| 13 | 2,440 | 0.000 | 0.0 | 73,377 |
| 14 | 3,233 | 0.000 | 0.0 | 92,408 |
| 15 | 326 | 0.000 | 0.0 | 10,373 |
| 16 | 6,604 | 0.022 | 0.0 | 219,281 |

**Table 74: Electric Space Heating Replacements First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 2,279 | 0.000 | 0.0 | 69,800 |
| 2 | 1,093 | 0.012 | 0.0 | 33,460 |
| 3 | 747 | 0.000 | 0.0 | 23,064 |
| 4 | 580 | 0.000 | 0.0 | 18,122 |
| 5 | 543 | 0.000 | 0.0 | 17,678 |
| 6 | 123 | 0.000 | 0.0 | 3,906 |
| 7 | 64 | 0.000 | 0.0 | 1,784 |
| 8 | 271 | 0.040 | 0.0 | 9,492 |
| 9 | 429 | 0.043 | 0.0 | 14,329 |
| 10 | 588 | 0.055 | 0.0 | 18,896 |
| 11 | 1,480 | 0.068 | 0.0 | 44,640 |
| 12 | 1,355 | 0.029 | 0.0 | 42,160 |
| 13 | 1,107 | 0.082 | 0.0 | 35,487 |
| 14 | 1,302 | 0.061 | 0.0 | 39,837 |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 15 | 339 | 0.097 | 0.0 | 12,371 |
| 16 | 2,475 | 0.000 | 0.0 | 87,505 |

### 3.3.3.2 Electric Water Heating Equipment

Energy savings and peak demand reductions per unit are presented in Table 75 through Table 76 for the single family and low-rise garden prototype, respectively. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For the single family prototype per-unit savings for the first year are expected to range from 1,079 to 1,624 kWh/yr depending upon climate zone. There are no natural gas savings for this submeasure. Demand reductions are expected to range between 0.048 kW and 0.362 kW depending on climate zone.

Energy savings are based on the water heater located in the garage for single family and an exterior closet for multifamily.

**Table 75: Electric Water Heating Replacements First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 1,592 | 0.190 | 0.0 | 43,190 |
| 2 | 1,377 | 0.239 | 0.0 | 38,595 |
| 3 | 1,406 | 0.349 | 0.0 | 43,240 |
| 4 | 1,375 | 0.287 | 0.0 | 36,580 |
| 5 | 1,404 | 0.362 | 0.0 | 37,446 |
| 6 | 1,393 | 0.186 | 0.0 | 36,813 |
| 7 | 1,394 | 0.126 | 0.0 | 36,247 |
| 8 | 1,358 | 0.077 | 0.0 | 32,801 |
| 9 | 1,341 | 0.071 | 0.0 | 32,035 |
| 10 | 1,320 | 0.076 | 0.0 | 32,717 |
| 11 | 1,262 | 0.148 | 0.0 | 32,101 |
| 12 | 1,333 | 0.132 | 0.0 | 34,449 |
| 13 | 1,285 | 0.151 | 0.0 | 33,383 |
| 14 | 1,231 | 0.048 | 0.0 | 31,885 |
| 15 | 1,079 | 0.212 | 0.0 | 27,289 |
| 16 | 1,624 | 0.216 | 0.0 | 45,138 |

**Table 76: Electric Water Heating Replacements First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 966 | 0.166 | 0.0 | 23,925 |
| 2 | 1,031 | 0.149 | 0.0 | 25,700 |
| 3 | 1,160 | 0.085 | 0.0 | 29,589 |
| 4 | 1,111 | 0.094 | 0.0 | 29,041 |
| 5 | 1,131 | 0.097 | 0.0 | 28,675 |
| 6 | 1,144 | 0.102 | 0.0 | 29,110 |
| 7 | 1,148 | 0.111 | 0.0 | 29,023 |
| 8 | 1,103 | 0.108 | 0.0 | 28,005 |
| 9 | 1,100 | 0.128 | 0.0 | 28,040 |
| 10 | 1,042 | 0.094 | 0.0 | 25,578 |
| 11 | 933 | 0.094 | 0.0 | 23,969 |
| 12 | 1,025 | 0.096 | 0.0 | 26,840 |
| 13 | 947 | 0.106 | 0.0 | 24,029 |
| 14 | 907 | 0.097 | 0.0 | 21,872 |
| 15 | 874 | 0.066 | 0.0 | 21,585 |
| 16 | 668 | 0.117 | 0.0 | 15,590 |

## 3.4 Cost and Cost Effectiveness

### 3.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 3.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures). The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 30 years. TDV energy cost factors of 0.173 2023 PV$/kBtu and 0.173 Nominal$/kBtu were applied.

### 3.4.2 Energy Cost Savings Results

#### *3.4.2.1 Electric Space Heating Equipment*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 77 through Table 78. Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. There are no peak savings for this submeasure since it is a heating measure.

**Table 77: Electric Space Heating Replacements 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $33,114 | $0 | $33,114 |
| 2 | $15,226 | $0 | $15,226 |
| 3 | $12,245 | $0 | $12,245 |
| 4 | $9,382 | $0 | $9,382 |
| 5 | $9,019 | $0 | $9,019 |
| 6 | $2,855 | $0 | $2,855 |
| 7 | $1,633 | $0 | $1,633 |
| 8 | $3,871 | $0 | $3,871 |
| 9 | $5,674 | $0 | $5,674 |
| 10 | $7,316 | $0 | $7,316 |
| 11 | $18,305 | $0 | $18,305 |
| 12 | $17,179 | $0 | $17,179 |
| 13 | $12,694 | $0 | $12,694 |
| 14 | $15,986 | $0 | $15,986 |
| 15 | $1,795 | $0 | $1,795 |
| 16 | $37,936 | $0 | $37,936 |

**Table 78: Electric Space Heating Replacements 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $12,075 | $0 | $12,075 |
| 2 | $5,789 | $0 | $5,789 |
| 3 | $3,990 | $0 | $3,990 |
| 4 | $3,135 | $0 | $3,135 |
| 5 | $3,058 | $0 | $3,058 |

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 6 | $676 | $0 | $676 |
| 7 | $309 | $0 | $309 |
| 8 | $1,642 | $0 | $1,642 |
| 9 | $2,479 | $0 | $2,479 |
| 10 | $3,269 | $0 | $3,269 |
| 11 | $7,723 | $0 | $7,723 |
| 12 | $7,294 | $0 | $7,294 |
| 13 | $6,139 | $0 | $6,139 |
| 14 | $6,892 | $0 | $6,892 |
| 15 | $2,140 | $0 | $2,140 |
| 16 | $15,138 | $0 | $15,138 |

#### 3.4.2.2 Electric Water Heating Equipment

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 79 through Table 80. Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

**Table 79: Electric Water Heating Replacements 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $7,472 | $0 | $7,472 |
| 2 | $6,677 | $0 | $6,677 |
| 3 | $7,481 | $0 | $7,481 |
| 4 | $6,328 | $0 | $6,328 |
| 5 | $6,478 | $0 | $6,478 |
| 6 | $6,369 | $0 | $6,369 |
| 7 | $6,271 | $0 | $6,271 |
| 8 | $5,674 | $0 | $5,674 |
| 9 | $5,542 | $0 | $5,542 |
| 10 | $5,660 | $0 | $5,660 |
| 11 | $5,554 | $0 | $5,554 |

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 12 | $5,960 | $0 | $5,960 |
| 13 | $5,775 | $0 | $5,775 |
| 14 | $5,516 | $0 | $5,516 |
| 15 | $4,721 | $0 | $4,721 |
| 16 | $7,809 | $0 | $7,809 |

**Table 80: Electric Water Heating Replacements 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $4,139 | $0 | $4,139 |
| 2 | $4,446 | $0 | $4,446 |
| 3 | $5,119 | $0 | $5,119 |
| 4 | $5,024 | $0 | $5,024 |
| 5 | $4,961 | $0 | $4,961 |
| 6 | $5,036 | $0 | $5,036 |
| 7 | $5,021 | $0 | $5,021 |
| 8 | $4,845 | $0 | $4,845 |
| 9 | $4,851 | $0 | $4,851 |
| 10 | $4,425 | $0 | $4,425 |
| 11 | $4,147 | $0 | $4,147 |
| 12 | $4,643 | $0 | $4,643 |
| 13 | $4,157 | $0 | $4,157 |
| 14 | $3,784 | $0 | $3,784 |
| 15 | $3,734 | $0 | $3,734 |
| 16 | $2,697 | $0 | $2,697 |

### 3.4.3 Incremental First Cost

#### *3.4.3.1 Electric Space Heating Equipment*

Incremental costs for this measure reflect the difference between replacing an electric resistance furnace and condenser unit with a split heat pump. Estimated costs are based on data collected from online product research from distributor websites. Cost data was validated based on stakeholder feedback during interviews and meetings.

The estimated incremental cost used in this analysis is $408 per system for material for a 3-ton system. There is no incremental labor cost for this measure since both the basecase and the upgrade case include replacing the outdoor compressor unit which in both instances would require refrigerant charging and duct testing. While HERS testing is required, the requirements do not differ between the basecase and upgrade case.

#### *3.4.3.2 Electric Water Heating Equipment*

Incremental costs for this measure reflect the difference between replacing an electric resistance water heater with a heat pump water heater. Estimated costs are based on data collected from stakeholder interviews and review of a quote for a multifamily project where water heaters were mostly located within conditioned space.

The estimated incremental cost used in this analysis is $2,000 per system which includes both material and labor. Of the four cost estimates received two were rough and cited $1,500 per system. The third cost estimate was for $2,236. The fourth was the multifamily project quote which estimated an incremental cost of about $2,500 per system. This quote included a cost of about $500 per system for a condensate pump, which is necessary in this application because the water heaters were located within conditioned space. Since this submeasure is based on water heaters located in a garage or an exterior closet, condensate pumps are typically not required, and the condensate can be disposed of with a gravity fed line. After removing the cost of the condensate pumps the incremental cost is closer to $2,000. A couple of mechanical contractors commented that the additional cost for a heat pump water heater within the conditioned space relative to a garage for single family homes is $500 to $900 per system.

### 3.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the $n^{th}$ year is calculated as follows:

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

#### *3.4.4.1 Electric Space Heating Equipment*

The electric furnace and air conditioner have an estimated useful life of 20 years which the heat pump has an estimated useful life of 15 years based on DEER (Statewide Reach Code Team 2019). The present values of the replacement costs at year 15 and

20 are calculated and based on a total installed cost of $5,000 for the electric resistance furnace and air conditioner and $5,408 for the heat pump. At the end of the 30-year period of analysis there are 10 years of useful life remaining for the electric resistance furnace and air conditioner. The value of this is calculated and subtracted from the total present value of the cost of the system. The total present value of the incremental cost for this code change proposal is $2,141, see Table 81 for details. There is no difference in regular maintenance between the two system types.

**Table 81: Electric Space Heating Summary of Replacement Cost**

| | Electric Resistance Furnace & Air Conditioner | Split Heat Pump |
|---|---|---|
| First Cost | $5,000 | $5,408 |
| Useful Life | 20 | 15 |
| Present Value of Replacement Cost at Year 15 | - | $3,471 |
| Present Value of Replacement Cost at Year 20 | $2,768 | - |
| Present Value of Remaining Useful Life at Year 30 | ($1,030) | - |
| ***Total Cost*** | ***$6,738*** | ***$8,879*** |
| ***Incremental Cost*** | ***-*** | ***$2,141*** |

#### *3.4.4.2 Electric Water Heating Equipment*

The electric resistance and the heat pump water heater have an estimated useful life of 15 years based on Northwest Energy Efficiency Alliance study (Northwest Energy Efficiency Alliance 2016). The present values of the replacement costs at year 13 and 26 are calculated and based on a total installed cost of $1,000 for the electric resistance water heater and $3,000 for the heat pump. At the end of the 30-year period of analysis there are 9 years of useful life remaining for both water heaters. The value of this is calculated and subtracted from the total present value of the cost of the system. The total present value of the incremental cost for this code change proposal is $3,719, see Table 82 for details. There is no difference in regular maintenance between the two system types.

**Table 82: Electric Water Heating Summary of Replacement Cost**

| | Electric Resistance Water Heater | Heat Pump Water Heater |
|---|---|---|
| First Cost | $1,000 | $3,000 |
| Useful Life | 13 | 13 |
| Present Value of Replacement Cost at Year 13 | $680 | $2,043 |

| | Electric Resistance Water Heater | Heat Pump Water Heater |
|---|---|---|
| Present Value of Replacement Cost at Year 26 | $464 | $1,391 |
| Present Value of Remaining Useful Life at Year 30 | ($285) | ($856) |
| ***Total Cost*** | ***$1,859*** | ***$5,578*** |
| ***Incremental Cost*** | ***-*** | ***$3,719*** |

### 3.4.5 Cost Effectiveness

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

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the 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 2023 PV costs and cost savings.

#### *3.4.5.1 Electric Space Heating Equipment*

Results of the per-unit cost-effectiveness analyses are presented in Table 83 through Table 84.

The proposed measure saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except for 7 and 15 for single family buildings and 6 through 8 and 15 for multifamily buildings, where heating loads are very low.

**Table 83: Electric Space Heating Replacements 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $33,114 | $2,141 | 15.47 |

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 2 | $15,226 | $2,141 | 7.11 |
| 3 | $12,245 | $2,141 | 5.72 |
| 4 | $9,382 | $2,141 | 4.38 |
| 5 | $9,019 | $2,141 | 4.21 |
| 6 | $2,855 | $2,141 | 1.33 |
| 7 | $1,633 | $2,141 | 0.76 |
| 8 | $3,871 | $2,141 | 1.81 |
| 9 | $5,674 | $2,141 | 2.65 |
| 10 | $7,316 | $2,141 | 3.42 |
| 11 | $18,305 | $2,141 | 8.55 |
| 12 | $17,179 | $2,141 | 8.02 |
| 13 | $12,694 | $2,141 | 5.93 |
| 14 | $15,986 | $2,141 | 7.47 |
| 15 | $1,795 | $2,141 | 0.84 |
| 16 | $37,936 | $2,141 | 17.72 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 84: Electric Space Heating Replacements 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $12,075 | $2,141 | 5.64 |
| 2 | $5,789 | $2,141 | 2.70 |
| 3 | $3,990 | $2,141 | 1.86 |
| 4 | $3,135 | $2,141 | 1.46 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 5 | $3,058 | $2,141 | 1.43 |
| 6 | $676 | $2,141 | 0.32 |
| 7 | $309 | $2,141 | 0.14 |
| 8 | $1,642 | $2,141 | 0.77 |
| 9 | $2,479 | $2,141 | 1.16 |
| 10 | $3,269 | $2,141 | 1.53 |
| 11 | $7,723 | $2,141 | 3.61 |
| 12 | $7,294 | $2,141 | 3.41 |
| 13 | $6,139 | $2,141 | 2.87 |
| 14 | $6,892 | $2,141 | 3.22 |
| 15 | $2,140 | $2,141 | 0.9998 |
| 16 | $15,138 | $2,141 | 7.07 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

#### 3.4.5.2 Electric Water Heating Equipment

Results of the per-unit cost-effectiveness analyses are presented in Table 85 through Table 86.

The proposed measure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone except in Climate Zone 16 for multifamily buildings.

**Table 85: Electric Water Heating Replacements 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $7,472 | $3,719 | 2.01 |
| 2 | $6,677 | $3,719 | 1.80 |
| 3 | $7,481 | $3,719 | 2.01 |
| 4 | $6,328 | $3,719 | 1.70 |
| 5 | $6,478 | $3,719 | 1.74 |
| 6 | $6,369 | $3,719 | 1.71 |
| 7 | $6,271 | $3,719 | 1.69 |
| 8 | $5,674 | $3,719 | 1.53 |
| 9 | $5,542 | $3,719 | 1.49 |
| 10 | $5,660 | $3,719 | 1.52 |
| 11 | $5,554 | $3,719 | 1.49 |
| 12 | $5,960 | $3,719 | 1.60 |
| 13 | $5,775 | $3,719 | 1.55 |
| 14 | $5,516 | $3,719 | 1.48 |
| 15 | $4,721 | $3,719 | 1.27 |
| 16 | $7,809 | $3,719 | 2.10 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

**Table 86: Electric Water Heating Replacements 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $4,139 | $3,719 | 1.11 |

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 2 | $4,446 | $3,719 | 1.20 |
| 3 | $5,119 | $3,719 | 1.38 |
| 4 | $5,024 | $3,719 | 1.35 |
| 5 | $4,961 | $3,719 | 1.33 |
| 6 | $5,036 | $3,719 | 1.35 |
| 7 | $5,021 | $3,719 | 1.35 |
| 8 | $4,845 | $3,719 | 1.30 |
| 9 | $4,851 | $3,719 | 1.30 |
| 10 | $4,425 | $3,719 | 1.19 |
| 11 | $4,147 | $3,719 | 1.12 |
| 12 | $4,643 | $3,719 | 1.25 |
| 13 | $4,157 | $3,719 | 1.12 |
| 14 | $3,784 | $3,719 | 1.02 |
| 15 | $3,734 | $3,719 | 1.00 |
| 16 | $2,697 | $3,719 | 0.73 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

## 3.5 First-Year Statewide Impacts

### 3.5.1 Statewide Energy and Energy Cost Savings

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

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

#### 3.5.1.1 Electric Space Heating Equipment

Table 87 presents the first-year statewide energy and energy cost savings by climate zone.

**Table 87: Electric Space Heating Replacements Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 0.00 | 0.00 | $0.00 |
| 2 | 0 | 0.00 | 0.00 | 0.00 | $0.00 |
| 3 | 471 | 0.35 | (0.00) | 0.00 | $1.88 |
| 4 | 1,773 | 1.13 | 0.00 | 0.00 | $6.11 |
| 5 | 0 | 0.00 | (0.00) | 0.00 | $0.00 |
| 6 | 228 | 0.12 | 0.00 | 0.00 | $0.65 |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 114 | 0.08 | 0.00 | 0.00 | $0.44 |
| 9 | 1,820 | 1.51 | 0.03 | 0.00 | $8.01 |
| 10 | 687 | 0.70 | 0.02 | 0.00 | $3.65 |
| 11 | 651 | 2.42 | 0.00 | 0.00 | $11.92 |
| 12 | 521 | 1.11 | 0.01 | 0.00 | $5.75 |
| 13 | 279 | 0.59 | 0.01 | 0.00 | $3.10 |
| 14 | 45 | 0.09 | 0.00 | 0.00 | $0.44 |
| 15 | N/A | N/A | N/A | N/A | N/A |
| 16 | 242 | 1.17 | 0.00 | 0.00 | $6.84 |
| **TOTAL** | **6,830** | **9.27** | **0.07** | **0.00** | **$48.79** |

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

#### *3.5.1.2 Electric Water Heating Equipment*

Table 88 presents the first-year statewide energy and energy cost savings by climate zone.

**Table 88: Electric Water Heating Replacements Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | 282 | 0.40 | 0.05 | 0.00 | $1.83 |
| 2 | 2,121 | 2.75 | 0.46 | 0.00 | $13.04 |
| 3 | 4,826 | 6.04 | 0.88 | 0.00 | $28.91 |
| 4 | 3,480 | 4.04 | 0.46 | 0.00 | $18.36 |
| 5 | 996 | 1.20 | 0.17 | 0.00 | $5.34 |
| 6 | 4,434 | 5.27 | 0.52 | 0.00 | $23.39 |
| 7 | 2,972 | 3.56 | 0.34 | 0.00 | $15.68 |
| 8 | 4,417 | 5.21 | 0.44 | 0.00 | $22.49 |
| 9 | 6,470 | 7.48 | 0.74 | 0.00 | $32.42 |
| 10 | 3,842 | 4.77 | 0.31 | 0.00 | $20.43 |
| 11 | 2,771 | 3.13 | 0.35 | 0.00 | $13.81 |
| 12 | 9,021 | 10.82 | 1.05 | 0.00 | $48.59 |
| 13 | 3,445 | 4.28 | 0.50 | 0.00 | $19.20 |
| 14 | 869 | 1.03 | 0.05 | 0.00 | $4.59 |
| 15 | 640 | 0.66 | 0.11 | 0.00 | $2.85 |
| 16 | 514 | 0.83 | 0.11 | 0.00 | $4.01 |
| **TOTAL** | **51,100** | **61.46** | **6.54** | **0.00** | **$274.96** |

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

### 3.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard goal of 33 percent renewable electricity generation by 2020.[17] Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix D for additional details on the methodology used to calculate GHG emissions.

Table 89 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 17,002 metric tons of carbon dioxide equivalents (Metric TonnesCO2e) would be avoided.

**Table 89: First-Year Statewide GHG Emissions Impacts**

| Measure | Electricity Savings[a] (GWh/yr) | Reduced GHG Emissions from Electricity Savings[a] (Metric Tonnes CO2e) | Natural Gas Savings[a] (million therms/y) | Reduced GHG Emissions from Natural Gas Savings[a] (Metric TonnesCO2e) | Total Reduced $CO_2e$ Emissions[a,b] (Metric TonnesCO2e) |
|---|---|---|---|---|---|
| Electric Space Heating Replacements | 9.27 | 2,229 | 0.00 | 0 | 2,229 |
| Electric Water Heating Replacements | 61.46 | 14,773 | 0.00 | 0 | 14,773 |

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

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

### 3.5.3 Statewide Water Use Impacts

The proposed submeasures would not result in water savings.

### 3.5.4 Statewide Material Impacts

[17] When evaluating the impact of increasing the Renewable Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020, the California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

The proposed submeasures would not result in impacts on the use of toxic or energy intensive materials.

### 3.5.5 Other Non-Energy Impacts

The proposed submeasures would not result in other non-energy impacts.

## 3.6 Proposed Revisions to Code Language

### 3.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

### 3.6.2 Standards

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

(b) **Alterations.** Alterations to existing low-rise residential buildings or alterations in conjunction with a change in building occupancy to a low-rise 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 Section 150.0(a) through (l); 150.0(m)1 through 150.0 (m)10, Section 150.0(o) through (q); and

   **C. Entirely New or Complete Replacement Space-Conditioning Systems** installed as part of an alteration, shall include all the system heating or cooling equipment, including but not limited to: ~~.~~ condensing unit, ~~and~~ cooling or heating coil, and air handler for split systems; or complete replacement of a packaged unit; plus entirely new or replacement duct system (Section 150.2(b)1Diia)~~; plus a new or replacement air handler~~. Entirely ~~N~~new or complete replacement space-conditioning systems shall:

   i. Meet the requirements of Sections 150.0(h), 150.0(i), 150.0(j)2, 150.0(j)3, 150.0(m)1 through 150.0(m)10; 150.0(m)12; 150.0(m)13, 150.1(c)6, 150.1(c)7, 150.1(c)10 and TABLE 150.2-A; and

   ~~ii. Be limited to natural gas, liquefied petroleum gas, or the existing fuel type.~~

   ~~**EXCEPTION to Section 150.2(b)1Cii:** When the fuel type of the replaced heating system was natural gas or liquefied petroleum gas, the new or complete replacement space-conditioning system may be a heat pump.~~

   **G. Altered Space-Heating~~Conditioning~~ System.** Altered or r~~R~~eplacement space-heating~~conditioning~~ systems shall comply with Section 150.1(c)6~~be limited to natural gas, liquefied petroleum gas, or the existing fuel type~~.

**EXCEPTION 1 to Section 150.2(b)1G:** A non-ducted electric resistance space heating system if the existing space heating system is electric resistance.When the fuel type of the replaced heating system was natural gas or liquefied petroleum gas, the replacement space-conditioning system may be a heat pump

**EXCEPTION 2 to Section 150.2(b)1G:** A ducted electric resistance space heating system where only the electric resistance heating system is being replaced.

**EXCEPTION 3 to Section 150.2(b)1G:** An electric resistance space heating system if the existing space heating system is electric resistance in a single family building in Climate Zones 7 or 15 or a multifamily building in Climate Zones 6, 7, 8 or 15.

H**. Water-Heating System**. Altered or replacement service water-heating systems or components shall meet the applicable requirements below:

- **i. Pipe Insulation.** For newly installed piping, the insulation requirements of Section 150.0(j)2 shall be met. For existing accessible piping the applicable requirements of Section 150.0(j)2Ai, and iii, and iv shall be met.
- **ii. Distribution System.** For recirculation distribution system serving individual dwelling units, only Demand Recirculation Systems with manual on/off control as specified in the Reference Appendix RA4.4.9 shall be installed.
- **iii. Water heating system.** The water heating system shall meet one of the following:
  - a. A natural gas or propane water-heating system; or
  - b. For Climate Zones 1 through 15, a single heat pump water heater. The storage tank shall not be located outdoors and be placed on an incompressible, rigid insulated surface with a minimum thermal resistance of R-10. The water heater shall be installed with a communication interface that meets either the requirements of 110.12(a) or CTA-2045; or
  - c. For Climate Zones 1 through 15, a single heat pump water heater that meets the requirements of NEEA Advanced Water Heater Specification Tier 3 or higher. The storage tank shall not be located outdoors; or
  - d. If no natural gas is connected to the existing water heater location, one of the following: consumer electric water heater
    - i. A single heat pump water heater; or
    - ii. A consumer electric resistance water heater if one of the following conditions are met:

a. The water heater is located within conditioned space or the proposed location is not large enough to accommodate a heat pump water heater equivalent in size to the existing water heater or the next nominal size available per manufacturer specifications. Water heaters 40 gallons or greater shall be CTA-2045 compliant and meet the installation criteria specified in Reference Joint Appendix JA13; or

b. A solar water-heating system is installed meeting the installation criteria specified in Reference Residential Appendix RA4.20 and with a minimum solar savings fraction of 60 percent.

c. The water heater is in a multifamily building in Climate Zone 16.

### 3.6.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

### 3.6.4 ACM Reference Manual

**2 Proposed, Standard, and Reference Design**

2.4 Building Mechanical Systems

*2.4.1 Heating Subsystems*

**Table 6: Standard Design Heating System**

| Proposed Design | Standard Design |
|---|---|
| Central furnace, ducted | 80 percent AFUE central furnace, default duct |
| Electric heating including cCentral heat pump, ~~ducted~~minisplit, multisplit, or variable refrigerant charge heat pump, and electric resistance | 8.2 HSPF central heat pump, auto size capacity, default duct |
| Wall furnace, gravity | 59 percent AFUE gravity wall furnace |
| Wall furnace, fan type | 72 percent AFUE fan-type wall furnace |
| ~~Ducted minisplit, multisplit, and variable refrigerant charge heat pump, ducted~~ | ~~8.2 HSPF central heat pump, auto-size capacity, default duct~~ |
| ~~Ductless minisplit, multisplit, and variable refrigerant charge heat pump, ductless~~ | ~~8.2 HSPF central heat pump, auto-size capacity, default duct~~ |
| ~~Room heater, ductless~~ | |

2.10 Additions/Alterations

*2.10.4.8 Space Conditioning System*

**Table 32: ~~Addition~~ Standard Design for Space Conditioning Systems**

| Proposed Design Space-Conditioning System Type | Standard Design Based on Proposed Space-Conditioning Status | | |
|---|---|---|---|
| | Added | Altered | Verified Altered |
| Heating System | See Section 2.4 and 2015 Federal Appliance Stds based on fuel source and equipment type | Same as Addition | Existing heating fuel type and equipment type/efficiency |

*2.10.4.10 Water Heating System*

**Table 34: ~~Addition~~ Standard Design for Water Heater Systems**

| Proposed Design Water Heating System Type | Standard Design Based on Proposed Water Heating Status | | |
|---|---|---|---|
| | Addition (adding water heater) | Altered | Verified Altered |
| Single~~-~~_ Family | Prescriptive water heating system (see Section 2.9) | ~~Existing fuel type, proposed tank type, mandatory requirements (excluding any solar)~~ Same as Addition | Existing water heater type(s), efficiency, distribution system. |
| Multifamily: Individual Water Heater for Each Dwelling Unit | Prescriptive water heating system for each dwelling unit (see Section 2.9) | ~~Existing fuel type, proposed tank type, mandatory requirements (excluding any solar)~~ Same as Addition | Existing water heater type(s), efficiency, distribution system |

### 3.6.5 Compliance Manuals

Chapter 9 of the Residential Compliance Manual would need to be revised. Section 9.2 What's New in the 2019 Energy Standards, Section 9.4.5 Water Heating Alterations, and Section 9.4.6 HVAC System Alterations would need to be updated to describe the proposed code changes.

### 3.6.6 Compliance Documents

Compliance documents CF1R-ALT-02-E and CF1R-ALT-05-E would need to be revised. No new compliance documents are being proposed. Subsections D, E & F of CF1R-ALT-02-E would need to be updated to reflect requirements for space conditioning heat pumps under certain conditions. Subsection H of CF1R-ALT-05-E would need to be updated to reflect requirements for heat pump water heaters under certain conditions.

# 4. Duct Measures

## 4.1 Measure Description

### 4.1.1 Measure Overview

This section of the CASE Report covers three prescriptive code change proposals: 1) revise duct sealing requirements for extensions of an existing duct system and altered space conditioning systems, 2) align the prescriptive duct insulation requirements in Table 150.2-A with new construction Tables 150.1-A and 150.1-B for duct insulation, Option B, and 3) revise the 40-foot threshold and require prescriptive duct sealing and duct insulation for all additions and when 25 feet or greater of new or replacement duct is installed serving an existing space.

All three submeasures would require updates to the compliance software for existing plus addition plus alteration analysis.

#### *4.1.1.1 Prescriptive Duct Sealing*

When an existing duct system is extended or a space conditioning system is altered the system must meet prescriptive duct sealing requirements and demonstrate a measured duct leakage equal to or less than 15 percent of system air handler airflow (or one of the acceptable alternative paths per Section 150.2(b)1Diib). System air handler airflow is calculated according to Reference Appendix 3.1.4.2 and allows either nominal or measured airflow. Nominal airflow shall be the greater of 400 cubic feet per minute (cfm) per nominal ton of condensing unit cooling capacity or 21.7 CFM per kBtu/hr of rated heating output capacity. Airflow is required to be measured for altered systems in Climate Zones 2 and 8 through 15 when an air conditioner or heat pump is altered by the installation or replacement of refrigerant-containing system components. The target airflow for altered systems is 300 cfm per ton of nominal cooling capacity.

The proposed submeasure would reduce the total duct leakage requirement for single family buildings to less than or equal to 10 percent of system air handler airflow and the duct leakage to outside requirement to less than or equal to 7 percent of system air handler airflow. Additionally, the proposal revises the procedure for calculating duct leakage percentage to require that measured airflow be used in place of nominal airflow if measured airflow is available. There is no proposed reduction for leakage in low-rise multifamily buildings provided that the current requirement for new duct systems is 12 percent of system air handler air flow, versus 5 percent for single family buildings. The proposed revision to the procedure in Reference Appendix 3.1.4.2 would impact both single family and multifamily buildings.

#### 4.1.1.2 Prescriptive Duct Insulation

Prescriptive duct insulation requirements per Table 150.2-A apply to new ducts in unconditioned space and require R-6 insulation in Climate Zones 1 through 10, 12 and 13 and R-8 insulation in Climate Zones 11 and 14 through 16. The proposed submeasure aligns the prescriptive duct insulation requirements with new construction Tables 150.1-A and 150.1-B for duct insulation, Option B and increase the required duct insulation from R-6 to R-8 in Climate Zones 1, 2, 4, 8 through 10, 12, and 13.

Table 90 describes the existing and proposed code requirements for duct insulation.

**Table 90: Summary of Existing and Proposed Duct Insulation Requirements for New Ducts in an Alteration**

| Climate Zones | Existing | Proposed |
|---|---|---|
| 3, 5-7 | R-6 | R-6 |
| 1-2, 4, 8-10, 12-13 | R-6 | R-8 |
| 11, 14-16 | R-8 | R-8 |

#### 4.1.1.3 40 Foot Duct Extension Trigger

For low-rise residential buildings, the prescriptive duct sealing and duct insulation requirements of Section 150.2(b)1D of the 2019 Title 24, Part 6 code are triggered when more than 40 feet of new or replacement space-conditioning system ducts are installed. When prescriptive requirements are not triggered, mandatory measures apply which per 150.0(m)1B require R-6 on all ducts in unconditioned space. The proposed submeasure would reduce the 40 foot threshold to 25 feet for systems serving existing spaces, and eliminate the threshold when ducts are extended to serve an addition applying the prescriptive requirements to any new ducts in an addition. In these cases, this submeasure would require duct sealing in all climate zones, where it is currently not required, and increase required duct insulation for ducts in unconditioned space from R-6 to R-8 in climate zones where R-8 is prescriptively required.

### 4.1.2 Measure History

In many homes, ductwork is responsible for carrying conditioned air throughout the building. Thermal and air leakage losses can be significant, particularly when ducts are in unconditioned spaces such as vented attics. Temperature differences between the supply air and a vented attic on either a hot summer or a cold winter day can be as high as 100°F. Research has shown that typical duct leakage in old duct systems can be 20 to 40 percent (ENERGY STAR n.d.).

Prescriptive duct sealing and insulation requirements for alterations were introduced in the 2005 Title 24, Part 6 code cycle. Duct systems were required to be sealed to less than 15 percent total leakage (or meet one of the alternative options) in Climate Zones 2 and 9 through 16 and insulated to meet new construction standards in all climate zones when 40 feet of new or replacement ducts were installed in unconditioned space. There has been little change to the requirements since then. In 2013 the duct sealing was expanded to cover all climate zones and increases to the minimum duct insulation were made in Climate Zones 6 through 8 and 11.

The Statewide CASE Team was not able to locate any documentation of how the 15 percent leakage target and 40-foot length exception were determined. The Duct Sealing Requirements upon HVAC or Duct-System Replacement CASE Report (Pacific Gas & Electric 2002) recommended a measured leakage target of 10 percent of system airflow. However, the proposal first presented by the Energy Commission in February 2003 (California Energy Commission 2003a) increased the target to 15 percent of system airflow. Neither the 2005 CASE report nor the February 2003 draft standards language mentions the 40-foot exception. This was added in the 45-day language version of the standards (California Energy Commission 2003b). Presumably, this was to provide relief for small alteration projects and support the HVAC industry in this transition to sealing existing ducts.

In 2020, duct sealing with a 15 percent total leakage target for existing systems has been prescriptive for 15 years and the HVAC industry is experienced with the requirement. The 40-foot exception can currently be used to bypass sealing and prescriptive duct insulation requirements when extending an existing duct system to serve a small addition, adding registers to a room, or replacing a section of ductwork. Whenever work is completed on existing duct systems regardless of the length of new ductwork added, this represents a prime opportunity to seal the ducts, reduce system leakage, and save energy.

### 4.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 2.5.5.1 of this report for detailed proposed revisions to code language.

#### *4.1.3.1 Summary of Changes to the Standards*

This proposal would modify the following sections of the California Energy Code as shown below. See Section 4.6.2 of this report for marked-up code language.

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

**Section 150.2(a):** Revise Exception 5 to require that that applicable requirements specified in Section 150.2(b)1D be met regardless of the length of the extended duct serving the addition.

**Section 150.2(b)1D:** Reduce the length of feet of new or replacement ductwork that triggers the prescriptive duct requirements. Revise the requirement for extension of an existing duct system to reflect 10 percent total leakage and 7 percent leakage to outside. Also revise TABLE 150.2-A DUCT INSULATON R-VALUE to reflect the new climate zones where R-8 duct insulation is proposed.

**Section 150.2(b)1E:** Revise the requirement for extension of an existing duct system to reflect 10 percent total leakage and 7 percent leakage to outside.

#### *4.1.3.2 Summary of Changes to the Reference Appendices*

Revise RA3.1.4.2 to indicate that when measured system airflow is available it should be used for establishing the target duct leakage rate. See Section 4.6.3 of this report for marked-up code language.

#### *4.1.3.3 Summary of Changes to the Residential ACM Reference Manual*

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

**SECTION 2.10 Additions/Alterations**

**Section 2.10.4.9 Duct System:** Update Table 33 to reflect changes to the prescriptive duct leakage rates and insulation by climate zone. Add a Proposed Design subsection that specifies the assumptions for the Proposed Design. In CBECC-Res currently there is no penalty if the prescriptive duct sealing requirement are not met. It is proposed that if the prescriptive requirements are triggered, then the default assumption for the Proposed Design is 30 percent leakage unless the user indicates that duct sealing and HERS verification would be completed. See below for justification of the 30 percent.

Energy losses from leaky ducts have been noted to range from 20 to 40 percent of the heating and cooling energy in residential buildings and the average duct leakage in residential buildings is also noted to vary between 20 to 40 percent (ENERGY STAR n.d.). The U.S. DOE assumes a baseline of 15 percent supply and 15 percent return leakage in its residential codes analyses for cases that do not require duct leakage testing per code, for e.g., the 2006 IECC (Mendon, Lucas and Goel 2013). This is consistent with Building America research (Building America n.d.). A review conducted by Proctor Engineering in 1999 concludes a CFM25 average of 270 of leakage to outdoors (Proctor, Neme and Nadel 1999). This works out to a roughly 22 percent leakage before accounting for supply and return factors. Note that this value is for the leakage to outdoors and the total leakage is likely higher. Based on these studies, a total duct leakage of 30 percent is a reasonable assumption for existing duct systems in existing residential buildings.

#### *4.1.3.4 Summary of Changes to the Residential Compliance Manual*

The proposed code change would modify the following section of the Residential Compliance Manual:

- Section 9.2 What's New in the 2019 Energy Standards
- Section 9.4.6 HVAC System Alterations

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

#### *4.1.3.5 Summary of Changes to Compliance Documents*

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 4.6.6.

- CF1R-ALT-02-E – Revise subsections B, C and D to revise the reference to ductwork length from 40 feet to 25 feet and differentiate between extensions of existing duct systems that serve an addition.
- CF2R-MCH-01-H – Revise subsections B and F to revise the reference to ductwork length from 40 feet to 25 feet and differentiate between extensions of existing duct systems that serve an addition.

### 4.1.4 Regulatory Context

#### *4.1.4.1 Existing Requirements in the California Energy Code*

For low-rise residential buildings, the prescriptive duct sealing and duct insulation requirements of Section 150.2(b)1D of the 2019 Title 24, Part 6 code are triggered when more than 40 feet of new or replacement space-conditioning system ducts are installed. Prescriptive duct sealing requirements apply to ductwork regardless of the location and in the case of an extension of an existing duct system or altered space conditioning system require that the existing system demonstrate duct leakage equal to or less than 15 percent of system airflow or duct leakage to outside equal to or less than 10 percent of system airflow. If these targets cannot be met, then all accessible leaks must be sealed and verified through a visual inspection and smoke test. Prescriptive duct insulation requirements apply to new ducts in unconditioned space and require R-6 insulation in Climate Zones 1 through 10, 12 and 13 and R-8 insulation in Climate Zones 11 and 14 through 16. When prescriptive requirements are not triggered, mandatory measures apply which per 150.0(m)1B requires R-6 on all ducts in unconditioned space.

There is an exception to the duct sealing requirements for altered space conditioning systems, Exception 2 to Section 150.2(b)1E in the 2019 Title 24, Part 6 code, which exempts duct systems with less than 40 linear feet. This is separate from the 40 feet of new or replacement duct trigger in Section 150.2(b)1D.

System air handler airflow is calculated according to Reference Appendix 3.1.4.2 and allows either nominal or measured airflow. Nominal airflow shall be the greater of 400 cfm per nominal ton of condensing unit cooling capacity or 21.7 cfm per kBtu/hr of rated heating output capacity. Airflow is required to be measured for altered systems in Climate Zones 2 and 8 through 15 when an air conditioner or heat pump is altered by the installation or replacement of refrigerant-containing system components. The target airflow for altered systems is 300 cfm per ton of nominal cooling capacity.

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

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

#### *4.1.4.3 Relationship to Local, State, or Federal Laws*

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

#### *4.1.4.4 Relationship to Industry Standards*

The 2018 IECC (International Code Council 2019) requires that new duct systems in residential buildings that are part of an alteration comply with new construction standards for duct sealing and duct insulation. There is an exception to the duct sealing requirements for existing duct systems that are extended where less than 40 linear feet of ductwork is in unconditioned spaces. However, per the IECC code if an existing duct system with greater than or equal to 40 linear feet of duct in unconditioned space is extended duct sealing is required regardless of the length of new ductwork added. This is similar to Exception 2 to Section 150.2(b)1E in the 2019 Title 24, Part 6 code which exempts duct systems with less than 40 linear feet from the duct sealing requirement in the case of an altered space conditioning system.

The 2018 IECC prescriptively requires that duct leakage be tested to less than or equal to 4 cfm per 100 square feet of conditioned floor area at 25 Pascals. Based on example calculations the Statewide CASE Team conducted this typically correlates with five to 10 percent of system airflow, depending on the house size and system capacity.

The 2018 IECC also requires R-8 insulation on all new or replacement ductwork in an alteration that is three-inches in diameter or greater. Otherwise R-6 is required.

### 4.1.5 Compliance and Enforcement

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

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

- **Design Phase:** In many instances HVAC and duct alterations are completed as isolated retrofits rather than part of a larger remodel. In the former case the mechanical contractor corresponds directly with the homeowner, recommends the replacement equipment and needs to be aware of Title 24, Part 6 requirements related to the scope of work.
- **Permit Application Phase:** The mechanical contractor submits the project for permit to the local building department. If ductwork is extended to serve an addition, or if greater than 25 feet of ductwork is being replaced or added to serve an existing space, then duct sealing and insulation requirements would be triggered. If the space conditioning system is altered, then duct sealing requirements would be triggered. In both cases the mechanical contractor would complete the required Certificate of Compliance forms and register them with a HERS registry. Otherwise, there are no required Certificate of Compliance documents to complete and, depending on the requirements at the local jurisdiction level, a permit may not be required for the scope of work.
- **Construction Phase:** The mechanical contractor installs the HVAC equipment and inspects and seals the ductwork if required. The contractor would test duct leakage with duct pressurization equipment, verify that the required leakage target is met, and complete the required Certificate of Installation forms.
- **Inspection Phase:** If duct testing is required, a HERS Rater would conduct verification testing and complete the Certificate of Verification forms. Duct insulation is not verified by a HERS Rater. A building inspector would conduct a final inspection. In the case where 25 feet or less of ductwork is being replaced or added that is not serving an addition and no space conditioning equipment is being altered it is unlikely that the new ductwork would be inspected.

The compliance process described above does not differ from the existing compliance process for the proposed code changes to duct leakage and prescriptive duct insulation requirements.

The proposal to revise the 40-foot exception would require additional scope of work during the permit application, construction and inspection phases of the project for some projects, but it’s expected this would impact a small number of projects since many include other scopes of work, such as an altered space conditioning system, which otherwise trigger duct sealing requirements. The other submeasure proposals increase the stringency for prescriptive duct leakage targets and prescriptive duct insulation levels, but the compliance process remains the same. The mechanical contractor would need to complete the Certificate of Compliance forms at permit application and during construction seal the ducts to meet the code requirements. A HERS rater would verify the required duct leakage target is met in the inspection phase. These changes fit within the existing permitting process and they are not expected to add substantial burden to building departments. There is no new process with which the building department or the contractor needs to become familiar.

## 4.2 Market Analysis

### 4.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

There are two broad categories of ductwork: flexible and rigid. Most ducts in residential homes are flexible duct which are cylindrical tubes comprised of steel wire helixes covered in flexible plastic. Insulation is easily integrated with flexible ducts and is purchased from the manufacturer with specific insulation values, typically R-4.2, R-6, or R-8. Rigid ductwork can be cylindrical or rectangular and is made from different materials, often sheet metal or fiberboard, and are assembled in the field. Sheet metal ducts are insulated in the field by the mechanical contractor. The fiberboard itself is inherently insulating.

Duct sealing of an existing distribution system is conducted by the mechanical contractor using Title 24 approved tapes and sealants. All accessible joints, seams, and connections must be inspected and sealed if necessary. If the mechanical contractor has a duct pressurizing fan system, they would test the leakage of the duct system at this point. Next, the HERS Rater conducts the third-party verification and submits the results to the HERS Registry.

Mechanical contractors are the primary market actors involved with implementing these code change proposals. Other market actors include plans examiners, building inspectors, HERS Raters, and building owners.

### 4.2.2 Technical Feasibility, Market Availability, and Current Practices

This code change proposal increases the stringency of existing requirements and expands current requirements to cover additional upgrade cases.

#### *4.2.2.1 Prescriptive Duct Sealing*

75 percent of single family prescriptive HVAC alterations in CalCERTS for the 2016 code cycle included duct testing of an altered or existing duct system (CalCERTS 2020).[18] For these single family and low-rise multifamily projects, Table 91 shows the breakdown of compliance results. 40 percent of single family projects tested at or below 10 percent total leakage while 40 percent tested between 10 and 15 percent total leakage. 15 percent of single family projects could not meet the 15 percent total leakage target and used the exception requiring a visual inspection and smoke test.

**Table 91: Duct Leakage Test Results for Altered or Existing Duct Systems from 2016 ALT-02 Projects in CalCERTS**

| Duct Leakage Results or Compliance Path | | % of Altered Duct Systems | |
|---|---|---|---|
| | | Single Family | Low-Rise Multifamily |
| Total Leakage | <=5% | 7% | 0% |
| | 5.1-10% | 33% | 28% |
| | 10.1-12% | 13% | 19% |
| | 12.1-13% | 7% | 8% |
| | 13.1-15% | 19% | 21% |
| Visual Inspection Exception | | 15% | 16% |
| Asbestos Exception | | 6% | 5% |
| Leakage to Outside | | 0% | 2% |

Source: CalCERTS (CalCERTS 2020)

Of the 40 percent of single family projects that tested between 10 and 15 percent total leakage, it's unknown how easily additional sealing could be accomplished to further reduce total leakage. Feedback from mechanical contractors and HERS Raters during stakeholder outreach was split. Some indicated that after many years of the duct sealing requirements the industry was comfortable with it enough to consistently meet lower leakage targets of 10 percent or lower. Some feedback was that contractors have a general feel for how much sealing needs to be completed in order to meet 15 percent. If the target was lower, they would become accustomed to this and apply a new level of effort to meet the new target. One HERS Rater commented that the majority of the time

[18] This does not include entirely new or complete replacement duct systems.

they participate in a smoke test for a project where the contractor could not meet the 15 percent, the smoke test revealed accessible areas of duct that could be sealed. After these areas were addressed total leakage was often reduced to below 15 percent.

Other stakeholders expressed concern that a lower leakage target would not be feasible on most projects. Some homes are more challenging than others because of inaccessible ducts. For example, multi-story homes and apartment buildings would have a greater percentage of inaccessible ductwork than a single story home with ductwork in the attic. Homes with the air handler in the garage also may have a higher percentage of inaccessible ductwork if they are routed through interior walls and floors.

85 percent of single family prescriptive HVAC alterations in CalCERTS for the 2016 code cycle included an altered cooling system in the climate zones[19] where this triggers cooling system airflow to be measured (CalCERTS 2020). Table 92 shows the breakdown of compliance results for single family and low-rise multifamily projects. Section 150.2(b)1Fiia requires a minimum flowrate of 300 cfm per ton of nominal cooling capacity. If this value cannot be met, as was the case for 10 percent of single family homes in this dataset, the installer is allowed to report a lower measured airflow after following a set of remedial actions as defined in RA3.3.3.1.5. 88 percent of single family projects measured a system airflow lower than the nominal cooling system airflow of 400 cfm per ton. 64 percent of single family projects reported a system airflow lower than 350 cfm per ton.

**Table 92: System Airflow Test Results for Altered or Existing Duct Systems from 2016 ALT-02 Projects in CalCERTS**

| Measured System Airflow (cfm/ton) | % of Altered Duct Systems | |
|---|---|---|
| | Single Family | Low-Rise Multifamily |
| 0 to 299 | 10% | 4% |
| 300 to 349 | 54% | 49% |
| 350 to 399 | 25% | 30% |
| 400 to 449 | 8% | 10% |
| 450 to 499 | 2% | 4% |
| 500 + | 1% | 3% |

Source: CalCERTS (CalCERTS 2020)

### Leakage to Outside

The Statewide CASE Team investigated the relationship between total leakage and leakage to outside to determine an appropriate leakage to outside target in alignment

[19] Climate Zones 2 and 8 through 15.

with the revised 10 percent total leakage requirement. Buildings with ductwork predominantly in unconditioned space, such as in a vented attic, typically have total leakage and leakage to outside tested values that are very similar, since the ducts are outside of the thermal envelope. Total leakage and leakage to outside diverge more in buildings with ductwork in directly or indirectly conditioned space, where some of the leakage would be to the conditioned space and some would be to outside the thermal envelope.

The 2019 code currently requires 15 percent total leakage or 10 percent leakage to outside; this relationship represents 67 percent of leakage to outside and 33 percent to inside the thermal envelope. Data from single family homes tested in the Residential Construction Quality Assessment Project (Davis Energy Group 2002) across 36 HVAC systems showed that leakage to outside was 75 to 100 percent of total leakage, with an average of 91%, for systems with ducts predominantly located in vented attics. There were four homes with ductwork located in sealed attics which showed leakage to outside was 45 to 65 percent of total leakage.

The 2011 Efficiency Characteristics and Opportunities for New California Homes analysis (California Energy Commission 2011) tested total leakage and leakage to outside for single family detached homes, townhomes, and apartments. The duct leakage results for single family homes where all but one of the buildings had ductwork completely or partially in an attic showed similar alignment between total leakage and leakage to outside as was observed in the Residential Construction Quality Assessment Project. Data for apartments where 83 percent of buildings had ductwork in directly or indirectly conditioned space also appears to show alignment with the RQA results for homes with ductwork located in sealed indirectly conditioned attics.

For this submeasure proposal the recommendation is for a 7 percent leakage to outside target, or 70 percent of the total leakage target of 10 percent. This is in between what is expected for buildings with ducts in conditioned space and those with ducts in unconditioned space. This also aligns well with the relationship between the current requirements of 15 percent total leakage and 10 percent leakage to outside.

#### 4.2.2.2 Prescriptive Duct Insulation

Prescriptive duct insulation increases from R-6 to R-8 in certain climate zones; however, R-8 is already prescriptively required in other climate zones and building types therefore there is an existing market for it and the industry is familiar with installing it. There may be potential space limitations with fitting R-8 ducts in small areas, but this can typically be resolved. R-6 is still the most commonly installed duct insulation product in residential buildings, though. 20 percent of prescriptive HVAC alterations registered with CalCERTS under the 2016 code cycle with new ductwork installed ducts with R-8 insulation (CalCERTS 2020). See Table 93 for a breakdown by climate zone and building type.

**Table 93: Percent of New Ducts in Alterations with R-8 Insulation from 2016 ALT-02 Projects in CalCERTS**

| Climate Zones | Current/Proposed Insulation Requirement | % of New Ducts with R-8 Insulation | |
|---|---|---|---|
| | | Single Family | Low-Rise Multifamily |
| All | N/A | 20% | 20% |
| 3, 5-7 | R-6/R-6 | 5% | 20% |
| 1-2, 4, 8-10, 12-13 | R-6/R-8 | 13% | 3% |
| 11, 14-16 | R-8/R-8 | 100% | 100% |

Source: CalCERTS (CalCERTS 2020)

#### *4.2.2.3 40 Foot Duct Extension Trigger*

Only 2 percent (~675 homes) of performance alteration projects (existing + alteration + addition) and 1 percent (~90 homes) of addition only performance projects registered with CalCERTS under the 2013 and 2016 code cycles took the exception for an extension of a duct system with less than or equal to 40 feet (CalCERTS 2020). This does not capture prescriptive projects that are not registered with CalCERTS, where most of these projects likely would fall under. However, the Statewide CASE Team expects that the code change proposal revising the exception for up to 40 feet of new or replacement ductwork would impact a small number of alteration projects statewide.

The proposal to reduce the 40 feet threshold to 25 feet is based on the length of flexible ductwork in a typical package. Keeping the exception for projects that install 25 feet or less of ductwork continues to allow a project to purchase a single package of flexible duct to repair a short section or install a short extension without triggering the prescriptive duct sealing and insulation requirements.

### 4.2.3 Market Impacts and Economic Assessments

#### *4.2.3.1 Impact on Builders*

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California’s construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 94).[20] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector, while another 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

**Table 94: California Construction Industry, Establishments, Employment, and Payroll, 2018**

| Construction Sectors | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| **Residential** | **59,287** | **420,216** | **$23.3** |
| Residential Building Construction Contractors | 22,676 | 115,777 | $7.4 |
| Foundation, Structure, & Building Exterior | 6,623 | 75,220 | $3.6 |
| Building Equipment Contractors | 14,444 | 105,441 | $6.0 |
| Building Finishing Contractors | 15,544 | 123,778 | $6.2 |
| **Commercial** | **17,273** | **343,513** | **$27.8** |
| Commercial Building Construction | 4,508 | 75,558 | $6.9 |
| Foundation, Structure, & Building Exterior | 2,153 | 53,531 | $3.7 |
| Building Equipment Contractors | 6,015 | 128,812 | $10.9 |
| Building Finishing Contractors | 4,597 | 85,612 | $6.2 |
| **Industrial, Utilities, Infrastructure, & Other** | **4,103** | **96,550** | **$9.2** |
| Industrial Building Construction | 299 | 5,864 | $0.5 |
| Utility System Construction | 1,643 | 47,619 | $4.3 |
| Land Subdivision | 952 | 7,584 | $0.9 |
| Highway, Street, and Bridge Construction | 770 | 25,477 | $2.4 |
| Other Heavy Construction | 439 | 10,006 | $1.0 |

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

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

The proposed changes to prescriptive duct insulation and sealing requirements would likely affect residential builders but would not impact commercial builders or firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 95 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Because the proposed code requirements come only into play new or replacement ductwork is installed or duct sealing is required due to cooling or heating equipment replacement, they are expected to impact mechanical contractors primarily. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 4.2.4 Economic Impacts.

**Table 95: Size of the California Residential Building Industry by Subsector, 2018**

| Residential Building Subsector | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| Residential plumbing and HVAC contractors | 8,086 | 66,177 | $3,778,328,951 |

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

#### *4.2.3.2 Impact on Building Designers and Energy Consultants*

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Energy Code) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 96 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The code change proposals the Statewide CASE Team is proposing for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for the residential duct submeasures to affect firms that focus on single family and low-rise multifamily construction.

There is not a North American Industry Classification System (NAICS)[21] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[22] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 96 provides an upper bound indication of the size of this sector in California.

**Table 96: California Building Designer and Energy Consultant Sectors, 2018**

| Sector | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|
| Architectural Services [a] | 3,704 | 29,611 | $2,906.7 |
| Building Inspection Services [b] | 824 | 3,145 | $223.9 |

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

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

#### *4.2.3.3 Impact on Occupational Safety and Health*

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain in place. Complying with the proposed code change is not

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[21] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

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

anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

#### 4.2.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)

According to data from the U.S. Census, American Community Survey (ACS), there were nearly 14.3 million housing units in California in 2018 and nearly 13.1 million were occupied (see Table 97). Most housing units (nearly 9.2 million) were single family homes (either detached or attached), while about 2 million homes were in buildings containing two to nine units and 2.5 million were in multifamily building containing 10 or more units. The U.S. Census reported that 59,200 single family and 50,700 multifamily homes were constructed in 2019.

**Table 97: California Housing Characteristics, 2018**

| **Housing Measure** | **Estimate** |
|---|---|
| Total housing units | 14,277,867 |
| Occupied housing units | 13,072,122 |
| Vacant housing units | 1,205,745 |
| Homeowner vacancy rate | 1.2% |
| Rental vacancy rate | 4.0% |
| **Units in Structure** | **Estimate** |
| 1-unit, detached | 8,177,141 |
| 1-unit, attached | 1,014,941 |
| 2 units | 358,619 |
| 3 or 4 units | 783,963 |
| 5 to 9 units | 874,649 |
| 10 to 19 units | 742,139 |
| 20 or more units | 1,787,812 |
| Mobile home, RV, etc. | 538,603 |

Source: (2018 American Community Survey n.d.)

Table 98 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59 percent of the total) were built between 1950 and 1989, a period of rapid population and economic growth in California. Finally, about 2.1 million homes in California were built before 1950. According to Kenney et al, 2019, more than half of California's existing multifamily buildings (those with five or more units) were constructed before 1978 when there were no building energy efficiency standards (California Energy Commission 2019).

**Table 98: Distribution of California Housing by Vintage, 2018**

| Home Vintage | Units | Percent | Cumulative Percent |
|---|---|---|---|
| Built 2014 or later | 343,448 | 2.4% | 2.4% |
| Built 2010 to 2013 | 248,659 | 1.7% | 4.1% |
| Built 2000 to 2009 | 1,553,769 | 10.9% | 15.0% |
| Built 1990 to 1999 | 1,561,579 | 10.9% | 26.0% |
| Built 1980 to 1989 | 2,118,545 | 14.8% | 40.8% |
| Built 1970 to 1979 | 2,512,178 | 17.6% | 58.4% |
| Built 1960 to 1969 | 1,925,945 | 13.5% | 71.9% |
| Built 1950 to 1959 | 1,896,629 | 13.3% | 85.2% |
| Built 1940 to 1949 | 817,270 | 5.7% | 90.9% |
| Built 1939 or earlier | 1,299,845 | 9.1% | 100.0% |
| **Total housing units** | **14,277,867** | **100%** | |

Source: (2018 American Community Survey n.d.)

Table 99 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 income below $50,000 is only 37 percent, whereas the owner occupancy rate is 72 percent for households earning $100,000 or more.

**Table 99: Owner- and Renter-Occupied Housing Units in California by Income, 2018**

| Household Income | Total | Owner Occupied | Renter Occupied |
|---|---|---|---|
| Less than $5,000 | 391,235 | 129,078 | 262,157 |
| $5,000 to $9,999 | 279,442 | 86,334 | 193,108 |
| $10,000 to $14,999 | 515,804 | 143,001 | 372,803 |
| $15,000 to $19,999 | 456,076 | 156,790 | 299,286 |
| $20,000 to $24,999 | 520,133 | 187,578 | 332,555 |
| $25,000 to $34,999 | 943,783 | 370,939 | 572,844 |
| $35,000 to $49,999 | 1,362,459 | 590,325 | 772,134 |
| $50,000 to $74,999 | 2,044,663 | 1,018,107 | 1,026,556 |
| $75,000 to $99,999 | 1,601,641 | 922,609 | 679,032 |
| $100,000 to $149,999 | 2,176,125 | 1,429,227 | 746,898 |
| $150,000 or more | 2,780,761 | 2,131,676 | 649,085 |
| **Total Housing Units** | **13,072,122** | **7,165,664** | **5,906,458** |
| **Median household income** | **$75,277** | **$99,245** | **$52,348** |

Source: (2018 American Community Survey n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 97 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 98 and Table 99.

For California residents, the code changes that the Statewide CASE Team is proposing for the 2022 code cycle regulation would result in lower energy bills. When homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors 2011).]

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

The Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers.

#### *4.2.3.6 Impact on Building Inspectors*

Table 100 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

**Table 100: Employment in California State and Government Agencies with Building Inspectors, 2018**

| Sector | Govt. | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|---|
| Administration of Housing Programs[a] | State | 17 | 283 | $29.0 |
| | Local | 36 | 2,882 | $205.7 |
| Urban and Rural Development Admin[b] | State | 35 | 552 | $48.2 |
| | Local | 52 | 2,446 | $186.6 |

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

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

#### *4.2.3.7 Impact on Statewide Employment*

As described in Sections 4.2.3.1 through 4.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 4.2.4, the Statewide CASE Team estimated how the proposed change to prescriptive duct insulation and sealing requirements 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 to duct insulation and sealing requirements would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

### 4.2.4 Economic Impacts

For the 2022 code cycle, the CASE team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes. [23] While this is the first code cycle in which the CASE team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts

[23] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the residential building and remodeling industry 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. There may also be some non-residential 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 or have measurable economic impacts. Table 101 and Table 102 demonstrate economic impacts based on the estimated additional spending from the proposed submeasures. These figures assume that there would be no reduction in the number of homes completing relevant projects as a direct result of these proposed code changes. Estimated impacts to the residential construction sector and on discretionary spending by residents is based on the incremental cost and energy savings presented in this report for each submeasure. There are no estimated impacts to building inspectors.

**Table 101: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Duct Sealing | Direct Effects (Additional spending by Residential Builders) | 46.7 | $2,992,308 | $5,043,126 | $8,189,220 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 18.0 | $1,154,877 | $1,800,105 | $3,196,687 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 22.1 | $1,232,805 | $2,206,086 | $3,601,218 |
| | **Total Submeasure Impacts** | **86.8** | **$5,379,990** | **$9,049,317** | **$14,987,124** |
| Duct Insulation | Direct Effects (Additional spending by Residential Builders) | 7.5 | $481,431 | $811,386 | $1,317,560 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 2.9 | $185,808 | $289,618 | $514,313 |
| | Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects) | 3.6 | $198,345 | $354,936 | $579,398 |
| | **Total Submeasure Impacts** | **14.0** | **$865,584** | **$1,455,941** | **$2,411,272** |
| **Total Economic Impacts** | | **100.8** | **$6,245,574** | **$10,505,258** | **$17,398,396** |

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

### Table 102: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Duct Sealing | Direct Effects (Additional spending by households) | 162.9 | $8,431,214 | $15,507,498 | $24,984,058 |
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 57.9 | $3,976,206 | $6,602,975 | $11,109,207 |
| | Induced Effect (Spending by employees of businesses experiencing “indirect” effects) | 66.3 | $3,702,273 | $6,624,507 | $10,815,014 |
| | **Total Submeasure Impacts** | **287.1** | **$16,109,693** | **$28,734,981** | **$46,908,279** |
| Duct Insulation | Direct Effects (Additional spending by households) | 8.0 | $415,296 | $763,852 | $1,230,638 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 2.9 | $195,856 | $325,242 | $547,205 |
| | Induced Effect (Spending by employees of businesses experiencing "indirect" effects) | 3.3 | $182,363 | $326,303 | $532,714 |
| | **Total Submeasure Impacts** | **14.1** | **$793,514** | **$1,415,397** | **$2,310,558** |
| **Total Economic Impacts** | | **301.2** | **$16,903,207** | **$30,150,378** | **$49,218,837** |

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

#### *4.2.4.1 Creation or Elimination of Jobs*

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 4.2.4 would lead to modest changes in employment of existing jobs.

#### *4.2.4.2 Creation or Elimination of Businesses in California*

As stated in Section 4.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to ductwork requirements , which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes to the California Energy Code.

#### *4.2.4.3 Competitive Advantages or Disadvantages for Businesses in California*

The code changes the Statewide CASE Team is proposing for the 2022 code cycle would apply to all businesses operating in California, regardless of whether the business is located inside or outside of the state.[24] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

#### 4.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[25] As Table 103 shows between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, and the average was 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

**Table 103: Net Domestic Private Investment and Corporate Profits, U.S.**

| Year | Net Domestic Private Investment by Businesses, Billions of Dollars | Corporate Profits After Taxes, Billions of Dollars | Ratio of Net Private Investment to Corporate Profits |
|---|---|---|---|
| 2015 | 609.245 | 1,740.349 | 35% |
| 2016 | 455.980 | 1,739.838 | 26% |
| 2017 | 509.276 | 1,813.552 | 28% |
| 2018 | 618.247 | 1,843.713 | 34% |
| 2019 | 580.849 | 1,826.971 | 32% |
| | | **5-Year Average** | **31%** |

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

The estimated increase in investment in California is $1.1 million. The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in

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[24] Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for CA businesses currently doing business in the state.

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

investment by California businesses by multiplying the sum of Business Income estimated in Table 101 and Table 102 above by 31 percent.

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

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

**Cost of Enforcement**

*Cost to the State*

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. Because the proposed code change applies to residential buildings alone, impact to state buildings is not expected.

*Cost to Local Governments*

All revisions to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 3.1.5 and Appendix F, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

#### 4.2.4.6 Impacts on Specific Persons

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team does not expect that the proposed submeasures would result in negative impacts on specific persons.

## 4.3 Energy Savings

The submeasure to revise the 40-foot trigger for prescriptive duct sealing and insulation eliminates an exception to the primary code requirements. The Statewide CASE Team interprets this type of change as not requiring a cost effectiveness justification. The cost effectiveness analysis that was conducted when the prescriptive duct requirements were first added for the 2005 code cycle did not depend on this exception to demonstrate cost effectiveness; the measure was cost effective regardless of the length of ductwork added to the existing system. Therefore, energy savings and cost effectiveness analysis are not presented for this submeasure.

Sections 4.3 through 4.5 are presented for the reduction in duct leakage target and increase to duct insulation measures only.

As of the Draft CASE Report's date of publication, the Energy Commission has not released the final 2022 TDV factors that are used to evaluate TDV energy savings and cost effectiveness. The energy and cost analysis presented in this report used the TDV factors that were released in the 2022 CBECC-Res research version that was released in December 2019. These TDV factors were consistent with the TDV factors that the Energy Commission presented during their public workshop on compliance metrics held October 17, 2019 (California Energy Commission 2019). The electricity TDV factors did not include the 15 percent retail adder and the natural gas TDV factors did not include the impact of methane leakage on the building site, updates that the Energy Commission presented during their workshop on March 27, 2020. Presentations from Bruce Wilcox and NORESCO during the March 27, 2020 workshop indicated that the 15 percent retail adder and methane leakage would result in most energy efficiency measures having slightly higher TDV energy and energy cost savings than using the TDV factors without these refinements. As a result, the TDV energy savings presented in this report are lower than the values that would have been obtained using TDV with the 15 percent retail adder and methane leakage, and the proposed code changes would be more cost effective using the revised TDV. The Energy Commission notified the Statewide CASE Team on April 21, 2020 that they were investigating further refinements to TDV factors using 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. It is anticipated that the 20-year GWP values may increase the TDV factors slightly making proposed changes that improve energy efficiency more cost effective. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

When the Energy Commission releases the final TDV factors, the Statewide CASE Team will consider the need to re-evaluate energy savings and cost-effectiveness analyses using the final TDV factors for the results that will be presented in the Final CASE Report.

The Energy Commission is developing a source energy metric (energy design rating or EDR 1) for the 2022 code cycle. As of the date this Draft CASE Report was published, the source energy metric has not been finalized and the Energy Commission has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

### 4.3.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relies on results of California Building Energy Code Compliance (CBECC) software simulations to estimate energy use for single family and multifamily prototype buildings. Various scenarios were evaluated comparing different duct insulation values against a range of basecase conditions (primarily HVAC system efficiency). The prototypes evaluated are mixed-fuel with natural gas used for space heating, water heating, cooking, and clothes drying represent the majority of existing residential buildings (see Appendix H for further details). All sixteen climate zones were evaluated, even though ultimately the submeasure is recommended only in a subset of climate zones based on the cost effectiveness results and efforts to align the alteration requirements with those for new construction.

### 4.3.2 Energy Savings Methodology

#### *4.3.2.1 Energy Savings Methodology per Prototypical Building*

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. These prototypes represent new construction buildings and therefore in some cases the prototypes were revised to better reflect the existing building stock relative to new construction. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 104. Refer to Appendix H for further details on the prototypes.

This duct sealing proposal impacts single family building only while the duct insulation proposal impacts single family and multifamily buildings. In addition to the single family alteration prototype the duct insulation measure was evaluated for the low-rise garden multifamily prototype which includes an unconditioned attic. The low-rise loaded corridor prototype was not evaluated because the energy savings and cost effectiveness are expected to be very similar to the low-rise garden prototype.

**Table 104: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis**

| Prototype Name | Number of Stories | Floor Area (square feet) | Description | Measures evaluated |
|---|---|---|---|---|
| Single Family Alteration | 1 | 1,665 | Single story house with attached garage. 8-ft ceilings. Steep-slope roof above attic with ducts in attic. | Prescriptive duct insulation, duct sealing |
| Low-Rise Garden Multifamily | 2 | 6,960 | 2-story, 8-unit apartment building. Average dwelling unit size: 870 ft2. Individual HVAC & DHW systems. Steep-slope roof above attic with ducts in attic. | Prescriptive duct insulation |

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of the CBECC software for residential buildings (CBECC-Res for low-rise residential (California Energy Commission 2019c)).

CBECC-Res generates two models based on user inputs: the Standard Design and the Proposed Design.[26] The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Residential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building.

There is an existing Title 24, Part 6 requirement that covers the building system in question, so the Standard Design is minimally compliant with the 2019 Title 24 requirements with two exceptions for alterations. For single family buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one aspect. The existing condition building infiltration assigned to the

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[26] 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.

existing home (10 ACH50) is not reflected in the CBECC-Res Standard Design calculation per the ACM Reference Manual rules. For multifamily buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. Ductwork was located within the vented attic, which is common for this building type, while the CBECC-Res Standard Design for multifamily buildings assumes that ductwork is located within conditioned space. Therefore, two simulations were conducted for each submeasure: one to represent the revised Standard Design and another to represent the Proposed Design. Refer to Appendix H for additional details.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 105 and Table 106 describe precisely which parameters were modified and what values were used in the Standard Design and Proposed Design.

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

**Table 105: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Duct Sealing**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration | All | Distribution System: Duct Leakage | 15% | 10% |

**Table 106: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Duct Insulation**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration & Low-Rise Garden Multifamily | 1-2, 4, 8-10, 12-13 | Distribution System: Duct Insulation R-value | 6.0 | 8.0 |

CBECC-Res calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). CBECC-Res also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars.

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 TDV factors when calculating energy and energy cost impacts.

Per unit energy impacts for single family buildings are presented in savings per prototype building. Per-unit energy impacts for multifamily buildings are presented in savings per dwelling unit. Annual energy and peak demand impacts for each prototype building were translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building.

#### *4.3.2.2 Statewide Energy Savings Methodology*

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2019d). The Statewide Construction Forecasts estimate the size of the total existing building stock by building type and climate zone in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. In order to translate per unit savings to statewide energy impacts, The Statewide CASE Team conducted research to determine appropriate weighting factors for each submeasure. Table 107 and Table 108 present the prototypical buildings and weighting factors used for the duct sealing and duct insulation submeasures, respectively. The percent of building type represented by prototype is 100 percent for single family since there is only a single prototype. The portion of multifamily impacted is based on the portion of total California multifamily dwelling units in buildings three stories or less, according to the CoStar database (CoStar 2018). The percent of prototype impacted by the proposed code change is estimated based on CalCERTS data (CalCERTS 2020). Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

**Table 107: Residential Building Types and Associated Prototype Weighting for the Duct Sealing Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.357% | 0.357% |

**Table 108: Residential Building Types and Associated Prototype Weighting for the Duct Insulation Submeasure**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.067% | 0.067% |
| Multifamily | Low-Rise Garden | 84% | 0.002% | 0.002% |

### 4.3.3 Per-Unit Energy Impacts Results

#### *4.3.3.1 Prescriptive Duct Sealing*

Energy savings and peak demand reductions per unit are presented in Table 109. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For single family homes per-unit savings for the first year are expected to range from 8 to 631 kWh/yr and 1 to 38 therms/yr depending upon climate zone. Demand reductions/increases are expected to range between 0 kW and 0.238 kW depending on climate zone.

**Table 109: Duct Leakage First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 22 | 0.000 | 25.0 | 9,157 |
| 2 | 40 | 0.016 | 12.6 | 9,690 |
| 3 | 10 | 0.002 | 9.4 | 4,362 |
| 4 | 85 | 0.066 | 7.3 | 9,324 |
| 5 | 8 | 0.000 | 8.4 | 3,347 |
| 6 | 44 | 0.033 | 2.3 | 3,646 |
| 7 | 42 | 0.028 | 1.4 | 2,314 |
| 8 | 100 | 0.042 | 3.1 | 9,207 |
| 9 | 102 | 0.105 | 4.7 | 8,924 |
| 10 | 146 | 0.062 | 6.5 | 10,623 |
| 11 | 266 | 0.167 | 18.1 | 20,246 |
| 12 | 111 | 0.075 | 13.5 | 12,504 |
| 13 | 289 | 0.209 | 9.7 | 17,399 |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 14 | 242 | 0.105 | 18.3 | 20,846 |
| 15 | 631 | 0.238 | 2.0 | 26,141 |
| 16 | 82 | 0.040 | 37.7 | 15,518 |

### 4.3.3.2 Prescriptive Duct Insulation

Energy savings and peak demand reductions per unit are presented in Table 110 through Table 111. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For single family homes per-unit savings for the first year are expected to range from 5 to 67 kWh/yr and 1 to 6 therms/yr depending upon climate zone. Demand reductions/increases are expected to range between 0 kW and 0.040 kW depending on climate zone.

**Table 110: Duct Insulation First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 5 | 0.000 | 5.5 | 2,015 |
| 2 | 10 | 0.007 | 2.8 | 2,131 |
| 3 | N/A | N/A | N/A | N/A |
| 4 | 24 | 0.018 | 1.9 | 2,547 |
| 5 | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A |
| 8 | 27 | 0.018 | 0.8 | 2,181 |
| 9 | 28 | 0.029 | 1.2 | 2,331 |
| 10 | 37 | 0.024 | 1.7 | 2,631 |
| 11 | N/A | N/A | N/A | N/A |
| 12 | 29 | 0.012 | 3.1 | 3,696 |
| 13 | 67 | 0.040 | 2.3 | 4,762 |
| 14 | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A |

Table 111: Duct Insulation First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 2 | 0.000 | 2.9 | 1,044 |
| 2 | 8 | 0.001 | 1.5 | 1,488 |
| 3 | N/A | N/A | N/A | N/A |
| 4 | 16 | 0.011 | 0.9 | 1,401 |
| 5 | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A |
| 8 | 19 | 0.014 | 0.4 | 1,148 |
| 9 | 19 | 0.018 | 0.7 | 1,209 |
| 10 | 24 | 0.010 | 0.9 | 1,496 |
| 11 | N/A | N/A | N/A | N/A |
| 12 | 18 | 0.010 | 1.7 | 1,810 |
| 13 | 39 | 0.022 | 1.3 | 2,384 |
| 14 | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A |

## 4.4 Cost and Cost Effectiveness

### 4.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures). The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 30 years. TDV energy cost factors of 0.173 2023 PV$/kBtu and 0.173 Nominal$/kBtu were applied.

### 4.4.2 Energy Cost Savings Results

#### *4.4.2.1 Prescriptive Duct Sealing*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 112.

Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

**Table 112: Duct Leakage 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $115 | $1,469 | $1,584 |
| 2 | $910 | $766 | $1,676 |
| 3 | $190 | $565 | $755 |
| 4 | $1,167 | $446 | $1,613 |
| 5 | $72 | $507 | $579 |
| 6 | $490 | $141 | $631 |
| 7 | $314 | $86 | $400 |
| 8 | $1,406 | $187 | $1,593 |
| 9 | $1,256 | $288 | $1,544 |
| 10 | $1,440 | $398 | $1,838 |
| 11 | $2,402 | $1,100 | $3,503 |
| 12 | $1,345 | $818 | $2,163 |
| 13 | $2,422 | $588 | $3,010 |
| 14 | $2,492 | $1,115 | $3,606 |
| 15 | $4,401 | $121 | $4,522 |
| 16 | $432 | $2,253 | $2,685 |

#### *4.4.2.2 Prescriptive Duct Insulation*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 113 through Table 114. Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 113: Duct Insulation 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $26 | $323 | $349 |
| 2 | $202 | $167 | $369 |
| 3 | N/A | N/A | N/A |
| 4 | $328 | $112 | $441 |
| 5 | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $328 | $49 | $377 |
| 9 | $328 | $75 | $403 |
| 10 | $351 | $104 | $455 |
| 11 | N/A | N/A | N/A |
| 12 | $452 | $187 | $639 |
| 13 | $686 | $138 | $824 |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

Table 114: Duct Insulation 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $11 | $170 | $181 |
| 2 | $167 | $90 | $257 |
| 3 | N/A | N/A | N/A |
| 4 | $187 | $56 | $242 |
| 5 | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $175 | $24 | $199 |
| 9 | $169 | $41 | $209 |
| 10 | $203 | $56 | $259 |

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 11 | N/A | N/A | N/A |
| 12 | $208 | $105 | $313 |
| 13 | $330 | $83 | $412 |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

### 4.4.3 Incremental First Cost

#### *4.4.3.1 Prescriptive Duct Sealing*

Incremental costs for this measure reflect additional labor that may be required to conduct sealing above and beyond typical practice to meet the lower duct leakage target of 10 percent of system airflow. Feedback on how many hours may be typically required was provided during stakeholders interviews. Some projects would meet 10 percent without any additional work. Others would require that the contractors address additional areas of the duct system to meet the 10 percent. Still others would not be able to achieve the 10 percent due to inaccessible ducts and the contractors would be required to perform a smoke test with the HERS rater.

For a typical single family project it is estimated that 2 hours of additional labor would be required at an hourly rate of $120 per hour for a total incremental labor cost of $240. $20 or material is included for a total cost of $260 per home.

#### *4.4.3.2 Prescriptive Duct Insulation*

Incremental costs for this measure reflect the difference between R-6 and R-8 for flexible duct. Estimated costs are based on data collected from online product research from distributor and big box store websites. Cost data was also requested from stakeholders during interviews and meetings, but no concrete cost data was provided.

The estimated incremental cost used in this analysis is $0.49 per square foot of duct surface area for material. This is based on a cost of $0.43 per square foot for an average of 6-inch, 8-inch, and 12-inch duct, less a 10 percent discount to reflect contractor pricing. A 25 percent overhead and profit markup is then added to the top of this reduced price. There is no incremental labor cost for this measure. Table 115 summarizes the total cost for the single family and low-rise multifamily prototypes and the assumptions for supply duct surface area. Duct surface area is based on the 2019 Residential ACM Reference Manual which specifies that supply duct surface area is calculated as 0.27 times the floor area for single story buildings or units. This analysis assumes that the entire duct system is replaced and upgraded to R-8 duct insulation.

**Table 115: First Cost Summary for Duct Insulation**

| | Single Family | Multifamily (per unit) |
|---|---|---|
| Incremental cost per square foot of duct surface area | $0.489 | $0.489 |
| Square foot of duct surface area | 450 | 235 |
| ***Total Incremental First Cost*** | ***$220*** | ***$115*** |

### 4.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the $n^{th}$ year is calculated as follows:

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

#### *4.4.4.1 Prescriptive Duct Sealing*

There are no incremental maintenance or replacement costs associated with this measure. While the duct system would likely need to be replaced within the 30-year period of analysis, duct sealing would be required as part of the new duct system installation.

#### *4.4.4.2 Prescriptive Duct Insulation*

It's expected that the duct system would need to be replaced over the 30-year period of analysis at year 20. The present value of the replacement cost at year 20 is calculated and based on an incremental first cost of $0.49 per square foot of duct surface area. At the end of the 30-year period of analysis there are 10 years of useful life remaining for the duct system. The value of this is calculated and subtracted from the total present value of the cost of the system. The total present value of the incremental cost for this code change proposal is $0.66 per square foot of duct surface area, see Table 116 for details. There is no difference in regular maintenance between the two system types.

**Table 116: Duct Insulation Summary of Replacement Cost**

| | **R-8 vs R-6 Duct Insulation** (per square foot of duct surface area) |
|---|---|
| Incremental First Cost | $0.49 |
| Present Value of Replacement Cost at Year 20 | $0.27 |
| Present Value of Remaining Useful Life at Year 30 | -$0.10 |
| ***Total Present Value of Incremental Cost*** | ***$0.66*** |

### 4.4.5 Cost Effectiveness

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

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the 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 2023 PV costs and cost savings.

#### *4.4.5.1 Prescriptive Duct Sealing*

Results of the per-unit cost-effectiveness analyses are presented in Table 117. The proposed measure saves money over the 30-year period of analysis in all cases.

**Table 117: Duct Leakage 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| **Climate Zone** | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | **Benefit-to-Cost Ratio** |
|---|---|---|---|
| 1 | $1,584 | $260 | 6.09 |
| 2 | $1,676 | $260 | 6.45 |
| 3 | $755 | $260 | 2.90 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 4 | $1,613 | $260 | 6.20 |
| 5 | $579 | $260 | 2.23 |
| 6 | $631 | $260 | 2.43 |
| 7 | $400 | $260 | 1.54 |
| 8 | $1,593 | $260 | 6.13 |
| 9 | $1,544 | $260 | 5.94 |
| 10 | $1,838 | $260 | 7.07 |
| 11 | $3,503 | $260 | 13.47 |
| 12 | $2,163 | $260 | 8.32 |
| 13 | $3,010 | $260 | 11.58 |
| 14 | $3,606 | $260 | 13.87 |
| 15 | $4,522 | $260 | 17.39 |
| 16 | $2,685 | $260 | 10.33 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

#### *4.4.5.2 Prescriptive Duct Insulation*

Results of the per-unit cost-effectiveness analyses are presented in Table 118 through Table 119. The proposed measure saves money over the 30-year period of analysis in all climate zones where it is proposed.

**Table 118: Duct Insulation 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $349 | $296 | 1.18 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 2 | $369 | $296 | 1.24 |
| 3 | N/A | N/A | N/A |
| 4 | $441 | $296 | 1.49 |
| 5 | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $377 | $296 | 1.27 |
| 9 | $403 | $296 | 1.36 |
| 10 | $455 | $296 | 1.54 |
| 11 | N/A | N/A | N/A |
| 12 | $639 | $296 | 2.16 |
| 13 | $824 | $296 | 2.78 |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 119: Duct Insulation 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $181 | $155 | 1.17 |
| 2 | $257 | $155 | 1.66 |
| 3 | N/A | N/A | N/A |
| 4 | $242 | $155 | 1.57 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 5 | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $199 | $155 | 1.28 |
| 9 | $209 | $155 | 1.35 |
| 10 | $259 | $155 | 1.67 |
| 11 | N/A | N/A | N/A |
| 12 | $313 | $155 | 2.02 |
| 13 | $412 | $155 | 2.66 |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

## 4.5 First-Year Statewide Impacts

### 4.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 4.3.3, by assumptions about the percentage of existing buildings that would be impacted by the proposed code. The statewide existing building forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of existing buildings that would be impacted by the proposal (by climate zone and building type).

#### *4.5.1.1 Prescriptive Duct Sealing*

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

Table 120 presents the first-year statewide energy and energy cost savings by climate zone.

**Table 120: Duct Leakage Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | 156 | 0.00 | 0.00 | 0.00 | $0.25 |
| 2 | 928 | 0.04 | 0.02 | 0.01 | $1.56 |
| 3 | 3,437 | 0.04 | 0.01 | 0.03 | $2.59 |
| 4 | 1,746 | 0.15 | 0.11 | 0.01 | $2.82 |
| 5 | 340 | 0.00 | 0.00 | 0.00 | $0.20 |
| 6 | 2,103 | 0.09 | 0.07 | 0.00 | $1.33 |
| 7 | 1,744 | 0.07 | 0.05 | 0.00 | $0.70 |
| 8 | 3,260 | 0.33 | 0.14 | 0.01 | $5.19 |
| 9 | 4,416 | 0.45 | 0.47 | 0.02 | $6.82 |
| 10 | 3,723 | 0.55 | 0.23 | 0.02 | $6.84 |
| 11 | 1,134 | 0.30 | 0.19 | 0.02 | $3.97 |
| 12 | 4,549 | 0.50 | 0.34 | 0.06 | $9.84 |
| 13 | 2,187 | 0.63 | 0.46 | 0.02 | $6.58 |
| 14 | 844 | 0.20 | 0.09 | 0.02 | $3.04 |
| 15 | 600 | 0.38 | 0.14 | 0.00 | $2.71 |
| 16 | 329 | 0.03 | 0.01 | 0.01 | $0.88 |
| **TOTAL** | **31,497** | **3.76** | **2.32** | **0.26** | **$55.33** |

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

#### *4.5.1.2 Prescriptive Duct Insulation*

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

Table 121 presents the first-year statewide energy and energy cost savings by climate zone.

**Table 121: Duct Insulation Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family and multifamily: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | 45 | 0.00 | 0.00 | 0.00 | $0.02 |
| 2 | 266 | 0.00 | 0.00 | 0.00 | $0.10 |
| 3 | N/A | N/A | N/A | N/A | N/A |
| 4 | 503 | 0.01 | 0.01 | 0.00 | $0.22 |
| 5 | N/A | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 938 | 0.03 | 0.02 | 0.00 | $0.35 |
| 9 | 1,283 | 0.04 | 0.04 | 0.00 | $0.51 |
| 10 | 1,065 | 0.04 | 0.03 | 0.00 | $0.48 |
| 11 | N/A | N/A | N/A | N/A | N/A |
| 12 | 1,303 | 0.04 | 0.02 | 0.00 | $0.83 |
| 13 | 625 | 0.04 | 0.02 | 0.00 | $0.51 |
| 14 | N/A | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A | N/A |
| **TOTAL** | **6,027** | **0.19** | **0.13** | **0.01** | **$3.02** |

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

### 4.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard goal of 33 percent renewable electricity generation by 2020.[27] Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix D for additional details on the methodology used to calculate GHG emissions.

Table 122 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 2,420 metric tons of carbon dioxide equivalents (Metric TonnesCO2e) would be avoided.

**Table 122: First-Year Statewide GHG Emissions Impacts**

| Measure | Electricity Savings[a] (GWh/yr) | Reduced GHG Emissions from Electricity Savings[a] (Metric TonnesCO2e) | Natural Gas Savings[a] (million therms/yr) | Reduced GHG Emissions from Natural Gas Savings[a] (Metric TonnesCO2e) | Total Reduced $CO_2e$ Emissions[a,b] (Metric TonnesCO2e) |
|---|---|---|---|---|---|
| Duct Sealing | 3.76 | 904 | 0.26 | 1,407 | 2,311 |
| Duct Insulation | 0.19 | 46 | 0.01 | 62 | 109 |

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

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

### 4.5.3 Statewide Water Use Impacts

The proposed submeasures would not result in water savings.

### 4.5.4 Statewide Material Impacts

The proposed submeasures would not result in impacts on the use of toxic or energy intensive materials.

[27] When evaluating the impact of increasing the Renewable Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020, the California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

### 4.5.5 Other Non-Energy Impacts

In addition to energy savings, duct sealing improves occupant comfort and indoor air quality. Reducing leakage in ductwork results in more conditioned air being directed where it is designed to go, more quickly responding to calls for heating or cooling and providing comfort to occupants. Return duct leakage can also transfer indoor pollutants if the return ducts pass through an area where there is a pollutant source, particularly if the air filter is upstream of the leak. In multifamily buildings duct leakage can also contribute to air transfer from ducts in interstitial spaces across multiple units.

## 4.6 Proposed Revisions to Code Language

### 4.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

### 4.6.2 Standards

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

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

**EXCEPTION 5 to Section 150.2(a): Space-Conditioning System Ducts**. When ducts are extended from an existing duct system to serve the addition, the existing duct system and the extended ducts shall meet the applicable requirements specified in Section 150.2(b)1Di and 150.2(b)1Dii, regardless of the length of the extended ducts.

(b) **Alterations.** Alterations to existing low-rise residential buildings or alterations in conjunction with a change in building occupancy to a low-rise 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 Section 150.0(a) through (l); 150.0(m)1 through 150.0 (m)10, Section 150.0(o) through (q); and

   D. **Altered Duct Systems - Duct Sealing**: In all Climate Zones, when more than 25~~40~~ feet of new or replacement space-conditioning system ducts are installed, the ducts shall comply with the applicable requirements of subsections i and ii below. Additionally, when altered ducts, air-handling units, cooling or heating coils, or plenums are located in garage spaces, the system shall comply with subsection 150.2(b)1Diic regardless of the length of any new or replacement space-conditioning ducts installed in the garage space.

i. New ducts located in unconditioned space shall meet the applicable requirements of Sections 150.0(m)1 through 150.0(m)10~~11~~, and the duct insulation requirements of TABLE 150.2-A, and

*TABLE 150.2-A DUCT INSULATION R-VALUE*

| **Climate Zone** | 3, 5 through 7~~1 through 10, 12&13~~ | 1, 2, 4, 8 through 16~~11, 14 through 16~~ |
|---|---|---|
| **Duct R-Value** | R-6 | R-8 |

ii. The altered duct system, regardless of location, shall be sealed as confirmed through field verification and diagnostic testing in accordance with all applicable procedures for duct sealing of altered existing duct systems as specified in the Reference Residential Appendix RA3.1, utilizing the leakage compliance criteria specified in Subsection a or b below.

b. **Extension of an Existing Duct System**. If the new ducts are an extension of an existing duct system serving single family or multifamily dwellings, the combined new and existing duct system shall meet one of the following requirements:

I. The measured duct leakage shall be equal to or less than 10 percent for single family buildings and 15 percent for multifamily buildings of ~~nominal~~ system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1; or

II. The measured duct leakage to outside shall be equal to or less than 7 percent for single family buildings and 10 percent for multifamily buildings of ~~nominal~~ system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4; or

E. **Altered Space-Conditioning System - Duct Sealing:** In all Climate Zones, when a space-conditioning system serving a single family or multifamily dwelling is altered by the installation or replacement of space-conditioning system equipment, including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil; the duct system that is connected to the altered space-conditioning system equipment shall be sealed, as confirmed through field verification and diagnostic testing in accordance with the applicable procedures for duct sealing of altered existing duct systems as specified in Reference Residential Appendix RA3.1 and the leakage compliance criteria specified in subsection i, ii, or iii below. Additionally, when altered ducts, air-handling units, cooling or heating coils, or plenums are located in garage spaces, the system shall comply with Section 150.2(b)1Diic regardless of the length of any new or replacement space-conditioning ducts installed in the garage space.

i. The measured duct leakage shall be equal to or less than 10 percent for single family buildings and 15 percent for multifamily buildings of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1; or

ii. The measured duct leakage to outside shall be equal to or less than 7 percent for single family buildings and 10 percent for multifamily buildings of system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4; or

### 4.6.3 Reference Appendices

#### RA3.1.4.2 Determining Air Handler Airflow for Calculation of Duct Leakage Rate Compliance Targets

For use in establishing the target duct leakage rate compliance criteria, the system air handler airflow shall be calculated using RA3.1.4.2.1, RA3.1.4.2.2, or RA3.1.4.2.3 if measured system airflow is available. If measured system airflow is not available, the system air handler airflow shall be calculated using RA3.1.4.2.1 or RA3.1.4.2.2.

### 4.6.4 ACM Reference Manual

#### 2 Proposed, Standard, and Reference Design

#### 2.10 Additions/Alterations

#### 2.10.4.9 Duct System

#### STANDARD DESIGN

**Table 33: Addition Standard Design for Duct Systems**

| Proposed Design Duct System Type | Standard Design Based on Proposed Duct System Status | |
|---|---|---|
| | No Verification of Existing Conditions Extending Existing Ducts | Verified Existing ConditionsAltered |
| Altered or Extended Ducts >25ftAll Single Family | CZ 3, 5-71-10, 12-13: Duct insulation R-6 and duct leakage of 10% (single family) or 15% (multifamily)sealing < 15%<br>CZ 1-2, 4, 8-1611, 14-16: Duct insulation R-8 and duct leakage of 10% (single family) or 15% (multifamily)sealing < 15% | Existing duct R-value and duct leakage the lesser of 30% or the existing leakage rate of 15% |
| New Ducts | CZ 1-2, 4, 8-16: Duct insulation R-8 and duct sealing <leakage of 5% (single family) or 12% (multifamily)<br>CZ 3, 5-7: Duct insulation R-6 and duct sealing <leakage of 5% (single family) or 12% (multifamily) | N/A |

**PROPOSED DESIGN**

Duct insulation shall be based on the new or replacement R-value input by the user. Duct leakage shall be based on the tested duct leakage rate entered by the user or a default rate of 30 percent.

### 4.6.5 Compliance Manuals

Chapter 9 of the Residential Compliance Manual would need to be revised. Section 9.2 What's New in the 2019 Energy Standards would need to be updated to describe the proposed code changes. In addition, Section 9.4.6 HVAC System Alterations would need to updated, see below for suggested updates.

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

**9.4.6 HVAC System Alterations**

If the heating and cooling system is unchanged as part of an addition or alteration, compliance for the HVAC system is not necessary. Changing, altering, or replacing any component of a system often triggers a requirement to seal the ducts. A HERS Rater verifies the duct leakage is less than 10 percent for single family buildings and 15 percent for multifamily buildings. However, since the ducts are existing, if ~~15 percent~~the leakage target leakage is not feasible, there are alternatives, including all accessible leaks being sealed and confirmed by a visual inspection (Section 150.2(b)1E).

Extending ducts to condition an addition is not an alteration, however it does require duct leakage requirements per Section 150.2(b)1D regardless of the length or location of the new ductwork~~if more than 40 feet of new ductwork is installed in unconditioned space, Section 150.2(b)1D contains duct leakage requirements~~.

9.4.6.1 HVAC "Changeouts"

**C. New and Altered Duct System – Insulation**

When ~~any~~ more than 25 linear feet of new ducts are installed in an unconditioned space, the duct must be insulated to a minimum R-value as described in Table 9-11.

Table 9-11: Duct Minimum R-Value

| Climate Zone | 3 & 5 -7~~1 -10, 12 & 13~~ | 1, 2, 4, & 8 - 16~~11, 14 - 16~~ |
|---|---|---|
| Duct R-Value | R-6 | R-8 |

When ~~more than 40 linear feet of~~ ducts are installed in conditioned space, the ducts must be insulated to the minimum mandatory insulation level of R-4.2 and be verified to be in conditioned space by both visual verification and diagnostic testing in accordance to RA3.1.4.3.8. When ducts are installed in conditioned space but without verification in accordance to RA3.1.4.3.8, the requirements for ducts in unconditioned space must be met.

### 4.6.6 Compliance Documents

Compliance document CF1R-ALT-02-E would need to be revised. The language in subsections B, C, and D would need to changed to replace references to 40 feet of duct with 25 feet of duct and also specify that all extended systems serving additions are required to meet the prescriptive duct sealing and duct insulation requirements.

Compliance document CF2R-MCH-01-H would need to be revised. The language in subsections B and D would need to changed to replace references to 40 feet of duct with 25 feet of duct and also specify that all extended systems serving additions are required to meet the prescriptive duct sealing and duct insulation requirements.

# 5. Attic Insulation

## 5.1 Measure Description

### 5.1.1 Measure Overview

This is a submeasure of the CASE Report that covers two prescriptive code change proposals for attic insulation, one for alterations and another for additions. The two submeasures proposed are described below.

These measures apply to all low-rise residential buildings including single family and multifamily. Both submeasures would require updates to the compliance software for existing plus addition plus alteration and addition alone analysis.

#### *5.1.1.1 Attic Insulation for Alterations*

This submeasure adds a prescriptive requirement for ceiling insulation and air sealing for altered ceilings below a vented attic. Currently, the only requirement for an altered ceiling for low-rise buildings is that the mandatory requirements for R-19 ceiling insulation in Section 150.0 be met. This submeasure proposes to add a prescriptive requirement that increases the insulation value to R-49 and requires air sealing components. All accessible areas of the ceiling plane between the attic and the conditioned space shall be sealed in accordance with Section 110.7 of the standards. Recessed downlight luminaires in the ceiling must be covered with insulation to the same depth as the rest of the attic. This requires that fixtures that are not rated for Insulation Contact (IC) be retrofit or a fire rated cover be installed over the attic side of the fixture. If attic ventilation does not already comply with CBC requirements, ventilation must be added to meet code minimums.

This code change further clarifies that when an entirely new or complete replacement duct system is installed in a vented attic space, this constitutes an altered ceiling and the proposed attic insulation and air sealing requirements apply.

Table 123 describes the existing and proposed requirements by climate zone for this submeasure. Cost effectiveness analysis evaluated various packages of measures relative to a R-11 and R-19 attic insulation base case and identified which components of the proposal should be required in each climate zone. It also demonstrated that in cases where buildings have an existing level of attic insulation equal to or greater than R-19, the costs associated with removing the existing insulation and air sealing the ceiling floor were too high to justify the energy savings. Therefore, the air sealing related aspects of this proposal are excluded for these buildings. In some cases, the recessed cans and adding the R-49 attic insulation requirements were excluded when the costs associated with adding these measures were also found to be higher than could be justified by the energy savings. See Appendix I for detailed analysis results.

**Table 123: Summary of Existing and Proposed Attic Insulation Requirements for Alterations**

| Climate Zones | Existing | Proposed Building with < R-19 existing attic insulation | Proposed Building with ≥ R-19 existing attic insulation |
|---|---|---|---|
| Single Family | | | |
| 5, 7 | R-19 | R-19 | R-19 |
| 6 | R-19 | R-49 | R-19 |
| 1, 3 | R-19 | R-49 & recessed cans | R-19 |
| 2, 4, 8-10 | R-19 | R-49 & recessed cans & air sealing | R-49 |
| 11-16 | R-19 | R-49 & recessed cans & air sealing | R-49 & recessed cans |
| Multifamily | | | |
| 5-7 | R-19 | R-19 | R-19 |
| 1, 3, 4 | R-19 | R-49 & recessed cans | R-19 |
| 9 | R-19 | R-49 & recessed cans | R-19 |
| 8, 10 | R-19 | R-49 & recessed cans | R-49 |
| 2 | R-19 | R-49 & recessed cans & air sealing | R-49 |
| 11-16 | R-19 | R-49 & recessed cans & air sealing | R-49 & recessed cans |

The proposed submeasure includes several additional exceptions, listed below.

- **Buildings with at least R-38 existing attic insulation**
- **Buildings with asbestos or knob and tube wiring located in the attic.**
- Attics with limited vertical height that do not allow the installation of the required insulation R-value may install a lower R-value that maximizes the depth while still meeting code requirements including required air gaps.

#### *5.1.1.2 Attic Insulation for Additions*

This submeasure increases the prescriptive insulation requirement for attics in additions less than or equal to 700 square feet. This change aligns with the requirements for additions greater than 700 square foot as well as with those for new construction in Table 150.1-A and B, Option B, except there is no requirement for roof deck insulation. Table 124 describes the existing and proposed requirements for this submeasure by climate zone.

**Table 124: Summary of Existing and Proposed Attic Insulation Requirements for Additions Less Than or Equal to 700 Square Feet**

| Climate Zones | Existing | Proposed |
|---|---|---|
| 3, 5-7 | R-30 | R-30 |
| 2, 4, 8-10 | R-30 | R-38 |
| 1, 11-16 | R-38 | R-38 |

### 5.1.2 Measure History

Most single family buildings in California have vented attics. The 2009 Residential Appliance Saturation Study (California Energy Commission 2009) estimates that 82 percent of single family homes and 41 percent of multifamily homes have insulated attics. On a hot day, a typical vented attic is hotter than outside and if poorly ventilated the temperature difference between the attic and outdoors can be as high as 45°F (Less, Walker and Levinson 2016). Heat loss or gain through the ceiling is a significant portion of total loss or gains in homes with little or no insulation in the attic. Compared to other envelope assemblies in an existing home, such as walls, attics are a relatively accessible area.

When a new duct system is installed in an attic the work is disruptive of any existing attic insulation. At a minimum, existing insulation must be moved to access certain areas and later replaced. Worst case the attic insulation is disturbed and not fixed resulting in uneven insulation levels across the attic. If new registers are added as part of the scope of work new penetrations in the ceiling plane may be made that need to be properly air sealed. Duct replacement work is completed entirely in the attic representing an ideal time to address the attic as a system, including air sealing the ceiling plane and adding attic insulation.

Increasing insulation levels in vented attics represents a significant savings opportunity and is why the Statewide CASE Team is pursuing this submeasure.

Attic insulation is either batt, loose fill (blown-in), or spray foam and can be made of various materials. Most new or retrofit attics use blown-in fiberglass or cellulose insulation. Blown-in insulation is a loose fill product installed using a blowing machine with a large attached hose. While both blown-in and batt insulation have similar properties, it is much easier to achieve a consistent installation with loose fill since the particles more easily fill in small gaps and hard to reach areas. R-value ratings per inch vary somewhat by product type and across manufacturers. Manufacturers provide coverage charts which specify how many bags of insulation are needed to cover a certain square foot based on the ceiling framing spacing and depth. The charts account for settling of the insulation due to compression under its own weight.

There have never been low-rise residential prescriptive requirements for altered ceilings and attic insulation. This code change proposal adds a new requirement.

There are existing prescriptive requirements for attic insulation for additions in low-rise residential buildings. The current low-rise residential requirements for attic insulation in additions less than or equal to 700 square feet align with new construction standards, Standards Table 150.1-A/B Option C. However, Option C also requires ducts in conditioned space and therefore the ceiling insulation levels are lower than Option B.

### 5.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 5.62.5.5.1 of this report for detailed proposed revisions to code language.

#### *5.1.3.1 Summary of Changes to the Standards*

This proposal would modify the following sections of the California Energy Code as shown below. See Section 5.6.2 of this report for marked-up code language.

**SECTION 110.8 – MANDATORY REQUIREMENTS FOR INSULATION, ROOFING PRODUCTS AND RADIANT BARRIERS**

**Section 110.8(d)1:** Revise the reference for the R-value requirement for existing attics from Section 150.0 to 150.2.

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

**Section 150.2(a)1Bi:** Revise the climate zones where R-38 attic insulation is required.

**Section 150.2(b)1A:** Create a new section called Ceiling Insulation that defines the new prescriptive requirements for altered ceilings.

**Section 150.2(b)1Diia:** Add language to clarify when attic requirements shall be met when replacing duct system located in a vented attic.

#### *5.1.3.2 Summary of Changes to the Reference Appendices*

The proposed code change would not modify the Reference Appendices.

#### *5.1.3.3 Summary of Changes to the Residential ACM Reference Manual*

This proposal would modify the following sections of the Residential ACM Reference Manual as shown below. See Section 5.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

**SECTION 2.10 Additions/Alterations**

**Section 2.10.4.3 Roof/Ceilings:** Update Table 26 to reflect a change to the basis of the Standard Design for ceilings below attics for alterations and additions less than or equal to 700 square feet.

#### 5.1.3.4 Summary of Changes to the Residential Compliance Manual

The proposed code change would modify the following section of the Residential Compliance Manual:

- Section 9.2 What's New in the 2019 Energy Standards
- Section 9.4.4 Envelope Alterations

See Section 5.6.5 of this report for further details.

#### 5.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 5.6.6.

- CF1R-ALT-05-E –Revise subsection A to add a separate Project Scope for attic insulation. Create a new subsection for attic insulation that includes all the columns in current subsection B. Building Insulation Details and adds inputs relative to the air sealing, recessed can, and attic ventilation inputs. Add selections for the allowable exceptions and relevant details.
- CF1R-ALT-02-E would be revised to add a box in Subsection E where the documentation author indicates the location of the entirely new or complete replacement duct system.
- CF2R-ENV-03 – Revise subsection A of the form to include inputs for number of recessed cans retrofit and associated details for the prescriptive air sealing requirements. Revise subsection J to indicate that air sealing must be completed per Section 110.7.
- CF2R-ALT-05-E – Revise subsection B of the form to include inputs for number of recessed cans retrofit and associated details for the prescriptive air sealing requirements. Add a subsection similar to subsection J of the CF2R-ENV-03 which lists the applicable requirement for attic insulation installations and add language to indicate air sealing must be completed per Section 110.7.

### 5.1.4 Regulatory Context

#### 5.1.4.1 Existing Requirements in the California Energy Code

Currently, the only requirement for an altered ceiling below a vented attic is that the mandatory requirements for R-19 ceiling insulation in Section 150.0 of the low-rise residential code be met. There are no relevant existing prescriptive requirements.

The current low-rise residential requirements for attic insulation in additions less than or equal to 700 square feet require R-30 in Climate Zones 2 through 10 and R-38 in Climate Zones 1 and 11 through 16. This aligns with the new construction standards Table 150.1-A Option C and Table 150.2-B Option C for ceiling insulation.

#### *5.1.4.2 Relationship to Requirements in Other Parts of the California Building Code*

Section R806.2 of the 2019 California Residential Code, Title 24, Part 2.5 defines the requirements for minimum attic ventilation. The minimum net free ventilation area for a vented attic shall be 1/150 of the total area of the vented attic. This is allowed to be reduced to 1/300 if two conditions are met: 1) between 40 and 50 percent of the ventilation area is provided by vents located in the upper portion of the attic or rafter space, with the remainder in the bottom one-third of the attic space, and 2) a vapor retarder is installed at the ceiling level in Climate Zones 14 and 16.

Section R806.3 of the 2019 California Residential Code, Title 24, Part 2.5 describes insulation clearances and requires that blocking, bridging and insulation shall not block the free flow of air where eave or cornice vents are installed. A minimum one inch air space must be provided between the insulation and the roof sheathing and at vents.

#### *5.1.4.3 Relationship to Local, State, or Federal Laws*

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

#### *5.1.4.4 Relationship to Industry Standards*

The 2018 IECC (International Code Council 2019) requires that altered ceilings and additions meet new construction standards, which requires R-38 in most areas of California based on the IECC climate zones. R-49 is required is some areas of the mountains and the northern coast.

### 5.1.5 Compliance and Enforcement

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

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

- **Design Phase:** An altered ceiling would be triggered either as part of a complete duct system replacement or when work is conducted in the attic as part of a larger remodel. In the former case, the HVAC contractor typically coordinates the project and would advise the building owner of the associated code requirements. In some cases, HVAC contractors hold a general contractors license and offer a broader set of home performance services such as air sealing and insulation. In many instances the HVAC contractor would not have experience or license to perform the air sealing and insulation work and either the HVAC contractor, general contractor, or the building owner would need to engage an insulation contractor to perform the air sealing and attic insulation work. An energy consultant is often not engaged in these projects, and the HVAC contractor would complete the Certificates of Compliance.

In the case of a large remodel or an addition the primary designer is often either an architect, designer, or general contractor and the project team includes various contractors including an insulation contractor who would perform the air sealing and attic insulation work. The designer corresponds directly with the building owner on the design, recommends levels of insulation, and needs to be aware of Title 24, Part 6 requirements related to the project. It is more likely that an energy consultant may be engaged on this type of project to complete the Certificates of Compliance. If not, the designer or general contractor would be responsible.

- **Permit Application Phase:** The HVAC contractor, architect or general contractor submits the project for permit including the necessary Certificate of Compliance documents. The air sealing component of the proposed submeasure triggers HERS testing; if the duct system is being replaced, HERS testing is also required for mechanical system verifications. If the project is applying for one of the existing insulation R-value exceptions, this also triggers HERS verification of existing conditions and documentation of this must be provided at time of permit application.
- **Construction Phase:** The HVAC contractor or general contractor manages the project construction. In the case of a duct system replacement if the HVAC contractor is unable to perform the air sealing and attic insulation work then an insulation contractor is engaged.
- **Inspection Phase:** The installing contractor would complete the Certificate of Installation and a building inspector conducts a final inspection. A HERS rater would conduct verification of the air sealing requirement and any required HVAC testing and submit Certificates of Verification to a HERS Registry.

For alterations where the new requirement is triggered by a duct system replacement, the compliance process described above differs from the existing compliance process and represents a substantial change to the workflow to which contractors are accustomed. In many cases, new trades would need to be engaged to meet the new code requirements.

The installing contractor needs to ensure that the connection between the vented attic and conditioned space is properly air sealed (per Section 110.7 of the Standards and air sealing requirements in Reference Appendix RA3.5 for altered ceilings), in addition to meeting the minimum attic insulation requirements. They would indicate this has been completed on the Certificate of Installation and a HERS Rater would visually verify the air sealing work with a Certificate of Verification, before insulation is installed. On projects where the duct system is being replaced, the HERS Rater can likely conduct the air sealing, duct leakage testing, and any other required mechanical inspections during the same site visit. This would need to be done before the attic insulation is installed, which is recommended for the duct leakage test so that corrections can be easily made before the insulation is installed, if the system initially fails the duct leakage test. After insulation is installed, the inspector would then verify that the Certificate of Installation and Certificate of Verification are completed adequately, as well as that the attic insulation depth meets the requirements, that attic ventilation meets CBC requirements, and that clearance for attic vents is properly addressed. A HERS Rater inspection is not required to verify final attic insulation depth. If the home has recessed cans the inspector can verify that insulation is installed to full depth above the fixtures and the fixtures have been property retrofitted or covered.

If a project claims one of the existing insulation R-value exceptions, a HERS Rater would need to go on site and verify that the existing insulation meets the requirements of the exception. This involves measuring the depth of the existing insulation and confirming that it meets the minimum R-19 or R-38, depending on the exception and climate zone.

It is possible that the added requirements may result in projects being completed without applying for a permit. This code change should be accompanied by education and outreach programs targeted at contractors, building departments, and building owners. Utility incentive programs throughout the 2019 Title 24, Part 6 code cycle, and perhaps into the 2022 code cycle as well, can encourage early adopters and support a market transformation for insulating and air sealing existing attics. Local reach codes also can play a similar role.

There is a trend towards HVAC contractors offering whole building services including attic insulation and air sealing. This requires that the contractor hold other trade licenses such as a general contractor or insulating contractor license. HVAC contractors that don't have other licenses may be interested in offering the additional services required as part of this submeasure proposal, and the skills that are necessary to perform quality work align well with their existing work scope. Sealing leaks in ductwork and leaks in the attic ceiling plan require similar approaches. Additionally, in the course of replacing HVAC ductwork the contractor would be accessing most areas of the ceiling and providing potential efficiencies to be gained with one contractor performing both scopes of work. Other benefits to addressing air sealing and ceiling insulation when HVAC systems and ductwork are being replaced is the ability to downsize equipment by reducing heating and cooling loads.

For HVAC contractors to be able to conduct attic insulation and air sealing work under a mechanical contractor's license there needs to be a determination made by the Contractors State License Board that this type of work is allowable and incidental to the other work they typically conduct in attics. The Statewide CASE Team recommends that the feasibility of this be investigated further as a way to support HVAC contractors and ensure broad compliance with this proposed submeasure.

## 5.2 Market Analysis

### 5.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

Adding attic insulation in existing homes is seldom completed as a retrofit measure in isolation, it is often done as part of a larger retrofit or triggered based on other project scope. Sometimes it may be specified by an architect or energy consultant in order for a project to meet Title 24, Part 6 compliance via the performance path. Attic insulation and air sealing work is typically included in work done under home performance programs and is work completed either by a general contractor or an insulation contractor, though it can also be done by homeowner as part of a home improvement work scope. There are many contractors familiar with this work statewide.

There are a variety of major manufacturers of attic insulation products. Greenfiber and Insulmax are manufacturers of cellulose loose fill insulation. Owens Corning produces a fiberglass blown-in system called AttiCat. CertainTeed, Johns Manville, and Knauf Insulation are also major manufacturers of fiberglass loose fill insulation. There are various other smaller manufacturers.

HVAC contractors, general contractors, insulation contractors, and building owners are the primary market actors involved with implementing these code change proposals. Other market actors include architects, energy consultants, plans examiners, building inspectors, and manufacturers.

### 5.2.2 Technical Feasibility, Market Availability, and Current Practices

#### *5.2.2.1 Attic Insulation for Alterations*

There are over 13 million existing residential dwelling unit in California (see Appendix A). According to the 2009 Residential Appliance Saturation Study (California Energy Commission 2009) 81 percent of single family existing buildings have insulated attics.

Of those, 82 percent have less than R-19 insulation 21 percent have R-11 insulation or less.

Data from CalCERTS shows that 73 percent of new or altered ceilings in prescriptive alteration and performance alteration/addition projects installed R-30 insulation or less (CalCERTS 2020). The data covers both the 2013 and 2016 code cycles. Only 1 percent of projects installed only R-19 and only 2 percent of project installed greater than R-38.

Data from CalCERTS shows that 21 percent of prescriptive HVAC alteration projects (ALT-02) included a new or replacement duct system (CalCERTS 2020).

The Statewide CASE Team conducted a stakeholder outreach to architects, general contractors, and other industry representatives. Various stakeholders provided feedback that when attic insulation is added it is critical to address other aspects of the attic principally air sealing and duct sealing. If an attic is insulated without first air sealing the ceiling assembly, the opportunity is lost, and sealing can only be performed in the future if the insulation is removed. Air infiltration across the ceiling also reduces the effectiveness of attic insulation.

When present, recessed cans are often a significant contributor to total leakage through the ceiling plane. Old recessed cans are not airtight, and the perimeter may present a path for conditioned air into the attic. If they are not IC rated and insulation is added to the attic floor, dams must be built around each light to keep the insulation away. This degrades the overall performance of the attic and is not allowed in new homes.

Old recessed fixtures that are not IC rated can be retrofitted by replacing the entire assembly with fixtures that are rated to be Insulation Contact and Airtight (IC and AT). Housing units designed for retrofit applications, installed in place of the existing fixture in the attic, are coupled with LED retrofit trim kits, installed at the ceiling. Some older existing fixtures do not have thermal switches, which disconnect the electricity to the light if the temperature exceeds unsafe levels. If a thermal switch is present, a fire-rated attic recessed light cover can be installed. These covers are domes or boxes that are installed over the existing fixture and sealed around the perimeter to the ceiling floor. They are fire rated and insulation can be installed around and over the cover. An example product is the TENMAT[28] and Insullite[29] covers. There are similar products that dam the can but do not allow for insulation to cover the area. If the existing fixture is IC rated but not airtight, an LED retrofit trim kit only needs to be installed.

Other areas of an attic that present sources of air leakage include the following.

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[28] Pleas see https://www.recessedlightcover.com/ for example product.

[29] Please see https://www.isibp.com/products/insullite-recessed-light-covers/ for example product.

- Soffits, dropped ceilings, and chases
- Gaps around chimneys and combustion venting
- Along the top plate
- Electric and plumbing penetrations
- Ceiling mounted duct boots
- Ceiling mounted exhaust fans
- Attic hatches
- Kneewalls

Addressing air leaks in an existing attic requires that any existing insulation be removed or temporarily moved around the attic. Most air sealing can be done with caulking or foam. If larger holes exist, such as at soffits or dropped ceilings, an air barrier needs to be installed if one does not already exist and the perimeter must be secured and fully sealed.

#### *5.2.2.2 Attic Insulation for Additions*

Data from CalCERTS shows that 38 percent of addition only projects installed R-30 insulation or less. (CalCERTS 2020). The data covers both the 2013 and 2016 code cycles. 57 percent of projects installed between R-30 and R-38 insulation. See Table 125 for a breakdown by climate zone group.

**Table 125: Summary of Insulation Levels in Addition Only Performance Projects from 2013 and 2016 Code Cycles in CalCERTS**

| Climate Zones | Current/Proposed Insulation Requirement | % of Additions with Attic Insulation | |
|---|---|---|---|
| | | > R-30 | > R-38 |
| All | N/A | 62% | 5% |
| 3, 5, 7 | R-30/R-30 | 33% | 2% |
| 2, 4, 8-10 | R-30/R-38 | 58% | 2% |
| 1, 11-16 | R-38/R-38 | 92% | 13% |

Source: CalCERTS (CalCERTS 2020)

### 5.2.3 Market Impacts and Economic Assessments

#### *5.2.3.1 Impact on Builders*

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 126).[30] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector, while another 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

**Table 126: California Construction Industry, Establishments, Employment, and Payroll, 2018**

| Construction Sectors | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| **Residential** | **59,287** | **420,216** | **$23.3** |
| Residential Building Construction Contractors | 22,676 | 115,777 | $7.4 |
| Foundation, Structure, & Building Exterior | 6,623 | 75,220 | $3.6 |
| Building Equipment Contractors | 14,444 | 105,441 | $6.0 |
| Building Finishing Contractors | 15,544 | 123,778 | $6.2 |
| **Commercial** | **17,273** | **343,513** | **$27.8** |
| Commercial Building Construction | 4,508 | 75,558 | $6.9 |
| Foundation, Structure, & Building Exterior | 2,153 | 53,531 | $3.7 |
| Building Equipment Contractors | 6,015 | 128,812 | $10.9 |
| Building Finishing Contractors | 4,597 | 85,612 | $6.2 |
| **Industrial, Utilities, Infrastructure, & Other** | **4,103** | **96,550** | **$9.2** |
| Industrial Building Construction | 299 | 5,864 | $0.5 |
| Utility System Construction | 1,643 | 47,619 | $4.3 |
| Land Subdivision | 952 | 7,584 | $0.9 |
| Highway, Street, and Bridge Construction | 770 | 25,477 | $2.4 |
| Other Heavy Construction | 439 | 10,006 | $1.0 |

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

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

The proposed changes to attic insulation requirements for alterations and additions would likely affect residential builders but would not impact commercial builders or firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 127 shows the residential building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. Because the proposed code requirements come only into play for altered ceilings, with duct system replacements in vented attics, and additions, they are expected to impact mechanical contractors, insulation contractors and residential remodelers. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in 5.2.4 5.2.4 Economic Impacts.

**Table 127: Size of the California Residential Building Industry by Subsector, 2018**

| Residential Building Subsector | Establishments | Employment | Annual Payroll (billions $) |
|---|---|---|---|
| Residential Remodelers | 11,122 | 52,133 | $2,973,873,865 |
| Residential plumbing and HVAC contractors | 8,086 | 66,177 | $3,778,328,951 |

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

#### *5.2.3.2 Impact on Building Designers and Energy Consultants*

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Energy Code) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 128 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The code change proposals the Statewide CASE Team is proposing for the 2022 code cycle would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for the residential attic insulation submeasures to affect firms that focus on single family and low-rise multifamily construction.

There is not a North American Industry Classification System (NAICS)[31] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[32] 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 128 provides an upper bound indication of the size of this sector in California.

**Table 128: California Building Designer and Energy Consultant Sectors, 2018**

| Sector | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|
| Architectural Services [a] | 3,704 | 29,611 | $2,906.7 |
| Building Inspection Services [b] | 824 | 3,145 | $223.9 |

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

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

### 5.2.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain in place. Complying with the proposed code change is not

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[31] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

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

anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

#### *5.2.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)*

According to data from the U.S. Census, American Community Survey (ACS), there were nearly 14.3 million housing units in California in 2018 and nearly 13.1 million were occupied (see Table 129). Most housing units (nearly 9.2 million) were single family homes (either detached or attached), while about 2 million homes were in buildings containing two to nine units and 2.5 million were in multifamily building containing 10 or more units. The U.S. Census reported that 59,200 single family and 50,700 multifamily homes were constructed in 2019.

**Table 129: California Housing Characteristics, 2018**

| Housing Measure | Estimate |
|---|---|
| Total housing units | 14,277,867 |
| Occupied housing units | 13,072,122 |
| Vacant housing units | 1,205,745 |
| Homeowner vacancy rate | 1.2% |
| Rental vacancy rate | 4.0% |
| **Units in Structure** | **Estimate** |
| 1-unit, detached | 8,177,141 |
| 1-unit, attached | 1,014,941 |
| 2 units | 358,619 |
| 3 or 4 units | 783,963 |
| 5 to 9 units | 874,649 |
| 10 to 19 units | 742,139 |
| 20 or more units | 1,787,812 |
| Mobile home, RV, etc. | 538,603 |

Source: (2018 American Community Survey n.d.)

Table 130 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999.  The majority of California's existing housing stock (8.5 million homes – 59% 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 130: Distribution of California Housing by Vintage, 2018**

| Home Vintage | Units | Percent | Cumulative Percent |
|---|---|---|---|
| Built 2014 or later | 343,448 | 2.4% | 2.4% |
| Built 2010 to 2013 | 248,659 | 1.7% | 4.1% |
| Built 2000 to 2009 | 1,553,769 | 10.9% | 15.0% |
| Built 1990 to 1999 | 1,561,579 | 10.9% | 26.0% |
| Built 1980 to 1989 | 2,118,545 | 14.8% | 40.8% |
| Built 1970 to 1979 | 2,512,178 | 17.6% | 58.4% |
| Built 1960 to 1969 | 1,925,945 | 13.5% | 71.9% |
| Built 1950 to 1959 | 1,896,629 | 13.3% | 85.2% |
| Built 1940 to 1949 | 817,270 | 5.7% | 90.9% |
| Built 1939 or earlier | 1,299,845 | 9.1% | 100.0% |
| **Total housing units** | **14,277,867** | **100%** | |

Source: (2018 American Community Survey n.d.)

Table 131 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 income below $50,000 is only 37 percent, whereas the owner occupancy rate is 72 percent for households earning $100,000 or more.

**Table 131: Owner- and Renter-Occupied Housing Units in California by Income, 2018**

| Household Income | Total | Owner Occupied | Renter Occupied |
|---|---|---|---|
| Less than $5,000 | 391,235 | 129,078 | 262,157 |
| $5,000 to $9,999 | 279,442 | 86,334 | 193,108 |
| $10,000 to $14,999 | 515,804 | 143,001 | 372,803 |
| $15,000 to $19,999 | 456,076 | 156,790 | 299,286 |
| $20,000 to $24,999 | 520,133 | 187,578 | 332,555 |
| $25,000 to $34,999 | 943,783 | 370,939 | 572,844 |
| $35,000 to $49,999 | 1,362,459 | 590,325 | 772,134 |
| $50,000 to $74,999 | 2,044,663 | 1,018,107 | 1,026,556 |
| $75,000 to $99,999 | 1,601,641 | 922,609 | 679,032 |
| $100,000 to $149,999 | 2,176,125 | 1,429,227 | 746,898 |
| $150,000 or more | 2,780,761 | 2,131,676 | 649,085 |
| **Total Housing Units** | **13,072,122** | **7,165,664** | **5,906,458** |
| **Median household income** | **$75,277** | **$99,245** | **$52,348** |

Source: (2018 American Community Survey n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences and so the counts of housing units by building type shown in Table 129 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 130 and Table 131.

For California residents, the code changes that the Statewide CASE Team is proposing for the 2022 code cycle regulation would result in lower energy bills. When homeowners or building occupants save on energy bills, they tend to spend it elsewhere thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without other necessities to save money for energy bills (Association, National Energy Assistance Directors 2011).]

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

The Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers apart from a slight increase in economic activity for suppliers of insulation and air sealing products due to increased demand.

#### 5.2.3.6 Impact on Building Inspectors

Table 132 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

**Table 132: Employment in California State and Government Agencies with Building Inspectors, 2018**

| Sector | Govt. | Establishments | Employment | Annual Payroll (millions $) |
|---|---|---|---|---|
| Administration of Housing Programs[a] | State | 17 | 283 | $29.0 |
| | Local | 36 | 2,882 | $205.7 |
| Urban and Rural Development Admin[b] | State | 35 | 552 | $48.2 |
| | Local | 52 | 2,446 | $186.6 |

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

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

#### *5.2.3.7 Impact on Statewide Employment*

As described in Sections 5.2.3.1 through 5.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 5.2.4 the Statewide CASE Team estimated how the proposed changes for the attic insulation submeasures 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 changes for the attic insulation submeasures would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

### 5.2.4 Economic Impacts

For the 2022 code cycle, the CASE team used the IMPLAN model software, along with economic information from published sources, and professional judgement to developed estimates of the economic impacts associated with each proposed code changes. [33] While this is the first code cycle in which the CASE team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations  as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts

[33] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the residential building and remodeling industry 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. There may also be some non-residential 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 or have measurable economic impacts. Table 133, Table 134, and Table 135 demonstrate economic impacts based on the estimated additional spending from the proposed submeasures. These figures assume that there would be no reduction in the number of homes completing relevant projects as a direct result of these proposed code changes. Estimated impacts to the residential construction sector and on discretionary spending by residents is based on the incremental cost and energy savings presented in this report for each submeasure. Estimated impacts to building inspectors are based on an increase of additional time required for plan review and inspection of one hour per single family or multifamily building for the attic insulation for alterations submeasure, and no additional time for the attic insulation for additions submeasure.

**Table 133: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Attic Insulation for Alterations | Direct Effects (Additional spending by Residential Builders) | 440.3 | $28,227,812 | $47,574,117 | $77,252,657 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 170.0 | $10,894,479 | $16,981,215 | $30,155,806 |
| | Induced Effect (Spending by employees of firms experiencing | 208.6 | $11,629,615 | $20,811,01 | $33,971,933 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | "direct" or "indirect" effects) | | | | |
| | **Total Submeasure Impacts** | **818.9** | **$50,751,905** | **$85,366,349** | **$141,380,396** |
| Attic Insulation for Additions | Direct Effects (Additional spending by Residential Builders) | 1.2 | $75,860 | $127,851 | $207,610 |
| | Indirect Effect (Additional spending by firms supporting Residential Builders) | 0.5 | $29,278 | $45,635 | $81,041 |
| | Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects) | 0.6 | $31,254 | $55,928 | $91,297 |
| | **Total Submeasure Impacts** | **2.2** | **$136,391** | **$229,414** | **$379,947** |
| **Total Economic Impacts** | | **821.1** | **$50,888,296** | **$85,595,763** | **$141,760,343** |

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

### Table 134: Estimated Impact that Adoption of the Proposed Measure would have on California Building Inspectors

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Attic Insulation | Direct Effects (Additional spending by | 4.4 | $438,902 | $519,012 | $620,381 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| for Alterations | Building Inspectors) | | | | |
| | Indirect Effect (Additional spending by firms supporting Building Inspectors) | 0.5 | $34,847 | $56,146 | $97,399 |
| | Induced Effect (Spending by employees of Building Inspection Bureaus and Departments) | 2.5 | $142,381 | $254,721 | $415,933 |
| | **Total Submeasure Impacts** | **7.4** | **$616,131** | **$829,879** | **$1,133,714** |
| **Total Economic Impacts** | | **7.4** | **$616,131** | **$829,879** | **$1,133,714** |

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

**Table 135: Estimated Impact that Adoption of the Proposed Measure would have on Discretionary Spending by California Residents**

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| Attic Insulation for Alterations | Direct Effects (Additional spending by households) | 368.7 | $19,080,139 | $35,094,024 | $56,539,819 |
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 131.1 | $8,998,297 | $14,942,769 | $25,140,534 |

| Sub-Measure | Type of Economic Impact | Employment | Labor Income | Total Value Added | Output |
|---|---|---|---|---|---|
| | Induced Effect (Spending by employees of businesses experiencing "indirect" effects) | 150.0 | $8,378,376 | $14,991,497 | $24,474,763 |
| | **Total Submeasure Impacts** | **649.8** | **$36,456,811** | **$65,028,290** | **$106,155,116** |
| Attic Insulation for Additions | Direct Effects (Additional spending by households) | 0.9 | $45,494 | $83,678 | $134,813 |
| | Indirect Effect (Purchases by businesses to meet additional household spending) | 0.3 | $21,455 | $35,629 | $59,945 |
| | Induced Effect (Spending by employees of businesses experiencing "indirect" effects) | 0.4 | $19,977 | $35,746 | $58,357 |
| | **Total Submeasure Impacts** | **1.5** | **$86,927** | **$155,053** | **$253,115** |
| **Total Economic Impacts** | | **651.3** | **36,543,738.3** | **65,183,343.0** | **106,408,230.9** |

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

#### *5.2.4.1 Creation or Elimination of Jobs*

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 5.2.4 would lead to modest changes in employment of existing jobs.

### 5.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 5.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to attic insulation requirements, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes to the California Energy Code.

### 5.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The code changes the Statewide CASE Team is proposing for the 2022 code cycle would apply to all businesses operating in California, regardless of whether the business is located inside or outside of the state.[34] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

### 5.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[35] As Table 136 shows between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, and the average was 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

**Table 136: Net Domestic Private Investment and Corporate Profits, U.S.**

| Year | Net Domestic Private Investment by Businesses, Billions of Dollars | Corporate Profits After Taxes, Billions of Dollars | Ratio of Net Private Investment to Corporate Profits |
|---|---|---|---|
| 2015 | 609.245 | 1,740.349 | 35% |

[34] Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for CA businesses currently doing business in the state.

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

| | | | |
|---|---|---|---|
| 2016 | 455.980 | 1,739.838 | 26% |
| 2017 | 509.276 | 1,813.552 | 28% |
| 2018 | 618.247 | 1,843.713 | 34% |
| 2019 | 580.849 | 1,826.971 | 32% |
| | | **5-Year Average** | **31%** |

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

The estimated increase in investment in California is $4.6 million. The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 133 through Table 135 above by 31 percent.

#### *5.2.4.5 Effects on the State General Fund, State Special Funds, and Local Governments*

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

**Cost of Enforcement**

*Cost to the State*

State government already has budget for code development, education, and compliance enforcement. While state government would be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals. Because the proposed code change applies to residential buildings alone, impact to state buildings is not expected.

*Cost to Local Governments*

All revisions to Title 24, Part 6 would result in changes to compliance determinations. Local governments would need to train building department staff on the revised Title 24, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2022 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU codes and standards program (such as Energy Code Ace). As noted in Section 5.1.5 and Appendix F, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

#### *5.2.4.6 Impacts on Specific Persons*

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed update to the 2022 code cycle may result in unintended consequences. The Statewide CASE Team does not expect that the proposed submeasures would result in negative impacts on specific persons.

## 5.3 Energy Savings

As of the Draft CASE Report's date of publication, the Energy Commission has not released the final 2022 TDV factors that are used to evaluate TDV energy savings and cost effectiveness. The energy and cost analysis presented in this report used the TDV factors that were released in the 2022 CBECC-Res research version that was released in December 2019. These TDV factors were consistent with the TDV factors that the Energy Commission presented during their public workshop on compliance metrics held October 17, 2019 (California Energy Commission 2019). The electricity TDV factors did not include the 15 percent retail adder and the natural gas TDV factors did not include the impact of methane leakage on the building site, updates that the Energy Commission presented during their workshop on March 27, 2020. Presentations from Bruce Wilcox and NORESCO during the March 27, 2020 workshop indicated that the 15 percent retail adder and methane leakage would result in most energy efficiency measures having slightly higher TDV energy and energy cost savings than using the TDV factors without these refinements. As a result, the TDV energy savings presented in this report are lower than the values that would have been obtained using TDV with the 15 percent retail adder and methane leakage, and the proposed code changes would be more cost effective using the revised TDV. The Energy Commission notified the Statewide CASE Team on April 21, 2020 that they were investigating further refinements to TDV factors using 20-year global warming potential (GWP) values instead of the 100-year GWP values that were used to derive the current TDV factors. It is anticipated that the 20-year GWP values may increase the TDV factors slightly making proposed changes that improve energy efficiency more cost effective. Energy savings presented in kWh and therms are not affected by TDV or demand factors.

When the Energy Commission releases the final TDV factors, the Statewide CASE Team will consider the need to re-evaluate energy savings and cost-effectiveness analyses using the final TDV factors for the results that will be presented in the Final CASE Report.

The Energy Commission is developing a source energy metric (energy design rating or EDR 1) for the 2022 code cycle. As of the date this Draft CASE Report was published, the source energy metric has not been finalized and the Energy Commission has not provided guidance on analyses they would like to see regarding the impact of proposed code changes relative to the source energy metric. Pending guidance from the Energy Commission, the Final CASE Reports may include analyses on the source energy metric.

### 5.3.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relies on results of California Building Energy Code Compliance (CBECC) software simulations to estimate energy use for single family and multifamily prototype buildings. Various scenarios were evaluated comparing different attic insulation levels against a range of basecase conditions (i.e. existing attic insulation levels, duct location, and HVAC system efficiency). The prototypes evaluated are mixed-fuel with natural gas used for space heating, water heating, cooking, and clothes drying represent the majority of existing residential buildings (see Appendix H for further details). All sixteen climate zones were evaluated, even though ultimately each submeasure is recommended only in a subset of climate zones based on the cost effectiveness results and efforts to align the alteration requirements with those for new construction.

### 5.3.2 Energy Savings Methodology

#### *5.3.2.1 Energy Savings Methodology per Prototypical Building*

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. These prototypes represent new construction buildings and therefore in some cases the prototypes were revised to better reflect the existing building stock relative to new construction. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 156. Refer to Appendix H for further details on the prototypes.

These proposals impact single family and multifamily buildings. In addition to the single family alteration prototype the proposal for attic insulation for alterations was evaluated for the low-rise garden multifamily prototype. The low-rise loaded corridor prototype was not evaluated because the energy savings and cost effectiveness are expected to be very similar to the low-rise garden prototype.

The proposal for increasing insulation for additions was not evaluated with the low-rise multifamily prototype because additions are not common in multifamily buildings. While it is proposed that this code change proposal apply to multifamily buildings in the case of an addition, the Statewide CASE Team considers that this can be justified without direct modeling. However, because the expected number of buildings statewide impacted annually is expected to be very small for multifamily, the statewide savings only take into account single family buildings.

**Table 137: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis for Attic Insulation Measures**

| Prototype Name | Number of Stories | Floor Area (square feet) | Description | Measures evaluated |
|---|---|---|---|---|
| Single Family Alteration | 1 | 1,665 | Single story house. 8-ft ceilings. Steep-slope roof above attic with ducts in attic. | Altered ceilings, Addition ceilings |
| Low-Rise Garden Multifamily | 2 | 6,960 | 2-story, 8-unit apartment building. Average dwelling unit size: 870 ft2. Individual HVAC & DHW systems. Steep-slope roof above attic with ducts in attic. | Altered ceilings |

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of the CBECC software for residential buildings (CBECC-Res for low-rise residential (California Energy Commission 2019c)).

CBECC-Res generates two models based on user inputs: the Standard Design and the Proposed Design.[36] The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Residential ACM Reference Manual. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the

[36] 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.

Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building.

There is an existing Title 24, Part 6 requirement that covers the building system in question, so the Standard Design is minimally compliant with the 2019 Title 24 requirements with two exceptions for alterations. For single family buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. The existing condition building infiltration assigned to the existing home (10 ACH50) is not reflected in the CBECC-Res Standard Design calculation per the ACM Reference Manual rules. For multifamily buildings the Standard Design applied in this analysis differs from that calculated from the CBECC-Res software in one respect. Ductwork was located within the vented attic, which is common for this building type, while the CBECC-Res Standard Design for multifamily buildings assumes that ductwork is located within conditioned space. Therefore, two simulations were conducted for each submeasure: one to represent the revised Standard Design and another to represent the Proposed Design. Refer to Appendix H for additional details.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 138 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, for alterations the proposed conditions assume an increase of attic insulation from R-11 to R-49. While savings and cost effectiveness analysis for this submeasure are presented relative to a Standard Design with R-11 existing attic insulation, analysis was also conducted for a case with R-19 existing attic insulation. This analysis demonstrated where the proposal is not cost effective with higher levels of existing attic insulation and informed the proposed exceptions that exempt existing homes with R-19 attic insulation in certain climate zones from certain aspects of the requirements. See Appendix I for detailed analysis results.

The proposed conditions also assume a reduction in whole house building leakage. For single family buildings this is assumed to be from 10 to 8.6 ACH50. The impacts of air sealing on total house leakage can vary significantly. Air leakage requires both a hole and pressure difference between inside and outside. Attics are especially prone to thermal losses due to stack effect. The Statewide CASE Team looked at prior research to identify potential impacts of air sealing at the ceiling between attic and living space. Research by Owens Corning in 2010 (Wolf and Tyler 2013) looked at the impacts of air sealing in new homes and identified the areas that have the biggest impact on air leakage and are the easiest to address. The top three leakage areas found are between the attic and living space below: top-plate-to-attic connection, duct boots, and recessed lighting. Together they were found to be responsible for 0.6 to 2.2 ACH50 in a new home. Data from homes tested in the Residential Construction Quality Assessment Project (Davis Energy Group 2002) found that the average leakage from recessed cans to be 0.45 ACH50, based on an average of 14 recessed light fixtures per home. Based on this research, a reduction from 10 to 8.6 ACH60 (1.4 ACH50) was determined as an average of the range from 0.6 to 2.2 ACH50 in the Owens Corning study.

Provided that the low-rise garden multifamily prototype is two stories with half of the apartments underneath a vented attic on the second floor, the overall reduction in building infiltration was assumed to be half what it is for the single family single-story prototype. Reduced infiltration cannot be directly evaluated in CBECC-Res for multifamily buildings and the multifamily analysis was conducted using the default infiltration of 7 ACH50 for multifamily buildings. To estimate the impact of reducing infiltration from 10 ACH50 to 9.3 ACH50, a single case using the California Simulation Engine (CSE) was evaluated in one climate zone. Heating and cooling energy use was scaled for the simulations based on 7 ACH50 according to the results from the CSE simulations.

Savings from replacing existing incandescent or compact fluorescent recessed can fixtures with LED fixtures were not included in this analysis, but there are potentially additional energy savings resulting from installation of higher efficacy light fixtures.

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

**Table 138: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Ceiling Insulation for Alterations**

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Alteration & Low-Rise Garden Multifamily | All | Construction Assembly (Ceilings (below attic)): Cavity / Frame Cavity Path | R-11 | R-49 / R-38 |
| Single Family Alteration | All | Building: Air Leakage | 10 ACH50 | 8.6 ACH50 |
| Low-Rise Garden Multifamily | All | Building: Air Leakage | 10 ACH50 | 9.3 ACH50 |

| Prototype ID | Climate Zone | Parameter Name | Standard Design Parameter Value | Proposed Design Parameter Value |
|---|---|---|---|---|
| Single Family Addition | 2, 4, 8-10 | Construction Assembly (Ceilings (below attic)): Cavity / Frame Cavity Path | R-30 | R-38 |

CBECC-Res calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). CBECC-Res also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars.

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 TDV factors when calculating energy and energy cost impacts.

Per unit energy impacts for single family buildings are presented in savings per prototype building. Per-unit energy impacts for multifamily buildings are presented in savings per dwelling unit. Annual energy and peak demand impacts for each prototype building were translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building.

#### 5.3.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2019d). The Statewide Construction Forecasts estimate the size of the total existing building stock by building type and climate zone in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. In order to translate per unit savings to statewide energy impacts, The Statewide CASE Team conducted research to determine appropriate weighting factors for each submeasure. Table 158 and Table 159 present the prototypical buildings and weighting factors used for the attic insulation for alterations and additions submeasures.

For alterations, the percent of building type represented by prototype is 100 percent for single family since there is only a single prototype. The portion of multifamily impacted is based on the portion of total California multifamily dwelling units in buildings three stories or less, according to the CoStar database (CoStar 2018). The percent of prototype impacted by the proposed attic insulation for alterations code change is estimated based on the 2009 Residential Appliance Saturation Study (California Energy Commission 2009) and CalCERTS data (CalCERTS 2020). The figures represent the percent of the existing building stock with vented attics that trigger an altered ceiling, including projects where an entirely new duct system in installed in an attic.

For additions, the percent of building type represented by prototype is 50 percent and assumes that half of additions are less than or equal to and the other half greater than 700 square feet.

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

**Table 139: Residential Building Types and Associated Prototype Weighting - Attic Insulation for Alterations**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Alteration | 100% | 0.160% | 0.160% |
| Multifamily | Low-Rise Garden | 84% | 0.004% | 0.003% |

**Table 140: Residential Building Types and Associated Prototype Weighting - Attic Insulation for Additions**

| Building Type ID from Statewide Construction Forecast | Building Prototype for Energy Modeling | Weighting Factors for Statewide Impacts Analysis | | |
|---|---|---|---|---|
| | | % of Building Type Represented by Prototype | % of Prototype Impacted by Proposed Code Change | Total Weighting Factor |
| Single Family | Single Family Addition | 50% | 42% | 21% |

### 5.3.3 Per-Unit Energy Impacts Results

#### *5.3.3.1 Attic Insulation for Alterations*

Energy savings and peak demand reductions per unit are presented in Table 141 through Table 142. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. For the single family prototype per-unit savings for the first year are expected to range from 52 to 1,318 kWh/yr and 10 to 89 therms/yr depending upon climate zone. Demand reductions/increases are expected to range between 0.001 kW and 0.430 kW depending on climate zone.

The energy savings account for the thermal impact of increased insulation and reduced building infiltration. They do not account for any lighting savings from replacing existing incandescent or compact fluorescent recessed can fixtures with LED fixtures.

**Table 141: Attic Insulation for Alterations First-Year Energy Impacts Per Home – Single Family Alteration**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 52 | 0.001 | 58.6 | 21,795 |
| 2 | 285 | 0.134 | 42.8 | 33,800 |
| 3 | 68 | 0.056 | 32.3 | 21,845 |
| 4 | 420 | 0.287 | 32.0 | 29,853 |
| 5 | 53 | 0.001 | 29.2 | 13,869 |
| 6 | 283 | 0.182 | 13.6 | 15,984 |
| 7 | 259 | 0.179 | 10.1 | 12,904 |
| 8 | 565 | 0.231 | 14.2 | 31,002 |
| 9 | 516 | 0.312 | 18.3 | 29,937 |
| 10 | 638 | 0.173 | 22.8 | 32,085 |
| 11 | 721 | 0.260 | 48.9 | 45,754 |
| 12 | 559 | 0.297 | 42.0 | 41,009 |
| 13 | 919 | 0.430 | 31.4 | 45,338 |
| 14 | 635 | 0.146 | 48.1 | 44,539 |
| 15 | 1,318 | 0.281 | 10.4 | 47,852 |
| 16 | 321 | 0.189 | 89.3 | 39,810 |

**Table 142: Attic Insulation for Alterations First-Year Energy Impacts Per Home – Low-Rise Garden Multifamily**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | 12 | 0.000 | 16.9 | 6,125 |
| 2 | 90 | 0.028 | 11.2 | 7,965 |
| 3 | 24 | 0.018 | 8.6 | 4,646 |
| 4 | 94 | 0.049 | 7.6 | 6,569 |
| 5 | 22 | 0.013 | 8.1 | 3,645 |
| 6 | 75 | 0.027 | 3.3 | 3,419 |
| 7 | 73 | 0.018 | 2.2 | 2,593 |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 8 | 145 | 0.026 | 3.4 | 6,917 |
| 9 | 132 | 0.064 | 4.4 | 6,012 |
| 10 | 156 | 0.023 | 5.3 | 6,786 |
| 11 | 152 | 0.014 | 12.5 | 10,270 |
| 12 | 133 | 0.047 | 10.8 | 9,549 |
| 13 | 201 | 0.034 | 7.9 | 10,614 |
| 14 | 136 | -0.011 | 12.4 | 10,077 |
| 15 | 271 | -0.001 | 2.7 | 10,877 |
| 16 | 72 | 0.010 | 23.4 | 9,493 |

#### *5.3.3.2 Attic Insulation for Additions*

Energy savings and peak demand reductions per unit are presented in Table 143. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 3 to 5 kWh/yr and 0 to 0.4 therms/yr depending upon climate zone. Demand reductions/increases are expected to range between 0.002 kW and 0.003 kW depending on climate zone.

**Table 143: Attic Insulation for Additions First-Year Energy Impacts Per Home – Single Family Addition**

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 1 | N/A | N/A | N/A | N/A |
| 2 | 3 | 0.003 | 0.4 | 299 |
| 3 | N/A | N/A | N/A | N/A |
| 4 | 3 | 0.002 | 0.2 | 315 |
| 5 | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A |
| 8 | 5 | 0.002 | 0.0 | 234 |
| 9 | 5 | 0.002 | 0.1 | 430 |
| 10 | 5 | 0.002 | 0.1 | 272 |
| 11 | N/A | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A | N/A |

| Climate Zone | Electricity Savings (kWh/yr) | Peak Electricity Demand Reductions (kW) | Natural Gas Savings (therms/yr) | TDV Energy Savings (TDV kBtu/yr) |
|---|---|---|---|---|
| 13 | N/A | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A |

## 5.4 Cost and Cost Effectiveness

### 5.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 5.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures). The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 30 years. TDV energy cost factors of 0.173 2023 PV$/kBtu and 0.173 Nominal$/kBtu were applied.

### 5.4.2 Energy Cost Savings Results

#### *5.4.2.1 Attic Insulation for Alterations*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 144 through Table 145. Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

**Table 144: Attic Insulation for Alterations 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Alterations**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $274 | $3,497 | $3,771 |
| 2 | $3,252 | $2,595 | $5,847 |
| 3 | $1,820 | $1,959 | $3,779 |
| 4 | $3,223 | $1,941 | $5,165 |
| 5 | $631 | $1,769 | $2,399 |
| 6 | $1,936 | $830 | $2,765 |

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 7 | $1,607 | $625 | $2,232 |
| 8 | $4,491 | $873 | $5,363 |
| 9 | $4,059 | $1,120 | $5,179 |
| 10 | $4,156 | $1,394 | $5,551 |
| 11 | $4,937 | $2,978 | $7,915 |
| 12 | $4,537 | $2,558 | $7,095 |
| 13 | $5,922 | $1,921 | $7,843 |
| 14 | $4,770 | $2,935 | $7,705 |
| 15 | $7,642 | $637 | $8,278 |
| 16 | $1,530 | $5,358 | $6,887 |

**Table 145: Attic Insulation for Alterations 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Low-Rise Garden Multifamily**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | $60 | $999 | $1,060 |
| 2 | $727 | $651 | $1,378 |
| 3 | $283 | $521 | $804 |
| 4 | $677 | $459 | $1,136 |
| 5 | $143 | $488 | $631 |
| 6 | $387 | $205 | $592 |
| 7 | $315 | $134 | $449 |
| 8 | $987 | $209 | $1,197 |
| 9 | $772 | $268 | $1,040 |
| 10 | $849 | $325 | $1,174 |
| 11 | $1,056 | $721 | $1,777 |
| 12 | $1,025 | $627 | $1,652 |
| 13 | $1,375 | $461 | $1,836 |
| 14 | $1,026 | $718 | $1,743 |
| 15 | $1,718 | $164 | $1,882 |

#### *5.4.2.2 Attic Insulation for Additions*

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 146.

Further analysis showing the value in nominal dollars can be found in Appendix B. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

**Table 146: Attic Insulation for Additions 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Prototype Home – Single Family Additions**

| Climate Zone | 30-Year TDV Electricity Cost Savings (2023 PV$) | 30-Year TDV Natural Gas Cost Savings (2023 PV$) | Total 30-Year TDV Energy Cost Savings (2023 PV$) |
|---|---|---|---|
| 1 | N/A | N/A | N/A |
| 2 | $26 | $26 | $52 |
| 3 | N/A | N/A | N/A |
| 4 | $40 | $14 | $54 |
| 5 | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A |
| 8 | $40 | $1 | $40 |
| 9 | $71 | $3 | $74 |
| 10 | $39 | $8 | $47 |
| 11 | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |

### 5.4.3 Incremental First Cost

#### *5.4.3.1 Attic Insulation for Alterations*

Incremental costs for this measure reflect the full cost of adding R-49 attic insulation, conducting air sealing of the ceiling floor on an existing home, retrofitting existing recessed can fixtures that are not rated for insulation contact, and HERS verification of air sealing. Estimated costs are based on data provided during stakeholder interviews, collected from previous projects, and from online product research.

The total estimated incremental cost used in this analysis is $2.98 per square foot of ceiling area and the breakdown is described in Table 147.

**Table 147: Breakdown of Estimated Costs for R-49 Attic Insulation and Air Sealing in an Alteration**

| Component | Cost per square foot of ceiling | Cost per single family building (1,665 square foot ceiling) | Cost per 8-unit multifamily building (3,480 square foot ceiling) |
|---|---|---|---|
| R-49 attic insulation | $1.71 | $2,851 | $5,960 |
| Air sealing | $0.89 | $1,482 | $3,097 |
| Replace recessed cans | $0.29 | $481 | $1,005 |
| HERS rater | $0.09 | $150 | $314 |
| **Total** | **$2.98** | **$4,964** | **$10,375** |

**Attic Insulation**: $1.71 for R-49 attic insulation reflects costs that were provided by three stakeholders during interviews as well as previous projects and was validated against online material costs from Home Depot. In addition to the insulation itself, this also includes costs for baffles around attic vents and damming that might be required around exhaust pipes. This cost assumes little or no existing insulation.

**Air Sealing**: The $0.89 for air sealing is based on a stakeholder interview and verified against previous project data. This cost includes removing or shifting around any existing insulation in order to access the ceiling plane, provided the existing insulation is not too deep (less than R-19).

**Recessed Cans**: As a component of the air sealing, it is estimated that the home has seven recessed can fixtures that need to be retrofit to be airtight and allow for insulation contact. Data from 30 monitored homes in the Residential Construction Quality Assessment Project (Davis Energy Group 2002) was reviewed and the average number of recessed cans for a 1,665 square foot home was found to be around seven. The cost of $0.29 per square foot is based on a cost of $69 per recessed can provided by a stakeholder and based on installing a recessed light cover over existing non-compliant fixtures and sealing the covers to the ceiling plane with foam. This cost was validated against online product research which estimated costs for three different options. Material costs of $30.54 were estimated for a replacement IC-AT rated housing and an LED retrofit trim kit. Material costs for two recessed light covers, the TENMAT and Insullite, were found to range from about $10 to $15 per cover.

**HERS Rater**: The cost for the HERS Rater to visually verify the air sealing is estimated at $150 based on cost data provided by multiple HERS Raters for previous CASE work. Most altered ceiling projects are expected to be triggered by installation of a replacement attic duct system, in which case a HERS Rater would already be engaged on the project to conduct duct sealing testing at minimum, in addition to other mechanical verifications if equipment is also replaced. For costing purposes, it is assumed that the HERS Rater would conduct the air sealing inspection and duct testing during the same site visit.

In climate zones where air sealing is not required, the cost components for both the air sealing and the HERS verification of air sealing are not included. In addition, the R-49 attic insulation cost is reduced to account for use of the existing insulation. It is assumed that the existing insulation is not removed, and insulation is added on top of existing insulation to meet R-49 at full depth. With existing attic insulation levels of R-11 the estimated incremental cost is $1.54 per square foot of ceiling area. With existing attic insulation levels of R-19 the estimated incremental cost is $1.44 per square foot of ceiling area. These cost variations are based on online material costs from Home Depot.

#### *5.4.3.2 Attic Insulation for Additions*

Incremental costs for this measure reflect the incremental cost of increasing attic insulation to R-38 instead of R-30. Since the basecase is a new addition with an attic insulated to R-30, there is already an insulation contractor that would be on the project and therefore the incremental cost is the incremental labor and materials to add an additional R-8.

The total estimated incremental cost used in this analysis is $0.17 per square foot of ceiling area. This cost is based on a cost calculator provided by a contractor for a previous project.

### 5.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a 3 percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the $n^{th}$ year is calculated as follows:

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

Attic insulation and air sealing are expected to have a useful life of 30 years or greater. Therefore, there are no incremental maintenance or replacement costs associated with these measures.

### 5.4.5 Cost Effectiveness

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

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the 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 2023 PV costs and cost savings.

#### *5.4.5.1 Attic Insulation for Alterations*

Results of the per-unit cost-effectiveness analyses are presented in Table 148 through Table 149.

For the single family prototype, the proposed submeasure saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except 5 and 7. The cost effectiveness analysis account for air sealing not required in Climate Zones 1, 3 and 6 and recessed can upgrades not required in Climate Zone 6.

For the multifamily prototype, the proposed submeasure saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except 5 through 7. The cost effectiveness analysis account for air sealing not required in Climate Zones 1, 3, 4 and 8 through 10.

**Table 148: Attic Insulation for Alterations 30-Year Cost-Effectiveness Summary Per Home – Single Family Alterations**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $3,771 | $3,041 | 1.24 |
| 2 | $5,847 | $4,964 | 1.18 |
| 3 | $3,779 | $3,041 | 1.24 |
| 4 | $5,165 | $4,964 | 1.04 |
| 5 | $2,399 | $2,560 | 0.94 |
| 6 | $2,765 | $2,560 | 1.08 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 7 | $2,232 | $2,560 | 0.87 |
| 8 | $5,363 | $4,964 | 1.08 |
| 9 | $5,179 | $4,964 | 1.04 |
| 10 | $5,551 | $4,964 | 1.12 |
| 11 | $7,915 | $4,964 | 1.59 |
| 12 | $7,095 | $4,964 | 1.43 |
| 13 | $7,843 | $4,964 | 1.58 |
| 14 | $7,705 | $4,964 | 1.55 |
| 15 | $8,278 | $4,964 | 1.67 |
| 16 | $6,887 | $4,964 | 1.39 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 149: Attic Insulation for Alterations 30-Year Cost-Effectiveness Summary Per Home – Low-Rise Garden Multifamily

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,060 | $794 | 1.33 |
| 2 | $1,378 | $1,297 | 1.06 |
| 3 | $804 | $794 | 1.01 |
| 4 | $1,136 | $794 | 1.43 |
| 5 | $631 | $669 | 0.94 |
| 6 | $592 | $669 | 0.88 |
| 7 | $449 | $669 | 0.67 |
| 8 | $1,197 | $794 | 1.51 |
| 9 | $1,040 | $794 | 1.31 |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 10 | $1,174 | $794 | 1.48 |
| 11 | $1,777 | $1,297 | 1.37 |
| 12 | $1,652 | $1,297 | 1.27 |
| 13 | $1,836 | $1,297 | 1.42 |
| 14 | $1,743 | $1,297 | 1.34 |
| 15 | $1,882 | $1,297 | 1.45 |
| 16 | $1,642 | $1,297 | 1.27 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

#### *5.4.5.2 Attic Insulation for Additions*

Results of the per-unit cost-effectiveness analyses are presented in Table 150.

For the single family addition prototype the proposed submeasure saves money over the 30-year period of analysis relative to the existing conditions in all of the proposed climate zones.

**Table 150: Attic Insulation for Additions 30-Year Cost-Effectiveness Summary Per Home – Single Family Additions**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | N/A | N/A | N/A |
| 2 | $52 | $38 | 1.36 |
| 3 | N/A | N/A | N/A |
| 4 | $54 | $38 | 1.43 |
| 5 | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A |

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 7 | N/A | N/A | N/A |
| 8 | $40 | $38 | 1.06 |
| 9 | $74 | $38 | 1.96 |
| 10 | $47 | $38 | 1.24 |
| 11 | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

## 5.5 First-Year Statewide Impacts

### 5.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings by multiplying the per-unit savings, which are presented in Section 5.3.3, by assumptions about the percentage of existing buildings that would be impacted by the proposed code. The statewide existing building forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of existing buildings that would be impacted by the proposal (by climate zone and building type).

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

Table 151 through Table 152 present the first-year statewide energy and energy cost savings by climate zone.

**Table 151: Attic Insulation for Alterations Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family & multifamily: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | 93 | 0.00 | 0.00 | 0.01 | $0.35 |
| 2 | 555 | 0.16 | 0.07 | 0.02 | $3.22 |
| 3 | 2,061 | 0.14 | 0.11 | 0.07 | $7.72 |
| 4 | 1,047 | 0.44 | 0.30 | 0.03 | $5.36 |
| 5 | N/A | N/A | N/A | N/A | N/A |
| 6 | 1,246 | 0.35 | 0.23 | 0.02 | $3.44 |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 1,954 | 1.09 | 0.45 | 0.03 | $10.39 |
| 9 | 2,666 | 1.36 | 0.82 | 0.05 | $13.60 |
| 10 | 2,220 | 1.41 | 0.38 | 0.05 | $12.26 |
| 11 | 676 | 0.49 | 0.17 | 0.03 | $5.33 |
| 12 | 2,716 | 1.51 | 0.80 | 0.11 | $19.16 |
| 13 | 1,303 | 1.19 | 0.56 | 0.04 | $10.17 |
| 14 | 504 | 0.32 | 0.07 | 0.02 | $3.86 |
| 15 | 357 | 0.47 | 0.10 | 0.00 | $2.95 |
| 16 | 196 | 0.06 | 0.04 | 0.02 | $1.34 |
| **TOTAL** | **17,594** | **8.98** | **4.11** | **0.50** | **$99.14** |

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

**Table 152: Attic Insulation for Additions Statewide Energy and Energy Cost Impacts**

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 1 | N/A | N/A | N/A | N/A | N/A |
| 2 | 348 | 0.00 | 0.00 | 0.00 | $0.02 |

| Climate Zone | Statewide Existing Building Stock Impacted by Proposed Change in 2023 (single family: units) | First-Year[a] Electricity Savings (GWh) | First-Year Peak Electrical Demand Reduction (MW) | First-Year Natural Gas Savings (million therms) | 30-Year Present Valued Energy Cost Savings (million 2023 PV$) |
|---|---|---|---|---|---|
| 3 | N/A | N/A | N/A | N/A | N/A |
| 4 | 674 | 0.00 | 0.00 | 0.00 | $0.04 |
| 5 | N/A | N/A | N/A | N/A | N/A |
| 6 | N/A | N/A | N/A | N/A | N/A |
| 7 | N/A | N/A | N/A | N/A | N/A |
| 8 | 1,061 | 0.00 | 0.00 | 0.00 | $0.04 |
| 9 | 1,464 | 0.01 | 0.00 | 0.00 | $0.11 |
| 10 | 1,913 | 0.01 | 0.00 | 0.00 | $0.09 |
| 11 | N/A | N/A | N/A | N/A | N/A |
| 12 | N/A | N/A | N/A | N/A | N/A |
| 13 | N/A | N/A | N/A | N/A | N/A |
| 14 | N/A | N/A | N/A | N/A | N/A |
| 15 | N/A | N/A | N/A | N/A | N/A |
| 16 | N/A | N/A | N/A | N/A | N/A |
| **TOTAL** | **5,460** | **0.02** | **0.01** | **0.00** | **$0.30** |

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

### 5.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard goal of 33 percent renewable electricity generation by 2020.[37] Avoided GHG emissions from

[37] When evaluating the impact of increasing the Renewable Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020, the California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix D for additional details on the methodology used to calculate GHG emissions.

Table 153 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 4,915 million metric tons of carbon dioxide equivalents (MMTCO2e) would be avoided.

**Table 153: First-Year Statewide GHG Emissions Impacts for Attic Insulation Measures**

| Measure | Electricity Savings[a] (GWh/yr) | Reduced GHG Emissions from Electricity Savings[a] (Metric Tonnes $CO_2e$) | Natural Gas Savings[a] (million therms/yr) | Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tonnes CO2e) | Total Reduced $CO_2e$ Emissions[a,b] (Metric Tonnes CO2e) |
|---|---|---|---|---|---|
| Attic Insulation for Alterations | 8.98 | 2,159 | 0.50 | 2,746 | 4,906 |
| Attic Insulation for Additions | 0.0247 | 5.93 | 0.0006 | 3.54 | 9.47 |

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

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/million therms.

### 5.5.3 Statewide Water Use Impacts

The proposed submeasures would not result in water savings.

### 5.5.4 Statewide Material Impacts

The proposed submeasures would not result in impacts on the use of toxic or energy intensive materials.

### 5.5.5 Other Non-Energy Impacts

Adding attic insulation, especially to uninsulated or minimally insulated existing attic floors can greatly increase occupant comfort during both the summer and winter. Mean radiant temperature (MRT) is the "temperature of an imaginary isothermal black enclosure in which an occupant would exchange the same amount of heat by radiation as in the actual non-uniform environment" (ASHRAE 2015). MRT is a key indicator of thermal comfort in a building and expresses the effect of surface temperatures on occupant comfort. On a hot day, surfaces of uninsulated or minimally insulated building assemblies would have a higher surface temperature than a highly insulated surface, contributing to a higher MRT of the space. Even though the cooling system may be operating as expected and the indoor air temperature in the space is acceptable, the occupant may still be uncomfortable as a result of the higher MRT. When all building assemblies in a space are well insulated, the MRT is more in line with the interior air temperature resulting in greater occupant.

Air sealing also improves occupant comfort. Reducing air leakage from within the conditioned space through the ceiling plane reduces drafts in the house, and also limits the unfiltered air that would be infiltrating into the conditioned space from other locations, improving indoor air quality. When air sealing is coupled with attic insulation it reduces air infiltration through the insulation improving the durability of the insulation.

## 5.6 Proposed Revisions to Code Language

### 5.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

### 5.6.2 Standards

**SECTION 110.8 – MANDATORY REQUIREMENTS FOR INSULATION, ROOFING PRODUCTS AND RADIANT BARRIERS**

(d) **Installation of Insulation in Existing Buildings.** Insulation installed in an existing attic, or on an existing duct or water heater, shall comply with the applicable requirements of Subsections 1, 2, and 3 below. If a contractor installs the insulation, the contractor shall certify to the customer, in writing, that the insulation meets the applicable requirements of Subsections 1, 2, and 3 below.

1. **Attics.** If insulation is installed in the existing attic of a low-rise residential building, the R-value of the total amount of insulation (after addition of insulation to the amount, if any, already in the attic) shall meet the requirements of Section ~~150.0(a)~~150.2(b)1.

   **EXCEPTION to Section 110.8(d)1:** Where the accessible space in the attic is not large enough to accommodate the required R-value, the entire accessible space shall be filled with insulation provided such installation does not violate Section 1202.2~~1203.2~~ of Title 24, Part 2 or Section 806.2 of Title 24, Part 2.5.

**SECTION 150.2 – ENERGY EFFICIENCY STANDARDS FOR ADDITIONS AND ALTERATIONS TO EXISTING LOW-RISE RESIDENTIAL BUILDINGS**

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

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

   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 shall be installed in a~~n~~ ventilated attic with an R-value equal to or greater than ~~shall be insulated to~~ R38 in C~~c~~limate Z~~z~~ones 1, 2, 4, 8~~11-~~ through 16 or R-30 in C~~c~~limate Z~~z~~ones 3, 5 through 7~~2-10~~ located between the attic and the conditioned space; and

(b) **Alterations.** Alterations to existing low-rise residential buildings or alterations in conjunction with a change in building occupancy to a low-rise 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 Section 150.0(a) through (l); 150.0(m)1 through 150.0 (m)10, Section 150.0(o) through (q); and

   A. **Ceiling.** Vented attics shall meet the following:

      i. In Climate Zones 1 through 4, 6, and 8 through 16 in single family buildings and Climate Zones 1 through 4 and 8 through 16 in multifamily buildings insulation shall be installed to achieve a weighted U-factor of 0.020 or insulation installed at the ceiling level shall result in an installed thermal resistance of R-49 or greater for the insulation alone; and

         **EXCEPTION 1 to Section 150.2(b)1Ai:** Buildings with at least R-19 existing insulation installed at the ceiling level with third party verification of existing conditions in Climates Zones 1, 3, and 6 for single family buildings and Climate Zones 1, 3, 4, and 9 for multifamily buildings**.**

      ii. In Climate Zones 2, 4, and 8 through 16 in single family buildings and Climate Zones 2 and 11 through 16 for multifamily buildings, air seal all accessible areas of the ceiling plane between the attic and the conditioned space in accordance with Section 110.7. Air sealing shall be field verified in accordance with the procedures in Reference Residential Appendix RA3.5 for altered ceilings and Table D of the CF2R-ENV-21 form; and

         **EXCEPTION 1 to Section 150.2(b)1Aii:** Buildings with at least R-19 existing insulation installed at the ceiling level with third party verification of existing conditions.

      iii. In Climate Zones 1 through 4 and 8 through 16 recessed downlight luminaires in the ceiling shall be covered with insulation to the same depth as the rest of the ceiling. Luminaires not rated for insulation contact must be replaced or fitted with a fire-proof cover that allows for insulation to be installed directly over the cover; and

**EXCEPTION 1 to Section 150.2(b)1Aiii:** Buildings with at least R-19 existing insulation installed at the ceiling level with third party verification of existing conditions in Climates Zones 1 through 4 and 8 through 10.

iv. Attic ventilation shall comply with CBC requirements.

**EXCEPTION 1 to Section 150.2(b)1A:** Buildings with at least R-38 existing insulation installed at the ceiling level with third party verification of existing conditions.

**EXCEPTION 2 to Section 150.2(b)1A:** Buildings where the alteration would directly cause the disturbance of asbestos, unless the alteration is made in conjunction with asbestos abatement.

**EXCEPTION 3 to Section 150.2(b)1A:** Buildings with knob and tube wiring located in the vented attic.

**EXCEPTION 4 to Section 150.2(b)1A:** Where the accessible space in the attic is not large enough to accommodate the required R-value, the entire accessible space shall be filled with insulation provided such installation does not violate Section 806.3 of Title 24, Part 2.5.

D. **Altered Duct Systems - Duct Sealing**: In all Climate Zones, when more than 40 feet of new or replacement space-conditioning system ducts are installed, the ducts shall comply with the applicable requirements of subsections i and ii below. Additionally, when altered ducts, air-handling units, cooling or heating coils, or plenums are located in garage spaces, the system shall comply with subsection 150.2(b)1Diic regardless of the length of any new or replacement space-conditioning ducts installed in the garage space.

ii. The altered duct system, regardless of location, shall be sealed as confirmed through field verification and diagnostic testing in accordance with all applicable procedures for duct sealing of altered existing duct systems as specified in the Reference Residential Appendix RA3.1, utilizing the leakage compliance criteria specified in Subsection a or b below.

a. **Entirely New or Complete Replacement Duct System.** If the new ducts form an entirely new or complete replacement duct system directly connected to the air handler, the duct system shall meet one of the following requirements:

I. For single family dwellings, the measured duct leakage shall be equal to or less than 5 percent of the system air handler airflow as confirmed by field verification and diagnostic testing utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1.

II. For multifamily dwellings, regardless of duct system location,

A. The total leakage of the duct system shall not exceed 12 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.1, or

B. The duct system leakage to outside shall not exceed 6 percent of the nominal system air handler airflow as determined utilizing the procedures in Reference Residential Appendix Section RA3.1.4.3.4.

Entirely new or complete replacement duct systems installed as part of an alteration shall be constructed of at least 75 percent new duct material, and up to 25 percent may consist of reused parts from the dwelling unit's existing duct system, including but not limited to registers, grilles, boots, air handler, coil, plenums, duct material; if the reused parts are

accessible and can be sealed to prevent leakage.

Entirely new or complete replacement duct systems shall also conform to the requirements of Sections 150.0(m)12 and 150.0(m)13. If at least 25 percent of the duct system is located within a vented attic the requirements of Section 150.2(b)1A shall also be met.

### 5.6.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

### 5.6.4 ACM Reference Manual

**2 Proposed, Standard, and Reference Design**

**2.10 Additions/Alterations**

*2.10.4.3 Roof/Ceilings*

**Table 26: ~~Addition~~ Standard Design for Roofs/Ceilings**

| Proposed Design Roof/Ceiling Types | Standard Design Based on Proposed Roof/Ceiling Status | | | | |
|---|---|---|---|---|---|
| | Add ≤ 300 ft2 | Add > 300 ft2 and ≤ 700 ft | Addition > 700 ft2 | Altered | Verified Altered |
| Ceilings Below Attic | CZ 1, 2, 4, 8~~11~~-16 = R-38<br>CZ 3, 5-7~~2-10~~ = R-30 | CZ 1, 2, 4, 8~~11~~-16 = R-38<br>CZ 3, 5-7~~2-10~~ = R-30 | CZ 1, 2, 4, 8-16 = R-38 ~~ceiling~~<br>CZ 3, 5-7 = R-30 ~~ceiling~~ | ~~R-19/U-0.054~~<br>Single family:<br>CZ 5, 7 = R-19<br>CZ 1-4, 6, 8-10 = R-49<br>Multifamily:<br>CZ 5-7 = R-19<br>CZ 1-4, 8-10 = R-49 | Existing |

### 5.6.5 Compliance Manuals

Chapter 9 of the Residential Compliance Manual would need to be revised. Section 9.2 What's New in the 2019 Energy Standards and Section 9.4.4 Envelope Alterations would need to be updated to describe the proposed code changes.

### 5.6.6 Compliance Documents

Compliance documents CF1R-ALT-05-E, CF1R-ALT-02-E, CF2R-ALT-05-E and CF2R-ENV-03-E would need to be revised.

CF1R-ALT-05-E would be revised to add a separate Project Scope item under subsection A for attic insulation. A new subsection for attic insulation would be created that includes all the columns in the current subsection B. Building Insulation Details. A checkbox would be added to indicate air sealing of the ceiling floor is to be conducted and an input for the number of recessed cans to be retrofit. The subsection also would need to allow the documentation author to indicate if they are applying for one of the exceptions and to provide the necessary details. The exceptions related to minimum existing levels of attic insulation require HERS verification of existing conditions (CF3R-EXC-20-H) and this should be indicated on the forms.

CF1R-ALT-02-E would be revised to add a box in Subsection E where the documentation author indicates the location of the entirely new or complete replacement duct system. If it is located in a vented attic, this would trigger completion of CF1R-ALT-05-E.

Subsection A and J of CF2R-ENV-03 would be revised. In subsection A an input would be added for the contractor to indicate how many recessed cans they retrofit and with what method. In subsection J a new item 11 would be added that says "All accessible areas of the ceiling plane between the attic and the conditioned space are sealed in accordance with Section 110.7."

CF2R-ALT-05-E would be revised to reflect the information captured in CF2R-ENV-03 relative to attic insulation and this code change proposal. In subsection B an input would be added for the contractor to indicate how many recessed cans they retrofit and with what method. A subsection would be added that is identical to subsection J of the CF2R-ENV-03 including the revisions described in the paragraph above.

# 6. ACM Reference Manual Compliance Options

## 6.1 Measure Description

### 6.1.1 Measure Overview

This is a submeasure of the CASE Report that recommends three new compliance options for alterations: 1) revised blower door and air infiltration credit, 2) fireplace removal credit and 3) Quality Insulation Installation (QII) credit for altered assemblies. These three compliance options apply to all residential buildings including single family and multifamily and would require updates to the compliance software for existing plus addition plus alteration analysis.

#### *6.1.1.1 Revised Blower Door/Air Infiltration Compliance Credit*

As part of this submeasure the Statewide CASE Team is recommending a change to the default Standard Design air infiltration rate assumption for existing buildings as well as a change to how reduced infiltration is credited for single family alterations. Currently reduction in air infiltration is not credited in a performance run unless the post-retrofit blower door test reading is 5 ACH50 or less. This compliance credit allows credit for the full reduction in infiltration based on the test results when pre- and post-retrofit blower door testing is conducted by a HERS Rater. The Standard Design air infiltration rate default assumption for existing buildings is 5 ACH50; it's recommended this be increased to 10 ACH50 to better represent the existing residential building stock.

#### *6.1.1.2 Fireplace Removal Compliance Credit*

This submeasure adds a compliance credit for removal of an existing wood burning fireplace. The credit can be taken if certain prescriptive requirements are met. Credit is awarded based on a fixed infiltration reduction in the CBECC-Res software.

#### *6.1.1.3 QII for Alterations Compliance Credit*

This submeasure adds a QII compliance credit for altered wall, ceiling and floor assemblies. The credit can be taken for any altered assembly and does not need to apply to an entire building. It is similar to that allowed for new construction and additions, with some key differences due to challenges with existing buildings. Specifically, the following aspects of QII for new construction are proposed to not apply to the QII for alterations credit.

- Subfloor sealed to create continuous airtight air barrier
- Bottom plates sealed to the floor
- Rim joist gaps and opening fully sealed
- Inaccessible penetrations at the top plate in attics

- Insulation around structural framing such as structural bracing, tie-downs, and framing of steel
- Insulation in hard to access wall stud cavities
- Insulated window and door headers

Provided that some of the criteria is relaxed, the proposed credit in the software is lower for altered assemblies than for new construction. For new construction assemblies without QII, the effective R-value of cavity insulation is reduced according to Table 3 of the 2019 Residential ACM, and ceilings below attic are modeled with added winter heat flow between the conditioned zone and attic to represent construction cavities open to the attic. When QII credit is taken in new construction, the effective R-value of cavity insulation is not derated and the additional heat flow from the conditioned zone to the attic is removed. Assuming that QII for altered assemblies would achieve most of the benefit of the cavity R-value and air sealing, the proposed QII credit for altered assemblies would have a reduced derate factor of 20 percent of the values shown in Table 3 of the 2019 Residential ACM. For example, the cavity R-value of a wall without QII is derated to 70 percent of the rated R-value of the cavity insulation. An altered wall assembly taking the new QII credit would be derated to 94 percent of the rated R-value.

### 6.1.2 Measure History

Compliance credits for alterations provide an incentive to building owners who are completing a remodel or addition to upgrade the performance of the existing building. The existing plus addition plus alteration performance compliance approach provides this encouraging addition projects to expand the scope into the existing building allowing trade-offs between the existing and new construction. Third party verification of existing conditions is another example which credits projects for efficiency upgrades relative to the existing condition of the building component. The intent of these three new proposed compliance credits is to encourage envelope efficiency upgrades that reduce air infiltration and improve thermal performance of insulated assemblies.

### 6.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 6.6 of this report for detailed proposed revisions to code language.

#### *6.1.3.1 Summary of Changes to the Standards*

The proposed code change for this submeasure would not modify the standards.

#### 6.1.3.2 Summary of Changes to the Reference Appendices

This proposal would modify the sections of the Reference Appendices identified below. See Section 6.6.3 of this report for the detailed proposed revisions to the text of the reference appendices.

**RESIDENTIAL APPENDICIES**

**RA3 – Residential Field Verification and Diagnostic Test Protocols:** The proposed QII for alterations submeasure revises requirements in RA3.5 Quality Insulation Installation Procedures to reflect how the protocols would be applied to altered assemblies.

**RA4 – Eligibility Criteria for Energy Efficiency Measures:** The proposed fireplace removal credit submeasure add a new subsection called Masonry Fireplace Removal in an Alteration either under RA4.2 Envelope Measures or RA4.5 Other Measures that describes the eligibility criteria for the credit.

#### 6.1.3.3 Summary of Changes to the Residential ACM Reference Manual

This proposal would modify the following sections of the Residential ACM Reference Manual as shown below. See Section 6.6.4 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

**SECTION 2.10 Additions/Alterations**

**Section 2.10.4.1 QII:** The proposed QII for alterations submeasure adds language that describes the Proposed Design modeling rules.

**Section 2.10.4.7 Air Leakage and Infiltration:** The proposed blower door/air infiltration and fireplace removal credit submeasures add a section that describes the Proposed Design modeling rules with and without the air infiltration and fireplace removal credit. Table 31 is updated to reflect the recommended standard design ACH50 values for existing buildings.

#### 6.1.3.4 Summary of Changes to the Residential Compliance Manual

The proposed code change would modify the following section of the Residential Compliance Manual:

- Section 9.2 What's New in the 2019 Energy Standards
- Add a new subsection under Section 9.5 Performance Approach that describes the three proposed compliance credits for alterations.

See Section 6.6.5 of this report for further details.

#### 6.1.3.5 Summary of Changes to Compliance Documents

The proposed revised blower door submeasure would modify the compliance document listed below.

- CF3R-EXH-20-H – Revised to add new subsection for existing blower door test results.

The proposed fireplace removal credit submeasure would modify the compliance documents.

- CF2R-ENV-03-E – Revised to add a new subsection for fireplace removal credit.

The proposed QII for alterations submeasure would modify the compliance documents listed below. Alternatively, new compliance forms can be created that are specific to QII for alterations and preserve the following four forms for new construction only. Examples of the revised documents are presented in Section 6.6.6.

- CF2R-ENV-21-H – Revised to reflect differences in QII inspection process for altered assemblies
- CF2R-ENV-22-H – Revised to reflect differences in QII inspection process for altered assemblies
- CF3R-ENV-21-H – Revised to reflect differences in QII inspection process for altered assemblies
- CF3R-ENV-22-H – Revised to reflect differences in QII inspection process for altered assemblies

### 6.1.4 Regulatory Context

#### 6.1.4.1 Existing Requirements in the California Energy Code

QII is a prescriptive requirement in all climate zones for residential building except Climate Zone 7 for low-rise multifamily buildings. It is also prescriptive for additions greater than 700 square feet. There are provisions that exempt additions that convert existing unconditioned space to conditioned space from the insulated header requirement as well as air sealing requirements when the existing air barrier is not being removed. There is no requirement or credit for QII in existing buildings.

The current code does not address existing fireplaces.

#### 6.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

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

#### 6.1.4.3 Relationship to Local, State, or Federal Laws

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

#### 6.1.4.4 Relationship to Industry Standards

There are no relevant industry standards.

### 6.1.5 Compliance and Enforcement

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

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

- **Design Phase:** Both proposed compliance credits would be part of a larger remodeling project and it's likely that an architect or designer would be engaged during the design phase. The designer works directly with the building owner to develop drawings and detail the design. Either the designer or the building owner works directly with the energy consultant to specify the appropriate efficiency characteristics ensuring the project complies with Title 24, Part 6. The energy consultant provides guidance to the design team about what is required to meet the compliance credit criteria. The energy consultant develops the performance compliance model and completes the Certificates of Compliances.
- **Permit Application Phase:** The designer or building owner submits the project for permit to the local building department. The plans examiner would review the permit application and verify that specifications as called out in the Certificates of Compliance are noted on the drawings. If blower door testing is conducted as part of an air infiltration or fireplace removal credit, the HERS Rater needs to complete a pre-retrofit blower door test to verify pre-retrofit air infiltration test conditions.
- **Construction Phase:** A general contractor is likely engaged, and the project work is completed. The general contractor directs any subcontractors on the project and ensures that the criteria and procedures outlined in the Residential Appendices for the compliance credits are met. For the QII for alterations submeasure a HERS Rater conducts a framing inspection and the associated Certificate of Verification before the insulation is installed and the construction phase completed.
- **Inspection Phase:** The installing contractor completes the relevant Certificate of Installation documents. For the QII for alterations submeasure the HERS Rater completes the insulation inspection and the associated Certificate of Verification. For the fireplace credit submeasures, if blower door testing is conducted the HERS Rater completes the test and the Certificate of Verification. The building inspector reviews all documents, conducts an onsite inspection, and signs off on the project.

For the fireplace removal credit submeasure the compliance process described above is very similar to the current process. The primary difference is that the designer, contractor and building inspector verify that the criteria defined in the Residential Appendix is met.

For the QII for alterations submeasure the compliance process described above requires additional verification steps utilizing a HERS Rater. QII requires two inspections from the HERS Rater, one during framing before insulation has been installed and the second after insulation has been installed but before assemblies are closed. The timing of this requires close communication between the contractor, the subcontractors, and the HERS Rater. Project teams and HERS Raters that use the QII credit for new construction are familiar with this process and can apply similar procedures to alteration projects. The Certificate of Installation and Certificate of Verification documents would be revised. Since no additional inspection procedures are added for alterations, only some omitted, it's expected the contractors and HERS Raters can become comfortable with the changes quickly.

The proposed compliance credits fit within the existing compliance process structure and there are no foreseen challenges with compliance and enforcement.

## 6.2 Market Analysis

### 6.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 12, 2019 ( (Statewide CASE Team 2019a), (Statewide CASE Team 2019b), (Statewide CASE Team 2019c)) and March 5, 2020 ( (Statewide CASE Team 2020a), (Statewide CASE Team 2020b), (Statewide CASE Team 2020c)).

#### *6.2.1.1 Revised Blower Door/Air Infiltration Compliance Credit*

Air sealing and air infiltration testing can be part of a larger remodel to improve performance and comfort in a building. The general contractor, insulation contractor, and HERS Rater are primary actors involved. This submeasure would provide credit to contractors involved in energy retrofits as part of a remodel.

#### 6.2.1.2 Fireplace Removal Compliance Credit

Removal of a masonry fireplace is a substantial project and is usually done as part of a large remodeling project. A general contractor and the building owner are the primary market actors involved. Fireplace removal can be accomplished at different levels, by removing just a portion of the fireplace such as the chimney stack above the roof, or just the fireplace breast. Other times the masonry fireplace is left in place and a clean burning stove insert installed directly in the existing masonry opening. A chimney liner is also installed to safely vent the combustion gases and smoke. To receive the full benefit relative to reducing air leakage, the entire fireplace needs to be removed from its foundation to the chimney. Repairs would need to be made where the fireplace penetrates floors, walls, ceilings and roofs including installing a new air barrier, air sealing, and insulating. In addition to the infiltration benefit there would also be a thermal benefit where previously uninsulated exterior surfaces can now be insulated. This is particularly noticeable when the fireplace is located on an exterior wall and a new insulated framed wall is constructed in its place. Once removed, a gas or electric insert can still be installed where the fireplace once stood.

#### 6.2.1.3 QII for Alterations Compliance Credit

There is a developed market in place for QII for new construction homes with trained HERS Raters throughout California. This submeasure would expand the current market to cover existing buildings. HERS Raters and insulation contractors are the primary market actors involved.

### 6.2.2 Technical Feasibility, Market Availability, and Current Practices

#### 6.2.2.1 Revised Blower Door/Air Infiltration Credit

As part of this research, the Statewide CASE Team identified that average infiltration for existing homes is higher than what is assumed in CBECC-Res, which applies a 5 ACH50 both for new construction and existing single family homes (7 ACH50 for multifamily buildings). There is a wide range in tested ACH50 values for single family homes in the existing literature. A study by Max Sherman of Lawrence Berkeley National Laboratory (LBNL) (Sherman 2008) notes an infiltration rate of 12-30 ACH50 for existing homes in the U.S. with 24 ACH50 being the average for the stock. Data from the 2013 ASHRAE Handbook of Fundamentals (ASHRAE 2013) indicates a range of 0 to 50 ACH50 for a sample of 2,080 existing single family homes in the United States based on a study conducted by Sherman and Dickeroff in 1998 (American Society of Heating, Refrigerating and Air-Conditioning Engineers 2013). Based on this data, the Statewide CASE Team recommends that the default air leakage level for existing single family and multifamily homes in CBECC-Res be revised to 10 ACH50, even though a higher level is likely defensible.

#### 6.2.2.2 Fireplace Removal Compliance Credit

Based on the 2009 Residential Appliance Saturation Study (California Energy Commission 2009) almost 10 percent of homes, or 1.1 million homes, have a wood burning fireplace. The majority of these are in single family homes. Masonry wood burning fireplaces can be a significant source of air infiltration and exfiltration. Available disaggregated air leakage data by building component is limited. However, the 2013 ASHRAE Handbook of Fundamentals (ASHRAE 2013) indicates a range of 0 to 30 percent for fireplaces with a mean of 12 percent, based on studies conducted by Dickeroff et al. (Dickerhoff, Grimsrud and Lipschutz 1982) and Harrje and Born (Harrje and Born 1982).

The Residential Construction Quality Assessment Project conducted for the California Energy Commission conducted testing on “leading edge” new construction single family homes from 1999 to 2002 (Davis Energy Group 2002). In Phase II the project measured leakage through fireplaces. Eight homes with wood burning fireplaces were blower door tested with and without the fireplace face fully sealed. The average leakage through the fireplaces was 173 cubic feet per minute measured at 50 Pascals (CFM50). Average total house leakage including the fireplace was 5.1 air changes per hour measured at 50 Pascals (ACH50). Sealing off the fireplace face reduced total air leakage by 8 percent on average. These homes were relatively high performance for the time; in addition, the chimney may leak at other locations other than the fireplace face. Therefore, it can be assumed that leakage through fireplaces in older homes can be much higher.

Wood burning fireplaces produce elevated levels of indoor air pollutants contributing to poor indoor air quality. There are various wood-burning changeout campaigns initiated by local jurisdictions and at the state level in California. Senate Bill 563 established the Woodsmoke Reduction Program, administered by the California Air Resources Board, to promote the voluntary replacement of old wood-burning stoves with cleaner and more efficient alternatives. Similar programs, many with incentives, are active or have been in the past throughout the state including by the Bay Area Air Quality Management District, San Joaquin Valley Air Pollution Control District, and Sacramento Metropolitan Air Quality Management District.

#### 6.2.2.3 QII for Alterations Compliance Credit

As part of this research, the Statewide CASE Team did not identify any prior studies that specifically quantified the impacts of meeting air sealing and insulation requirements of QII in existing buildings. Aspects of QII that can and cannot be addressed in an existing assembly were identified through discussions with HERS Raters and practitioners. Identifying the potential impacts of the relative areas that need to be addressed, the Statewide CASE Team estimated that meeting QII criteria in an existing assembly could achieve 80 percent of the benefit of QII if the assembly was new construction. Except for a small number of areas identified, QII can be met in existing assemblies. Certain on-site conditions may exist that would make meeting QII for an existing assembly difficult and costly to achieve. This measure is only considered as a compliance credit. There may be on-site conditions where this credit would not apply.

HERS Raters currently receive training from their HERS Provider, either CalCERTS or CHEERS. Training covers HERS verification procedures for both alterations and new construction. Most HERS Raters are certified for both alterations and new construction; however, there are some that are only certified for alterations. The proposed QII for alterations compliance credit relies heavily on the existing procedures for new construction homes; therefore, it's expected that the HERS Providers' current training curriculum for QII could be revised to include requirements for existing homes.

## 6.3 Energy Savings

The code change proposal would not modify the stringency of the existing California Energy Code, so there would be no savings on a per-unit basis. 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 submeasure. Although this submeasure does not result in electricity or gas savings, the submeasure would encourage envelope efficiency upgrades that reduce air infiltration, improve indoor air quality and improve thermal performance of insulated assemblies.

## 6.4 Cost and Cost Effectiveness

The code change proposal would not modify the stringency of the existing California Energy Code, so the Energy Commission does not need a complete cost-effectiveness analysis to approve the proposed change. This section of the CASE Report typically presents a detailed cost-effectiveness analysis. For this proposed change, the Statewide CASE Team is presenting information on the cost implications in lieu of a full cost-effectiveness analysis.

## 6.5 First-Year Statewide Impacts

The code change proposal would not modify the stringency of the existing California Energy Code, 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. As discussed in Section 6.3, although the energy savings are limited, the measure would promote upgrades to existing buildings where they may not have been updated in the absence of a compliance credit.

## 6.6 Proposed Revisions to Code Language

### 6.6.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

### 6.6.2 Standards

There are no proposed changes to the standards.

### 6.6.3 Reference Appendices

#### *6.6.3.1 Fireplace Removal Compliance Credit*

**Appendix RA4 – Eligibility Criteria for Energy Efficiency Measures**

This compliance credit would add a new subsection called Masonry Fireplace Removal in an Alteration either under RA4.2 Envelope Measures or RA4.5 Other Measures.

*RA4.XX – Masonry Fireplace Removal in an Alteration*

Wood burning masonry fireplaces in older homes can represent a significant amount of building air leakage. Fireplace removal reduces air leakage, improves thermal performance of building assemblies, and improves indoor air quality.

Decommissioning. The existing masonry fireplace must be completely removed from its foundation through termination point at the roof. All altered assemblies, including floors, walls, ceiling, and roofs, shall be sealed as specified in Section 110.7 of the Standards. Altered assemblies shall be insulated to meet the prescriptive requirements of Section 150.2(b)1 of the Standards.

#### *6.6.3.2 QII for Alterations Compliance Credit*

**Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols**

The proposed submeasure revises RA3.5 – Quality Insulation Installation Procedures of the Residential Appendices to address changes in inspection procedures with altered assemblies as part of a performance credit taken in an alteration.

The Statewide CASE Team is recommending additional language in some parts of Section 3.5 of RA3.5 to provide more clarity on the inspection criteria for altered assemblies and avoid confusion with current inspection procedures that address QII for new buildings.

*RA3.5 – Quality Insulation Installation Procedures*

**RA3.5.1 Purpose and Scope**

RA3.5 is a procedure for verifying the quality of insulation installation and air leakage control used in low-rise residential buildings. This procedure is to be followed by the insulation installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance for meeting the requirements of Sections 150.1(c), and 110.7of the Standards.

The procedure applies to wood and metal construction of framed and non-framed envelope assemblies. Framed assemblies include wall stud cavities, roof/ceiling assemblies, and floors typically insulated with: (1) batts of mineral fiber and mineral wool; (2) loose-fill materials of mineral fiber, mineral wool, and cellulose; (3) spray polyurethane foam; and, (4) rigid board sheathing materials. Non-framed assemblies include wall, roof/ceiling, and floors constructed of structural insulated panels and insulated concrete forms.

Note 1: For newly constructed buildings, this procedure applies to the entire thermal envelope of the building. For new building assemblies, as part of an addition, this procedure applies to the entire building assembly, including connections to adjacent parts of the existing building. For applicable altered assemblies, this procedure applies to the altered assembly only. In many instances, residential homes will use several types of insulation material, even in the same framed assembly. Each insulation material and the integrity of air leakage control for the building's entire thermal envelope must be verified by the HERS Rater for the home to comply with the Standards.

### RA3.5.3 BATT AND BLANKET INSULATION

#### RA3.5.3.2 Wall Insulation

**Exception to RA3.5.3.2(b)**: Altered wall assemblies, where the bottom plate to the ground subfloor or slab, and above ground subfloor is remaining and cannot be sealed.

#### RA3.5.3.2.8 Special Situations—Structural Bracing, Tie-downs, Steel Structural Framing

**Exception to RA3.5.3.2.8(b)**: Altered wall assemblies where structural bracing or tie-downs exist, install insulation to minimize thermal bridging not required if it is not possible without moving the exterior or interior wall plane.

#### RA3.5.3.2.9 Special Situations—Window and Door Headers

**Exception to RA3.5.3.2.9**: Altered wall assemblies with existing window and wall headers do not need to meet the insulation criteria.

#### RA3.5.3.3 Roofs/Ceilings

**Exception to RA3.5.3.3(i) and (j):** Altered ceiling assemblies with non-IC-rated recessed fixtures shall be allowed to remain if fitted with an approved fire-proof cover. Insulation shall be installed to cover fire-proof cover to same depth as the rest of the ceiling.

### RA3.5.4 LOOSE FILL INSULATION

#### RA3.5.4.2 Wall Insulation

**Exception to RA3.5.4.2(b)**: Altered wall assemblies, where the bottom plate to the ground subfloor or slab, and above ground subfloor is remaining and cannot be sealed.

#### RA3.5.4.2.8 Special Situations—Structural Bracing, Tie-downs, Steel Structural Framing

**Exception to RA3.5.4.2.8(b)**: Altered wall assemblies where structural bracing or tie-downs exist, install insulation to minimize thermal bridging not required if it is not possible without moving the exterior or interior wall plane.

#### RA3.5.4.2.9 Special Situations—Window and Door Headers

**Exception to RA3.5.4.2.9**: Altered wall assemblies with existing window and wall headers do not need to meet the insulation criteria.

#### RA3.5.4.3 Roofs/Ceilings

**Exception to RA3.5.4.3(f) and (g):** Altered ceiling assemblies with non-IC-rated recessed fixtures shall be allowed to remain if fitted with an approved fire-proof cover. Insulation shall be installed to cover fire-proof cover to same depth as the rest of the ceiling.

### RA3.5.5 RIGID BOARD INSULATION

#### RA3.5.5.2 Wall Insulation

**Exception to RA3.5.5.2(b)**: Altered wall assemblies, where the bottom plate to the ground subfloor or slab, and above ground subfloor is remaining and cannot be sealed.

#### RA3.5.5.2.8 Special Situations—Structural Bracing, Tie-downs, Steel Structural Framing

**Exception to RA3.5.5.2.8(b)**: Altered wall assemblies where structural bracing or tie-downs exist, install insulation to minimize thermal bridging not required if it is not possible without moving the exterior or interior wall plane.

#### RA3.5.5.2.9 Special Situations—Window and Door Headers

**Exception to RA3.5.5.2.9**: Altered wall assemblies with existing window and wall headers do not need to meet the insulation criteria.

#### RA3.5.5.3 Roofs/Ceilings

**Exception to RA3.5.5.3(d) and (e):** Altered ceiling assemblies with non-IC-rated recessed fixtures shall be allowed to remain if fitted with an approved fire-proof cover. Insulation shall be installed to cover fire-proof cover to same depth as the rest of the ceiling.

### RA3.5.6 SPRAY POLYURETHANE FOAM INSULATION

#### RA3.5.6.2 Wall Insulation

**Exception to RA3.5.6.2(b)**: Altered wall assemblies, where the bottom plate to the ground subfloor or slab, and above ground subfloor is remaining and cannot be sealed.

#### RA3.5.6.2.8 Special Situations—Structural Bracing, Tie-downs, Steel Structural Framing

**Exception to RA3.5.6.2.8(b)**: Altered wall assemblies where structural bracing or tie-downs exist, install insulation to minimize thermal bridging not required if it is not possible without moving the exterior or interior wall plane.

#### RA3.5.6.2.9 Special Situations—Window and Door Headers

**Exception to RA3.5.6.2.9**: Altered wall assemblies with existing window and wall headers do not need to meet the insulation criteria.

#### RA3.5.6.3 Roofs/Ceilings

**Exception to RA3.5.6.3(g):** Altered ceiling assemblies with non-IC-rated recessed fixtures shall be allowed to remain if fitted with an approved fire-proof cover. Insulation shall be installed to cover fire-proof cover to same depth as the rest of the ceiling.

### RA3.5.7 STRUCTURAL INSULATED PANEL (SIP)

#### RA3.5.7.2 Wall Insulation

**Exception to RA3.5.7.2(b)**: Altered wall assemblies, where the bottom plate to the ground subfloor or slab, and above ground subfloor is remaining and cannot be sealed.

#### RA3.5.7.2.6 Special Situations—Structural Bracing, Tie-downs, Steel Structural Framing

**Exception to RA3.5.7.2.6(b)**: Altered wall assemblies where structural bracing or tie-downs exist, install insulation to minimize thermal bridging not required if it is not possible without moving the exterior or interior wall plane.

#### RA3.5.7.2.7 Special Situations—Window and Door Headers

**Exception to RA3.5.7.2.7**: Altered wall assemblies with existing window and wall headers do not need to meet the insulation criteria.

#### RA3.5.7.3 Roofs/Ceilings

**Exception to RA3.5.7.3(d) and (e):** Altered ceiling assemblies with non-IC-rated recessed fixtures shall be allowed to remain if fitted with an approved fire-proof cover. Insulation shall be installed to cover fire-proof cover to same depth as the rest of the ceiling.

### RA3.5.8 INSULATED CONCRETE FORM (ICF)

#### RA3.5.8.2 Wall Insulation

**Exception to RA3.5.8.2(b)**: Altered wall assemblies, where the bottom plate to the ground subfloor or slab, and above ground subfloor is remaining and cannot be sealed.

**RA3.5.8.2.6 Special Situations—Structural Bracing, Tie-downs, Steel Structural Framing**

**Exception to RA3.5.8.2.6(b)**: Altered wall assemblies where structural bracing or tie-downs exist, install insulation to minimize thermal bridging not required if it is not possible without moving the exterior or interior wall plane.

**RA3.5.8.2.7 Special Situations—Window and Door Headers**

**Exception to RA3.5.8.2.7**: Altered wall assemblies with existing window and wall headers do not need to meet the insulation criteria.

**RA3.5.8.3 Roofs/Ceilings**

**Exception to RA3.5.8.3(d) and (e):** Altered ceiling assemblies with non-IC-rated recessed fixtures shall be allowed to remain if fitted with an approved fire-proof cover. Insulation shall be installed to cover fire-proof cover to same depth as the rest of the ceiling.

### 6.6.4 ACM Reference Manual

#### *6.6.4.1 Revised Blower Door/Air Infiltration & Fireplace Removal Compliance Credits*

**2 Proposed, Standard, and Reference Design**

**2.10 Additions/Alterations**

**2.10.4.7 Air Leakage and Infiltration**

***PROPOSED DESIGN***

If diagnostic testing is completed by a HERS Rater, the proposed design air leakage is the diagnostic tested ACH50 value. If there is no diagnostic testing, the proposed design air leakage matches the standard design except as described below.

When an existing masonry wood burning fireplace is removed meeting the requirements of RA4.XX – Masonry Fireplace Removal in an Alteration, infiltration will be reduced by 12 percent relative to the standard design.

***STANDARD DESIGN***

Standard design air leakage and infiltration is shown in Table 31.

**Table 31: ~~Addition~~ Standard Design for Air Leakage and Infiltration**

| Proposed Air Leakage and Infiltration | Standard Design Air Leakage Based on Building Type | | |
|---|---|---|---|
| | Addition | Altered | Verified Altered |

| | | | |
|---|---|---|---|
| Single Family Buildings | 5 ACH50 | 10~~5~~ ACH50 | Diagnostic testing of existing ACH50 value by HERS Rater ~~or 7.0 ACH50, whichever is less~~ |
| Multifamily Buildings | 7 ACH50 | 10~~7~~ ACH50 | 10~~7~~ ACH50 |

#### *6.6.4.2 QII for Alterations Compliance Credit*

**2 Proposed, Standard, and Reference Design**

**2.10 Additions/Alterations**

**2.10.4.1 QII**

The compliance software user may specify quality insulation installation (QII) for the proposed design as yes or no. For additions compliance with QII must be met for all relevant assemblies in the addition. For alterations compliance with QII may be met for individual altered assemblies.

The modeling rules for assemblies with and without QII are shown in Table 26. When the QII credit is not taken and for additions with QII, the rules are the same as for new construction. The QII credit for altered assemblies is reduced by 20 percent relative to that for new construction and additions. QII does not affect the performance of continuous sheathing in any construction.

***PROPOSED DESIGN***

The compliance software user may specify compliance with QII. The default is “no” for QII.

***STANDARD DESIGN***

The standard design includes QII for additions greater than 700 square feet in any low-rise single-family building in Climate Zones 1-16 and in any low-rise multifamily building in Climate Zones 1-6 and 8-16 (Section 150.2[a]1Bv).

The provisions of Section 150.2(a)1Aiv, as applied to converting an existing unconditioned space to conditioned space, are accommodations made by the HERS rater in the field. No adjustments to the energy budget are made.

The standard design does not include QII for all other additions and alterations.

**Table 26: Modeling Rules for Verified Insulation Installation Quality**

| Component | Alteration or Addition - no QII | Alteration – QII | Addition – QII |
|---|---|---|---|
| Walls, Floors, Attic Roofs, Cathedral Ceilings | Multiply the cavity insulation R-value/inch by 0.7. | Multiply the cavity insulation R-value/inch by 0.94. | No adjustment to R-value |
| Ceilings Below Attic | Multiply the blown and batt insulation R- | Multiply the blown and batt insulation R- | No adjustment to R-value |

| | | | |
|---|---|---|---|
| | value/inch by 0.96-0.00347*R. | value/inch by 0.992-0.00069*R. | |
| Ceilings Below Attic | Add a heat flow from the conditioned zone to the attic of 0.015 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space. | Add a heat flow from the conditioned zone to the attic of 0.003 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space. | No heat flow added |

### 6.6.5 Compliance Manuals

Chapter 9 of the Residential Compliance Manual would need to be revised. Section 9.2 What's New in the 2019 Energy Standards would be updated to mention the new compliance credits. A new subsection is recommended under Section 9.5 Performance Approach for compliance credits for alterations. The new subsection would include a description of the criteria to meet the two compliance credits.

### 6.6.6 Compliance Documents

#### *6.6.6.1 Revised Blower Door/Air Infiltration Compliance Credit*

The Certification of Verification, CF3R-EXH-20-H, would need to be revised to add a new subsection where existing blower door test result may be recorded.

#### *6.6.6.2 Fireplace Removal Compliance Credit*

It's proposed that the CF2R-ENV-03-E be revised to add a new subsection for fireplace removal credit where the contractor would indicate that all the requirements of the compliance credit and Section 110.7 are met.

#### *6.6.6.3 QII for Alterations Compliance Credit*

The existing Certificate of Installation and Certificate of Verification documents for Quality Insulation Installation (CF2R-ENV-21-H, CF2R-ENV-22-H, CF3R-ENV-21-H, CF3R-ENV-22-H) are for new construction or entirely new assemblies. There are aspects of these documents that do not apply to the verification of QII for altered assemblies. Certain aspects of QII cannot be addressed in altered assemblies, including air sealing and insulation of parts of the assembly that are not accessible. These forms either need to be revised to specify which sections apply to altered assemblies, or new CF2R and CF3R documents need to be created that address installation and inspection requirements specific to altered assemblies.

The following changes need to be made to the CF2R and CF3R forms when being used for the QII compliance credit for altered assemblies.

**QII – AIR INFILTRATION SEALING – FRAMING STAGE: CF2R-ENV-21-H, CF3R-ENV-21-H**

| **A. Air Barrier Materials** | |
|---|---|
| 01 | A continuous sealed exterior air barrier is required in all thermal envelope assemblies to limit air movement between unconditioned/outside spaces and conditioned/inside spaces, and must comply using one of the following methods:<br>1. Using individual materials that have an air permeance not exceeding 0.004 cfm/ft$^2$ under a pressure differential of 0.3 in. w.g. (1.57 pcf) (0.02 L/s.m$^2$ at 75 pa) when tested in accordance with ASTM E2178; or<br>2. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft under a pressure differential of 0.3 in. w.g. (1.57 pcf) (0.2 L/s.m$^2$ at 75 pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680, or ASTM E283; or<br>3. Testing the complete building and demonstrating that the air leakage rate of the building envelope does not exceed 0.40 cfm/ft$^2$ at a pressure differential of 0.3 in. w.g. (1.57 pcf) (2.0 L/s.m$^2$ at 75 pa) in accordance with ASTM E779 or an equivalent approved method. |

| **B. Raised Floor Adjacent to Unconditioned Space or Separate Dwelling Units** | |
|---|---|
| 01 | All gaps in the raised floor are sealed. |
| 02 | All chases are sealed at floor level using a sealed hard cover. |
| 03 | All holes (e.g., for plumbing and electrical wires) that penetrate the floor or bottom plates of walls are sealed. |
| ~~04~~ | ~~Subfloor sheathing is glued or sealed at all panel edges to create a continuous air tight subfloor air barrier.~~ |

| **C. Walls Adjacent to Unconditioned Space** | |
|---|---|
| 01 | All penetrations through the exterior wall air barrier are sealed to provide an air tight envelope to unconditioned spaces such as the outdoors, attic, garage, and crawlspace. |
| 02 | Exterior wall air barrier is sealed to the top plate and bottom plate in each stud bay. |
| 03 | All electrical boxes, including knockouts, that penetrate the air barrier to unconditioned space are sealed. |
| 04 | All openings in the top and bottom plate, including all interior and exterior walls, to unconditioned space are sealed; such as holes drilled for electrical and plumbing. |
| ~~05~~ | ~~Exterior bottom plates (all stories) are sealed to the floor.~~ |
| 06 | All gaps around windows and doors are sealed. The sealant used follows manufacturer specifications. |
| ~~07~~ | ~~Rim joist gaps and openings are fully sealed.~~ |
| 08 | Fan exhaust duct outlet/damper at the exterior wall are sealed. |

| | |
|---|---|
| 09 | Knee walls have solid and sealed blocking at the bottom, top, left and right sides to prevent air movement into insulation. |

| **D. Ceiling Air Barrier Adjacent to Unconditioned Space** | |
|---|---|
| 01 | There is a continuous air barrier at the ceiling level. All openings into walls, drops, chases or double walls are sealed. |
| 02 | All accessible penetrations through the top plate of interior and exterior walls are sealed. |
| 03 | Fire sprinklers penetrating a ceiling air barrier shall be sealed to prevent air movement according to the manufacturer's instructions. |
| 04 | All fixtures cut into ceiling air barrier (e.g., HVAC registers, electrical boxes, fire alarm boxes, exhaust fan housing, and recessed lighting fixtures) are sealed to the surrounding dry wall. If it is not possible to seal the fixture directly, a secondary air barrier shall be created around the fixture. |
| 05 | All installed recessed lighting fixtures that penetrate the ceiling to unconditioned space are rated to be Insulation Contact and Airtight (IC and AT) which allow direct contact with insulation. |
| 06 | All dropped ceiling areas are covered with hard covers that are sealed to the framing, or else the bottom and sides of dropped ceiling areas are all insulated and sealed as ceilings and walls as required on the Certificate of Compliance. |
| 07 | All vertical chases (e.g., HVAC ducts and plumbing) and soffits are sealed at the ceiling level. |
| 08 | Chimneys and flues require sheet metal flashing at the ceiling level. The flashing shall be sealed to the chimney/flue with fire rated caulk. The flashing shall be sealed to the surrounding framing. |
| 09 | Framing locations where air may move down into the walls from the attic (e.g., double walls, pocket doors, architectural bump-outs, etc.) have a sealed hard cover to prevent air movement. |
| 10 | Attic access forms an airtight seal between the conditioned space and unconditioned space. Vertical attic access requires mechanical compression using screws or latches. |

| **E. Roof Air Barrier – Unvented Attics Adjacent to Unconditioned Space** | |
|---|---|
| 01 | There is a continuous air barrier at the roof deck and gable ends. |
| 02 | Chimneys and flues require sheet metal flashing at the roof deck. The flashing is sealed to the chimney/flue with fire rated caulk. The flashing is sealed to the surrounding framing. |
| 03 | All penetrations in the roof deck and gable ends for plumbing, electrical, etc. are sealed. |

| **F. Conditioned Space Above or Adjacent to Garage Air Barrier** | |
|---|---|
| 01 | All penetrations in the subfloor above the garage into conditioned space must follow the raised floor air barrier requirements. |
| 02 | Infiltration between the space above the garage and the subfloor is prevented by one of the following methods: |

| | |
|---|---|
| | • Seal all edges of the garage ceiling (typically drywall) at the perimeter of the garage to create a continuous air tight surface between the garage and adjacent conditioned envelope. Seal all plumbing, electrical, and mechanical penetrations between the garage and adjacent conditioned space. For an open-web truss, airtight blocking is added on all four sides of the garage perimeter. Insulation can be placed on the garage ceiling.<br>~~Seal the band joist above the wall at the garage to conditioned space transition. Seal all subfloor seams and penetrations between the garage and adjacent conditioned space. Insulation must be placed in contact with the subfloor below the conditioned space.~~ |

**ENV-21 User Instructions**

~~Quality Insulation Installation (QII) applies to the entire building (roof/ceiling, walls, and floor) for new construction and requires field verification by a third-party HERS Rater. For Alterations to existing buildings, compliance credit can only be taken when the "existing, plus addition, plus alteration" approach is used, but credit will only apply to the new surfaces in the new zone.~~

Quality Insulation Installation (QII) for Alterations to existing buildings, compliance credit can only be taken when the "existing, plus addition, plus alteration" approach is used, and credit will only apply to altered assemblies and new surfaces that are taking the QII credit in the PRF-01 Alterations form, and requires field verification by a third-party HERS Rater.

**QII – INSULATION INSTALLATION: CF2R-ENV-22-H, CF3R-ENV-22-H**

| **A. Insulation Materials Installed** | | | |
|---|---|---|---|
| 01 | Roof Deck Insulation Material Installed | □ Yes □ No | |
| 02 | Ceiling Insulation Material Installed | □ Yes □ No | |
| 03 | Exterior Wall Insulation Material Installed | □ Yes □ No | |
| 04 | Raised Floor Insulation Material Installed | □ Yes □ No | |
| ~~05~~ | ~~Slab Edge Insulation Material Installed~~ | | |

| B. All Surfaces | |
|---|---|
| 01 | Air barrier installation and preparation for insulation was done and verified prior to insulation being installed. |
| 02 | All surfaces between conditioned and unconditioned space are sealed and insulated to meet or exceed the levels specified on the Certificate of Compliance. |
| ~~03~~ | ~~All structural framing areas shall be insulated in a manner that resists thermal bridging through the assembly separating conditioned from unconditioned space. Structural bracing, tie-downs, and framing of steel, or specialized framing used to meet structural requirements of the CBC are allowed and must be insulated. These areas shall be called out on the building plans with diagrams and/or specified design drawings indicating the R-value of insulation and fastening method to be used.~~ |
| 04 | All insulation was installed according to the manufacturer's installation instructions. |
| 05 | Labels or specification/data sheets for each insulation material shall be provided to the HERS Rater. Loose-fill material includes insulation material bag labels or coverage charts. |
| 06 | Loose-fill insulation – The installed depth and density of insulation is verified in <u>each altered assembly</u> ~~at least 6 random locations~~ to ensure that the minimum thickness and installed density meet the R-value specified on the Certificate of Compliance, and are consistent with the manufacturer's coverage chart. |
| 07 | If kraft paper faced insulation is used, paper is installed on the conditioned (warm in winter) side of surface. Paper must be in contact with air barrier to within 2" framing (stud, joists, etc.). |

| C. Raised Floor Adjacent to Unconditioned Space | |
|---|---|
| 01 | Insulation is in full contact with the subfloor. |
| 02 | Insulation hangers are spaced at 18 inches or less. Insulation hangers do not compress insulation. |
| 03 | Netting, or mesh, can be used if the cavity under the floor is filled and in contact with the subfloor. |
| 04 | When daylight basements are adjacent to crawlspaces, if the basement is conditioned the walls adjacent to the crawlspace are insulated to the R-value listed on the Certificate of Compliance. This includes framed stem walls, and vertical concrete retaining walls. |
| 05 | If access to the crawlspace is from the conditioned area the raised floor includes an airtight insulated access hatch. Where possible locate crawl space access on the exterior. |

| D. Wall Adjacent to Unconditioned Space | |
|---|---|
| 01 | Insulation quality was verified prior to the installation of the interior air barrier (typically gypsum board). |
| 02 | Loose-fill and batt insulation is in contact with all six sides of wall cavities (top, bottom, back, left, right, front [to be installed later]) with no gaps, voids or compression. |

| | |
|---|---|
| | Exception: Where framing depth is greater than minimum required insulation thickness (e.g., R-19 batts in 2x10 walls). |
| 03 | Insulation fits snuggly around obstructions (e.g., electrical boxes, plumbing and wiring) with no gaps, voids or compression. |
| ~~04~~ | ~~Structural metal tie-downs and shear panels are insulated between exterior air barrier and metal.~~ |
| ~~05~~ | ~~Hard to access wall stud cavities, such as corner channels or wall intersections, are insulated to the proper R-value prior to the installation of exterior sheathing or exterior stucco lathe.~~ |
| 06 | Insulation and interior air barrier are installed behind tub, shower, fireplace enclosures and stairwells to the R-value listed on the Certificate of Compliance when located against exterior walls. |
| ~~07~~ | ~~All single-member window and door headers shall be insulated to a minimum of R-3 for a 2x4 framing, or equivalent width, and a minimum of R-5 for all other assemblies. If continuous exterior rigid insulation equal to or greater than R-2 is used, an insulated header is not required.~~ |
| 08 | After insulation is installed: All insulated walls have interior and exterior air barriers, including kneewalls and walls of skylight wells. Exception: Rim joists. Interior air barrier (typically gypsum board) is sealed to top plate. |

**ENV-22 User Instructions**

~~Quality Insulation Installation (QII) applies to the entire building (roof/ceiling, walls, and floor) for new construction and requires field verification by a third-party HERS Rater. For alterations to existing buildings, compliance credit can only be taken when the "existing, plus addition, plus alteration" approach is used, but credit will only apply the new surfaces in the new zone.~~

Quality Insulation Installation (QII) for Alterations to existing buildings, compliance credit can only be taken when the "existing, plus addition, plus alteration" approach is used, and credit will only apply to altered assemblies and new surfaces that are taking the QII credit in the PRF-01 Alterations form, and requires field verification by a third-party HERS Rater.

**Insulation Materials Installed**

For Items 1 – 5, select Yes or No to identify if assembly type is taking QII credit.

1. Roof Deck Insulation Material Installed: Using the drop down menu, indicate what type of insulation material is being installed (e.g., Batt and Blanket, Rigid Board, SPF, etc.).
2. Ceiling Insulation Material Installed: Using the drop down menu, indicate what type of insulation material is being installed (e.g., Batt and Blanket, Rigid Board, SPF, etc.).
3. Exterior Wall Insulation Material Installed: Using the drop down menu, indicate what type of insulation material is being installed (e.g., Batt and Blanket, Rigid Board, SPF, etc.).

4. Raised Floor Insulation Material Installed: Using the drop down menu, indicate what type of insulation material is being installed (e.g., Batt and Blanket, Rigid Board, SPF, etc.).

5. Slab Edge Insulation Material Installed: Using the drop down menu, indicate what type of insulation material is being installed (e.g., Batt and Blanket, Rigid Board, SPF, etc.).

6. Verification Status: HERS Rater to select from list:
    a. Pass – all applicable requirements are met.
    b. Fail – one or more applicable requirements are not met. Rater must enter reason for failure in correction notes field below.
    c. All N/A – This entire table is not applicable.

7. Correction Notes: Rater must enter the reason for failure.

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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 Energy Commission provided (California Energy Commission 2019d). The Statewide CASE Team made assumptions about the percentage of buildings in each climate zone that will be impacted by the proposed code change.

The multifamily building stock is further broken down based on the portion of dwelling units in low-rise (up to three stories) versus mid- and high-rise (four or greater stories) buildings. This is based on the CoStar database of existing multifamily buildings in California (CoStar 2018) which estimates that 84 percent of multifamily buildings are low-rise while would be directly impacted by these proposals.

### *Cool Roofs and Roof Insulation at Roof Replacement*

The cool roof measure would apply to existing single family and low-rise multifamily buildings. Because the energy impact of the measure is expected to be different for low-slope roofs compared to steep-slope roofs, the impacts are calculated separately for the two configurations using data from the 2009 RASS data (California Energy Commission 2009). While the data does not contain detail of low-slope versus steep-slope roofs explicitly, it does contain estimates of number of homes with insulated attics by building type and climate zone. These estimates are assumed to be a surrogate for steep-slope roofs and used to calculate the share of the existing construction stock impacted by this measure over time. The RASS data is processed to combine disaggregated numbers for single family homes, townhouses, duplexes and rowhouses into a single estimate of the existing single family building stock impacted by this measure that can be applied to the construction stock estimates provided by the Energy Commission. Similarly, the RASS data for apartments is similarly combined to calculate a single estimate of low-rise multifamily buildings impacted by this measure. Table 154 summarizes these shares of buildings estimated to be potentially impacted by this measure, by climate zone.

**Table 154: Estimated Residential Existing Building Stock by Climate Zone – Share of Homes with Steep-Slope Roofs Versus Low-Slope Roofs**

| Climate Zone | Steep-Slope Roofs | | Low-Slope Roofs | |
|---|---|---|---|---|
| | Single Family (Single Family, Townhouse, Duplex, Row House) | Low-Rise Multifamily (Apt Condo 2-4 and 5+ units) | Single Family (Single Family, Townhouse, Duplex, Row House) | Low-Rise Multifamily (Apt Condo 2-4 and 5+ units) |
| 1 | 91% | 51% | 9% | 49% |

| Climate Zone | Steep-Slope Roofs | | Low-Slope Roofs | |
|---|---|---|---|---|
| | Single Family (Single Family, Townhouse, Duplex, Row House) | Low-Rise Multifamily (Apt Condo 2-4 and 5+ units) | Single Family (Single Family, Townhouse, Duplex, Row House) | Low-Rise Multifamily (Apt Condo 2-4 and 5+ units) |
| 2 | 86% | 47% | 14% | 53% |
| 3 | 75% | 32% | 25% | 68% |
| 4 | 81% | 56% | 19% | 44% |
| 5 | 87% | 29% | 13% | 71% |
| 6 | 75% | 32% | 25% | 68% |
| 7 | 79% | 47% | 21% | 53% |
| 8 | 72% | 39% | 28% | 61% |
| 9 | 76% | 34% | 24% | 66% |
| 10 | 91% | 52% | 9% | 48% |
| 11 | 95% | 47% | 5% | 53% |
| 12 | 91% | 65% | 9% | 35% |
| 13 | 87% | 53% | 13% | 47% |
| 14 | 88% | 50% | 12% | 50% |
| 15 | 92% | 67% | 8% | 33% |
| 16 | 82% | 50% | 18% | 50% |
| **State Avg** | **82%** | **41%** | **18%** | **59%** |

Because this measure comes into play at re-roofing, the numbers in Table 154 need to be further combined with an estimated number of re-roofs that are expected to occur annually. Data on the number of re-roofs is limited. A 2013 state of the industry report from the roofing contractor website indicates an annual re-roofing rate of seven percent (Roofing Contractor 2013). The multipliers by climate zone are summarized in Table 155. Conversely, the roof insulation measure would apply only to low-slope roofs. The estimated portion of impacted buildings are summarized in Table 156 and Table 157 below.

Table 155 through Table 157 present the number of existing single family buildings and multifamily dwelling units that the Statewide CASE Team assumed would be impacted by the three proposed code changes during the first year the 2022 code is in effect.

**Table 155: Estimated Residential Existing Building Stock by Climate Zone – Steep-Slope Cool Roofs**

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0% | 0 | 14,386 | 0% | 0 |
| 2 | 260,224 | 0% | 0 | 85,446 | 3.3% | 2,801 |
| 3 | 963,408 | 0% | 0 | 445,275 | 0% | 0 |
| 4 | 489,254 | 5.7% | 27,839 | 233,969 | 3.9% | 9,102 |
| 5 | 95,423 | 0% | 0 | 37,645 | 0% | 0 |
| 6 | 589,387 | 0% | 0 | 265,259 | 0% | 0 |
| 7 | 488,748 | 0% | 0 | 245,115 | 0% | 0 |
| 8 | 913,789 | 5.0% | 45,968 | 411,043 | 2.7% | 11,262 |
| 9 | 1,237,621 | 5.3% | 65,992 | 912,827 | 2.4% | 21,555 |
| 10 | 1,043,549 | 0% | 0 | 265,763 | 0% | 0 |
| 11 | 317,948 | 0% | 0 | 68,729 | 0% | 0 |
| 12 | 1,275,153 | 0% | 0 | 382,423 | 0% | 0 |
| 13 | 612,938 | 0% | 0 | 129,400 | 0% | 0 |
| 14 | 236,635 | 0% | 0 | 66,479 | 0% | 0 |
| 15 | 168,190 | 0% | 0 | 33,628 | 0% | 0 |
| 16 | 92,126 | 0% | 0 | 23,104 | 0% | 0 |
| **TOTAL** | **8,828,191** | **1.6%** | **139,799** | **3,620,491** | **1.2%** | **44,719** |

### Table 156: Estimated Residential Existing Building Stock by Climate Zone – Low-Slope Cool Roofs

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0% | 0 | 14,386 | 0% | 0 |
| 2 | 260,224 | 0% | 0 | 85,446 | 3.7% | 3,181 |
| 3 | 963,408 | 0% | 0 | 445,275 | 0% | 0 |
| 4 | 489,254 | 1.3% | 6,408 | 233,969 | 3.1% | 7,276 |
| 5 | 95,423 | 0% | 0 | 37,645 | 0% | 0 |
| 6 | 589,387 | 1.7% | 10,154 | 265,259 | 0% | 12,707 |
| 7 | 488,748 | 1.5% | 7,226 | 245,115 | 0% | 9,171 |
| 8 | 913,789 | 2.0% | 17,997 | 411,043 | 4.3% | 17,511 |
| 9 | 1,237,621 | 1.7% | 20,642 | 912,827 | 4.6% | 42,343 |
| 10 | 1,043,549 | 0.6% | 6,681 | 265,763 | 3.4% | 8,936 |
| 11 | 317,948 | 0.4% | 1,117 | 68,729 | 3.7% | 2,552 |
| 12 | 1,275,153 | 0.6% | 7,714 | 382,423 | 2.4% | 9,343 |
| 13 | 612,938 | 0% | 0 | 129,400 | 0% | 0 |
| 14 | 236,635 | 0.9% | 2,052 | 66,479 | 3.5% | 2,344 |
| 15 | 168,190 | 0% | 0 | 33,628 | 0% | 0 |
| 16 | 92,126 | 0% | 0 | 23,104 | 0% | 0 |
| **TOTAL** | **8,828,191** | **0.91%** | **79,991** | **3,620,491** | **3.2%** | **115,364** |

Table 157: Estimated Residential Existing Building Stock by Climate Zone – Low-Slope Roof Insulation

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0.7% | 290 | 14,386 | 3.4% | 489 |
| 2 | 260,224 | 1.0% | 2,527 | 85,446 | 3.7% | 3,181 |
| 3 | 963,408 | 0% | 0 | 445,275 | 0% | 0 |
| 4 | 489,254 | 1.3% | 6,408 | 233,969 | 3.1% | 7,276 |
| 5 | 95,423 | 0% | 0 | 37,645 | 0% | 0 |
| 6 | 589,387 | 0% | 0 | 265,259 | 0% | 0 |
| 7 | 488,748 | 0% | 0 | 245,115 | 0% | 0 |
| 8 | 913,789 | 2.0% | 17,997 | 411,043 | 4.3% | 17,511 |
| 9 | 1,237,621 | 1.7% | 20,642 | 912,827 | 4.6% | 42,343 |
| 10 | 1,043,549 | 0.6% | 6,681 | 265,763 | 3.4% | 8,936 |
| 11 | 317,948 | 0.4% | 1,117 | 68,729 | 3.7% | 2,552 |
| 12 | 1,275,153 | 0.6% | 7,714 | 382,423 | 2.4% | 9,343 |
| 13 | 612,938 | 0.9% | 5,643 | 129,400 | 3.3% | 4,251 |
| 14 | 236,635 | 0.9% | 2,052 | 66,479 | 3.5% | 2,344 |
| 15 | 168,190 | 0.5% | 923 | 33,628 | 2.3% | 768 |
| 16 | 92,126 | 1.3% | 1,162 | 23,104 | 3.5% | 816 |
| **TOTAL** | **8,828,191** | **0.8%** | **73,156** | **3,620,491** | **2.8%** | **99,810** |

### *Electric Space Heating Equipment*

This measure would apply to existing single family homes and multifamily units with existing electric heating that is being replaced in combination with a ducted cooling system. The 2009 RASS data provides a breakdown of existing homes according to the primary heating system type and the presence of central air-conditioning (California Energy Commission 2009). Like the cool roofs measure, shares of single family homes and townhomes are combined into one category and those of apartments are combined into a second category for generating factors that would be consistent with the existing building stock estimates provided by the Energy Commission. Table 158 summarizes the share of single family homes and multifamily units with central forced air electric furnaces and central air-conditioning systems by climate zone.

**Table 158: Estimated Residential Existing Building Stock by Climate Zone – Share of Homes with Central Forced Air Electric Resistance Furnaces with Central Air-Conditioning**

| Climate Zone | Single Family (Single Family, Townhouse, Duplex, Row House) | Low-rise Multifamily (Apt Condo 2-4 and 5+ units) |
|---|---|---|
| 1 | 0.00% | 0.00% |
| 2 | 0.00% | 0.00% |
| 3 | 0.00% | 0.11% |
| 4 | 0.02% | 0.72% |
| 5 | 0.00% | 0.00% |
| 6 | 0.04% | 0.07% |
| 7 | 0.11% | 0.04% |
| 8 | 0.01% | 0.11% |
| 9 | 0.09% | 0.08% |
| 10 | 0.03% | 0.13% |
| 11 | 0.20% | 0.00% |
| 12 | 0.02% | 0.08% |
| 13 | 0.03% | 0.05% |
| 14 | 0.01% | 0.05% |
| 15 | 0.01% | 0.04% |
| 16 | 0.15% | 0.44% |
| **State Avg** | **0.04%** | **0.11%** |

An estimate of the portion of applicable homes that undergo a system change out annually is derived using data from CalCERTS which is expected to represent the majority of HERS inspections performed in California (CalCERTS 2020). The CalCERTS data indicates a total of 12,216 altered electric resistance heating systems for single family homes and 594 altered electric resistance heating systems for low-rise multifamily units over the 2016 code cycle. The number of system alterations annually is then calculated assuming the data are evenly distributed over the three-year period. This results in an annual total of 4,072 altered electric resistance heating systems for single family homes and 198 for low-rise multifamily units. The CalCERTS data does not indicate if these systems are ducted or split out homes with central air-conditioning systems from those without in these estimates; however, it can be presumed that since these projects are in the HERS registry and HERS verification was required this was triggered either due to the presence of a ducted system and/or air conditioning. This dataset likely does include some forced air electric resistance furnaces without central air-conditioning.

The CalCERTS estimates are compared with the RASS statewide total central forced air electric furnaces, with and without central air-conditioning, of 41,410 for single family and 66,292 for low-rise multifamily units from the 2009 RASS data for consistency as summarized in Table 159 below. These result in an approximate annual changeout rate of 9.8 percent for single family homes and 0.3 percent for the low-rise multifamily units.

**Table 159: Breakdown of Heating Systems for the Residential Existing Building Stock**

| Heating System | Single Family (Single Family, Townhouse, Duplex, Row House) | Multifamily (Apt Condo 2-4 and 5+ units) |
|---|---|---|
| **Total Electric** | | |
| Electric Resistance Heater (with Central Air-Conditioning) | 7,913 | 12,312 |
| Electric Resistance Heater (without Central Air-Conditioning) | 26,429 | 141,016 |
| Central Forced Air Electric Furnace (with Central Air-Conditioning) | 31,641 | 28,353 |
| Central Forced Air Electric Furnace (without Central Air-Conditioning) | 9,769 | 37,939 |
| Central Heat Pump | 34,800 | 30,851 |
| PTHP | 6,823 | 51,664 |
| Electric Portable/Other | 49,950 | 57,263 |
| **Natural Gas** | 6,175,628 | 1,844,153 |
| **LPG** | 246,324 | 26,937 |
| **Wood** | 197,756 | 4,856 |
| **Other** | 139,792 | 239,949 |
| **No Response** | 170,576 | 133,501 |
| **NA** | 225,500 | 271,215 |
| **Totals** | **7,322,901** | **2,880,009** |

Source: 2009 RASS data (California Energy Commission 2009).

Compared to the more robust single family sample, the CalCERTS data appears to be limited on low-rise multifamily. As such, the authors suspect the sample is incomplete and therefore, not suitable for use in calculations. Thus, the single family estimated changeout rate is applied to both single family as well as low-rise multifamily units in the statewide savings calculations. The numbers in Table 158 are further combined with a changeout rate of 9.8 percent to calculate the fraction of buildings impacted by this proposal. Table 160 presents the number of existing single family buildings and multifamily dwelling units that the Statewide CASE Team assumed would be impacted by the proposed code change during the first year the 2022 code is in effect.

**Table 160: Estimated Residential Existing Building Stock by Climate Zone – Electric Space Heating Equipment**

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0.00% | 0 | 14,386 | 0.00% | 0 |
| 2 | 260,224 | 0.00% | 0 | 85,446 | 0.00% | 0 |
| 3 | 963,408 | 0.00% | 0 | 445,275 | 0.11% | 471 |
| 4 | 489,254 | 0.02% | 88 | 233,969 | 0.72% | 1684 |
| 5 | 95,423 | 0.00% | 0 | 37,645 | 0.00% | 0 |
| 6 | 589,387 | 0.04% | 228 | 265,259 | 0% | 0 |
| 7 | 488,748 | 0% | 0 | 245,115 | 0% | 0 |
| 8 | 913,789 | 0.01% | 114 | 411,043 | 0% | 0 |
| 9 | 1,237,621 | 0.09% | 1096 | 912,827 | 0.08% | 725 |
| 10 | 1,043,549 | 0.03% | 346 | 265,763 | 0.13% | 340 |
| 11 | 317,948 | 0.20% | 651 | 68,729 | 0.00% | 0 |
| 12 | 1,275,153 | 0.02% | 197 | 382,423 | 0.08% | 324 |
| 13 | 612,938 | 0.03% | 212 | 129,400 | 0.05% | 67 |
| 14 | 236,635 | 0.01% | 14 | 66,479 | 0.05% | 31 |
| 15 | 168,190 | 0% | 0 | 33,628 | 0% | 0 |
| 16 | 92,126 | 0.15% | 139 | 23,104 | 0.44% | 102 |
| **TOTAL** | **8,828,191** | **0.03%** | **3,086** | **3,620,491** | **0.10%** | **3,744** |

### *Electric Water Heating Equipment*

This measure would only apply to existing single family homes and multifamily units with individual standard tank electric water heaters or whole house electric tankless water heater that are being replaced. Furthermore, the proposed code change exempts applicable water heaters which are located within conditioned spaces due to implementation challenges discussed in Section 3.1.1.2.

The 2009 RASS data provides a breakdown of existing homes according to the primary water heating system type (California Energy Commission 2009). Table 161 shows the breakdown of water heater types between different building types. While whole house tankless water heaters represent between 0.3-0.9 percent of the existing building stock, it is assumed that most whole house tankless water heaters would be located within conditioned space and would thus, be exempt from meeting this requirement. This is done to yield conservative estimates for statewide savings in absence of detailed data and represent a scenario more commonly expected in the field.

**Table 161: Breakdown of Water Heater Types for the Residential Existing Building Stock**

| DHW System | Single Family | Townhouse, Duplex, Row House | Apt Condo 2-4 Units | Apt Condo 5+ Units |
|---|---|---|---|---|
| **Total Electric** | | | | |
| Standard Tank | 378,550 | 65,518 | 105,328 | 229,192 |
| HPWH | 10,355 | 2,128 | 5,890 | 8,316 |
| Whole House Tankless | 20,077 | 4,550 | 4,052 | 18,222 |
| POU Tankless | 14,370 | 0 | 478 | 2,028 |
| **Natural Gas** | 5,476,698 | 600,827 | 494,608 | 735,219 |
| **Propane** | 312,971 | 11,245 | 11,515 | 18,765 |
| **Solar** | 1,070 | 0 | 0 | 710 |
| **Other** | 2,791 | 427 | 108 | 2,899 |
| **No Response** | 146,979 | 26,519 | 44,851 | 102,795 |
| **NA** | 150,256 | 87,867 | 205,260 | 887,363 |
| **Totals** | **6,514,117** | **799,081** | **872,090** | **2,005,509** |

Source: 2009 RASS data (California Energy Commission 2009).

Like the other measures, shares of single family homes and townhomes are combined into one category and those of apartments are combined into a second category for generating factors that would be consistent with the existing building stock estimates provided by the Energy Commission. Table 162 summarizes the share of single family homes and multifamily units with primary standard tank electric water heaters by climate zone that would be impacted by this proposal.

**Table 162: Estimated Residential Existing Building Stock by Climate Zone – Share of Homes with Primary Standard Tank Electric Water Heaters**

| Climate Zone | Single Family (Single Family, Townhouse, Duplex, Row House) | Multifamily (Apt Condo 2-4 and 5+ units) |
|---|---|---|
| 1 | 11.3% | 14.6% |
| 2 | 15.5% | 14.7% |
| 3 | 4.6% | 17.1% |
| 4 | 3.4% | 30.0% |
| 5 | 6.9% | 48.7% |
| 6 | 3.4% | 34.3% |
| 7 | 3.1% | 24.1% |
| 8 | 3.6% | 18.8% |
| 9 | 3.0% | 13.6% |
| 10 | 6.6% | 10.0% |
| 11 | 13.0% | 40.9% |
| 12 | 10.0% | 25.7% |
| 13 | 12.3% | 8.3% |
| 14 | 7.9% | 4.4% |
| 15 | 7.0% | 12.8% |
| 16 | 13.9% | 40.5% |
| **State Avg** | **6.4%** | **20.4%** |

a. The counts of “NAs” were observed to be disproportionately high in the RASS data for multifamily building type, potentially due to a data cleaning protocol. Thus, the NR and NA counts were dropped while calculating the shares summarized above to avoid skewed data and for consistency.

These numbers need to be further combined with an estimate of annual electric tank water heater changeouts, for which data is limited. In absence of detailed information, data on the age of water heaters from the 2009 RASS survey is used as a surrogate to calculate the portion of electric tank water heaters which would potentially need replacement annually.

Figure 6 shows the distribution of water heater age for standard electric water heaters from the 2009 RASS data (California Energy Commission 2009). While most of the water heaters are less than 10 years old, approximately 16 percent are between 14-30 years old and four percent are more than 31 years old. Even though the RASS data is a decade old today, it can be reasonably assumed that trends in terms of water heater age are still applicable. The typical useful lifetime of electric tank water heaters varies depending on usage patterns and maintenance. A previous CASE report on found estimates in the range of 5-13 years for storage type water heaters based on a survey of several studies and sources (Statewide CASE Team 2015). Thus, it can be assumed that approximately 20 percent of the existing storage type water heater stock are eligible for replacement every five years based on the configuration of the RASS data. Assuming an even distribution of replacements, this results in an approximate four percent changeout rate annually. Thus, the numbers in Table 162 are further combined with the changeout rates to calculate the fraction of buildings impacted by this proposal.

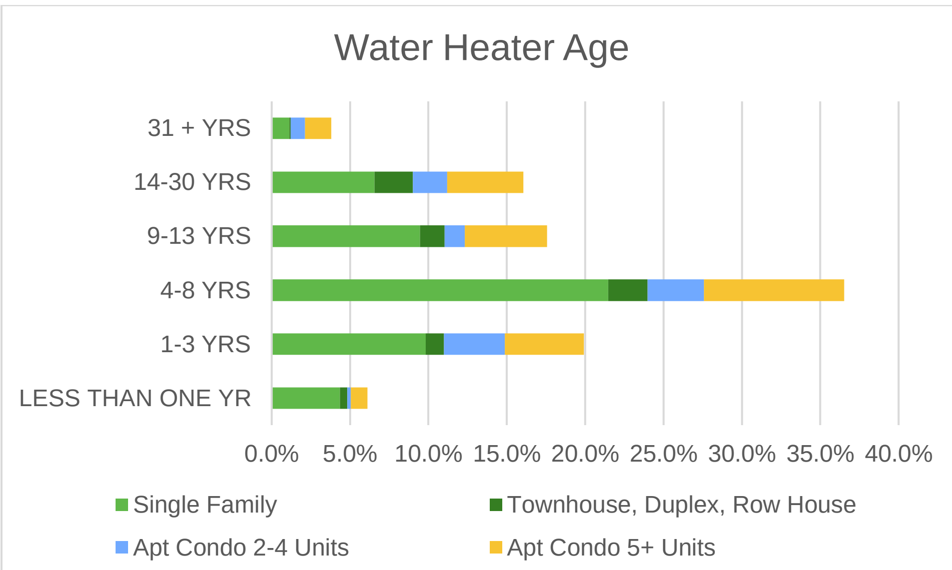


**Figure 6: Distribution of water heater age.**

Source: (California Energy Commission 2009).

Table 163 presents the number of existing single family buildings and multifamily dwelling units that the Statewide CASE Team assumed would be impacted by the proposed code change during the first year the 2022 code is in effect.

**Table 163: Estimated Residential Existing Building Stock by Climate Zone – Electric Space Water Equipment**

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0.5% | 198 | 14,386 | 0.6% | 84 |
| 2 | 260,224 | 0.6% | 1617 | 85,446 | 0.6% | 504 |
| 3 | 963,408 | 0.2% | 1783 | 445,275 | 0.7% | 3043 |
| 4 | 489,254 | 0.1% | 669 | 233,969 | 1.2% | 2811 |
| 5 | 95,423 | 0.3% | 263 | 37,645 | 1.9% | 733 |
| 6 | 589,387 | 0.1% | 797 | 265,259 | 1.4% | 3637 |
| 7 | 488,748 | 0.1% | 608 | 245,115 | 1.0% | 2364 |
| 8 | 913,789 | 0.1% | 1319 | 411,043 | 0.8% | 3098 |
| 9 | 1,237,621 | 0.1% | 1495 | 912,827 | 0.5% | 4975 |
| 10 | 1,043,549 | 0.3% | 2776 | 265,763 | 0.4% | 1066 |
| 11 | 317,948 | 0.5% | 1648 | 68,729 | 1.6% | 1124 |
| 12 | 1,275,153 | 0.4% | 5095 | 382,423 | 1.0% | 3927 |
| 13 | 612,938 | 0.5% | 3017 | 129,400 | 0.3% | 428 |
| 14 | 236,635 | 0.3% | 752 | 66,479 | 0.2% | 117 |
| 15 | 168,190 | 0.3% | 468 | 33,628 | 0.5% | 172 |
| 16 | 92,126 | 0.6% | 514 | 23,104 | 0% | 0 |
| **TOTAL** | **8,828,191** | **0.3%** | **23,019** | **3,620,491** | **0.8%** | **28,081** |

### *Duct Insulation & Sealing*

This measure has two components which were evaluated for statewide energy savings: first, it reduces the total allowable leakage for ducts in single family buildings to 10% and second, it requires new supply ducts in an alteration to be insulated to R-8 in climate zones 1, 2, 4, 8-10, 12 and 13. The energy analysis evaluates each of these components separately.

The number of homes that would likely be impacted by the proposed measure are calculated using data from CalCERTS (CalCERTS 2020). The duct sealing component of the proposed measure would be triggered for altered ducts. Thus, CalCERTS counts for number of projects with altered ducts over the 2016 code cycle are used in these calculations. Similar to the other measures described previously, data gathered from CalCERTS is normalized to per year estimate, assuming an equal distribution over the three-year data collection period. After normalizing, the annual number of projects with altered ducts is 31,497 for single family buildings. When compared to the total number of single family buildings in the existing stock estimated by the Energy Commission, this results in a fraction of 0.3568%. This calculation is summarized in Table 164.

**Table 164: Breakdown of Weighting Factors Applied for Duct Sealing for Alterations Submeasure**

| Component | Single Family |
|---|---|
| A: CalCERTS projects with altered ducts / year | 31,497 |
| B: Total CalCERTS projects / Total population | 0.3568% |
| C: Percent of building type represented by prototypes | 100.000% |
| Total for All Climate Zones (A x B x C) | 0.3568% |

Conversely, the duct insulation component of the proposed measure would be triggered for new supply ducts. Thus, CalCERTS counts for the number of projects with new supply ducts in the 2016 code cycle is used in this calculation. Data is again normalized to a per year estimate, assuming an equal distribution over the three-year data collection period. After normalizing, the annual number of projects with new supply ducts is 8,935 for single family buildings and 142 for multifamily dwelling units. When compared to the total number of single family buildings and multifamily dwelling units in the existing stock estimated by the Energy Commission, this results in a fraction of 0.101% for single family buildings and 0.003% for multifamily dwelling units. Because only 84% of the multifamily dwelling units are expected to be low-rise and hence impacted by the proposed change, the overall fraction for low-rise multifamily dwelling units is 0.0028%. This calculation is summarized in Table 165.

**Table 165: Breakdown of Weighting Factors Applied for Duct Insulation for Alterations Submeasure**

| Component | Single Family | Multifamily |
|---|---|---|
| A: CalCERTS projects with altered ducts / year | 8,935 | 142 |
| B: Total CalCERTS projects / Total population | 0.1012% | 0.003% |
| C: Percent of building type represented by prototypes | 100.000% | 84.000% |
| **Total for Climate Zones 1, 2, 4, 8-10, 12, 13 (A x B x C)** | 0.1012% | 0.0028% |

Table 166 and Table 167 present the number of existing single family buildings and multifamily dwelling units that the Statewide CASE Team assumed would be impacted by the proposed code change during the first year the 2022 code is in effect.

**Table 166: Estimated Residential Existing Building Stock by Climate Zone – Duct Sealing**

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0.357% | 156 | 14,386 | 0% | 0 |
| 2 | 260,224 | 0.357% | 928 | 85,446 | 0% | 0 |
| 3 | 963,408 | 0.357% | 3437 | 445,275 | 0% | 0 |
| 4 | 489,254 | 0.357% | 1746 | 233,969 | 0% | 0 |
| 5 | 95,423 | 0.357% | 340 | 37,645 | 0% | 0 |
| 6 | 589,387 | 0.357% | 2103 | 265,259 | 0% | 0 |
| 7 | 488,748 | 0.357% | 1744 | 245,115 | 0% | 0 |
| 8 | 913,789 | 0.357% | 3260 | 411,043 | 0% | 0 |
| 9 | 1,237,621 | 0.357% | 4416 | 912,827 | 0% | 0 |
| 10 | 1,043,549 | 0.357% | 3723 | 265,763 | 0% | 0 |
| 11 | 317,948 | 0.357% | 1134 | 68,729 | 0% | 0 |
| 12 | 1,275,153 | 0.357% | 4549 | 382,423 | 0% | 0 |
| 13 | 612,938 | 0.357% | 2187 | 129,400 | 0% | 0 |
| 14 | 236,635 | 0.357% | 844 | 66,479 | 0% | 0 |
| 15 | 168,190 | 0.357% | 600 | 33,628 | 0% | 0 |
| 16 | 92,126 | 0.357% | 329 | 23,104 | 0% | 0 |
| **TOTAL** | **8,828,191** | **0.357%** | **31,497** | **3,620,491** | **0%** | **0** |

Table 167: Estimated Residential Existing Building Stock by Climate Zone – Duct Insulation

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0.1012% | 44 | 14,386 | 0.003% | 0 |
| 2 | 260,224 | 0.1012% | 263 | 85,446 | 0.003% | 3 |
| 3 | 963,408 | 0% | 0 | 445,275 | 0% | 0 |
| 4 | 489,254 | 0.1012% | 495 | 233,969 | 0.003% | 8 |
| 5 | 95,423 | 0% | 0 | 37,645 | 0% | 0 |
| 6 | 589,387 | 0% | 0 | 265,259 | 0% | 0 |
| 7 | 488,748 | 0% | 0 | 245,115 | 0% | 0 |
| 8 | 913,789 | 0.1012% | 925 | 411,043 | 0.003% | 14 |
| 9 | 1,237,621 | 0.1012% | 1253 | 912,827 | 0.003% | 30 |
| 10 | 1,043,549 | 0.1012% | 1056 | 265,763 | 0.003% | 9 |
| 11 | 317,948 | 0% | 0 | 68,729 | 0% | 0 |
| 12 | 1,275,153 | 0.1012% | 1291 | 382,423 | 0.003% | 13 |
| 13 | 612,938 | 0.1012% | 620 | 129,400 | 0.003% | 4 |
| 14 | 236,635 | 0% | 0 | 66,479 | 0% | 0 |
| 15 | 168,190 | 0% | 0 | 33,628 | 0% | 0 |
| 16 | 92,126 | 0% | 0 | 23,104 | 0% | 0 |
| **TOTAL** | **8,828,191** | **0.0674%** | **5,947** | **3,620,491** | **0.0019%** | **80** |

### *Attic Insulation for Alterations*

This proposed measure increases the prescriptive ceiling insulation requirement for altered ceilings in certain climate zones to either R-38 or R-49 and add a requirement for air sealing. Thus, it increases stringency in climate zones 1, 2, 4 and 8 through 16 compared to the current code requirements.

The number of homes that would likely be impacted by the proposed measure are calculated using data from CalCERTS (CalCERTS 2020). Because the proposed measure would be triggered at ceiling alteration or entire duct system replacement, CalCERTS counts for number of projects with altered ceilings and projects with entirely new duct systems are used in the calculations. Similar to the other measures described previously, data gathered from CalCERTS is normalized to per year estimate, assuming an equal distribution over the three-year data collection period. After normalizing, the annual number of projects with altered ceilings works out to 4,599 for single family buildings and 87 for multifamily dwelling units. The corresponding annual numbers for systems with entirely new duct systems is 9,462 for single family buildings and 150 for multifamily dwelling units. When compared to the total number of single family buildings and multifamily dwelling units in the existing stock estimated by CEC, this results in a fraction of 0.211% for single family buildings and 0.006% for multifamily dwelling units. Because only 84% of the multifamily dwelling units are expected to be low-rise and hence impacted by the proposed change, the overall fraction for low-rise multifamily dwelling units is 0.0046%. This calculation is summarized in Table 168.

Table 169 presents the number of existing single family buildings and multifamily dwelling units that the Statewide CASE Team assumed would be impacted by the proposed code change during the first year the 2022 code is in effect.

**Table 168: Breakdown of Weighting Factors Applied for Attic Insulation for Alterations Submeasure**

| Component | Single Family | Multifamily |
|---|---|---|
| A: CalCERTS projects with altered ceilings / year | 18,660 | 237 |
| B: Total CalCERTS projects / Total population | 0.211% | 0.006% |
| C: Percent of building type represented by prototypes | 100% | 84% |
| **Total for All Climate Zones (A x B x C)** | **0.211%** | **0.0046%** |

**Table 169: Estimated Residential Existing Building Stock by Climate Zone – Attic Insulation for Alterations**

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 1 | 43,798 | 0.211% | 93 | 14,386 | 0.006% | 1 |
| 2 | 260,224 | 0.211% | 550 | 85,446 | 0.006% | 5 |

| Building Climate Zone | Single Family Existing Building Stock in 2023 (number of buildings) | | | Low-Rise Multifamily Existing Building Stock in 2023 (dwelling units) | | |
|---|---|---|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B | Total Existing Dwelling Units in 2023 [D] | Percent of Existing Dwelling Units Impacted by Proposal [E] | Dwelling Units Impacted by Proposal in 2023 F = D x E |
| 3 | 963,408 | 0.211% | 2,036 | 445,275 | 0.006% | 25 |
| 4 | 489,254 | 0.211% | 1,034 | 233,969 | 0.006% | 13 |
| 5 | 95,423 | 0% | 0 | 37,645 | 0% | 0 |
| 6 | 589,387 | 0.211% | 1,246 | 265,259 | 0% | 0 |
| 7 | 488,748 | 0% | 0 | 245,115 | 0% | 0 |
| 8 | 913,789 | 0.211% | 1,931 | 411,043 | 0.006% | 23 |
| 9 | 1,237,621 | 0.211% | 2,616 | 912,827 | 0.006% | 50 |
| 10 | 1,043,549 | 0.211% | 2,206 | 265,763 | 0.006% | 15 |
| 11 | 317,948 | 0.211% | 672 | 68,729 | 0.006% | 4 |
| 12 | 1,275,153 | 0.211% | 2,695 | 382,423 | 0.006% | 21 |
| 13 | 612,938 | 0.211% | 1,296 | 129,400 | 0.006% | 7 |
| 14 | 236,635 | 0.211% | 500 | 66,479 | 0.006% | 4 |
| 15 | 168,190 | 0.211% | 355 | 33,628 | 0.006% | 2 |
| 16 | 92,126 | 0.211% | 195 | 23,104 | 0.006% | 1 |
| **TOTAL** | **8,828,191** | **0.20%** | **17,425** | **3,620,491** | **0.005%** | **169** |

### *Attic Insulation for Additions*

This measure would increase prescriptive attic insulation requirements for small additions in Climate Zones 2, 4, and 8 through 10. The approach to estimate energy savings for additions and alterations is based on the methodology applied in the impact analysis report for the 2016 Title 24, Part 6 updates and the High Performance Walls 2019 CASE report ( (Statewide CASE Team 2017), (Noresco and Nittler 2016)). In these analyses, the projected savings for new construction buildings were increased by 43 percent to account for additions and alterations. The 43 percent factor was based on the dollars spent on new construction compared to that spent on additions and alterations according to 2011 data from the Construction Industry Research Board. For this proposal, the 43 percent is revised to reflect that the proposed code change does not apply to alterations, nor does it apply to additions that are greater than 700 square feet. In the absence of better information, it is assumed that additions represent half of the total dollars spent on additions and alterations. It is also assumed that half of all additions are less than or equal to 700 square feet and therefore would be subject to the new proposed prescriptive requirements. Taking all of this into account the single family new construction building starts have been reduced to 10.8 percent to provide an estimate of number of small additions constructed annually.

Table 170 presents the number of existing single family buildings that the Statewide CASE Team assumed would be impacted by the proposed code change during the first year the 2022 code is in effect.

**Table 170: Estimated Residential Existing Building Stock by Climate Zone – Attic Insulation for Additions**

| Building Climate Zone | Additions in 2023 (number of buildings) | | |
|---|---|---|---|
| | Total Existing Buildings in 2023 [A] | Percent of Existing Buildings Impacted by Proposal [B] | Buildings Impacted by Proposal in 2023 C = A x B |
| 1 | 117 | 0% | 0 |
| 2 | 696 | 50% | 348 |
| 3 | 2,677 | 0% | 0 |
| 4 | 1,347 | 50% | 674 |
| 5 | 270 | 0% | 0 |
| 6 | 1,423 | 0% | 0 |
| 7 | 1,139 | 0% | 0 |
| 8 | 2,122 | 50% | 1,061 |
| 9 | 2,929 | 50% | 1,464 |
| 10 | 3,825 | 50% | 1,913 |
| 11 | 1,106 | 0% | 0 |
| 12 | 4,284 | 0% | 0 |
| 13 | 1,890 | 0% | 0 |
| 14 | 731 | 0% | 0 |
| 15 | 729 | 0% | 0 |
| 16 | 308 | 0% | 0 |
| **TOTAL** | **25,595** | **21.3%** | **5,460** |

# Appendix B: Nominal Cost

In Sections 2.4.2, 3.4.2, 4.4.2, and 5.4.2, Energy Cost Savings Results, the present valued savings over a 30-year period of analysis is calculated using the TDV approach. When considering present value analysis over the 30-year period, energy cost savings escalate as energy rates increase but given the time value of money they are also discounted.

Another approach to evaluate energy cost savings is with nominal costs where energy costs still escalate as in the TDV analysis, but the time value of money is not included, and the results are not discounted. The approach to calculation nominal costs is under development and results will be included in the Final CASE Report.

# Appendix C: Embedded Electricity in Water Methodology

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

# Appendix D: Environmental Impacts Methodology

## Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 MMTCO2e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tonnes/GWh.

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

## GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – \$40/MT$CO_2$e.

## Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use for the proposed code changes.

# Appendix E: 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 Energy Commission staff and the technical support contractors would need to approve and implement the software revisions. This section describes changes for single family and low-rise multifamily residential buildings.

## Technical Basis for Software Change

The proposed prescriptive code changes require changes to the Standard Design for existing plus addition plus alterations and addition only performance compliance analyses.

The proposed new compliance options add new functionality for existing plus addition plus alteration performance compliance analysis.

## Description of Software Change

### Background Information for Software Change

Table 171 describes at a high level the type of software changes that would be required for each proposed submeasure.

**Table 171: Description of Software Changes**

| Measure | Alteration/ Addition | Climate Zones | Changes to Standard Design | New Features |
|---|---|---|---|---|
| Cool Roof at Roof Replacement | Alteration | See section 2.1.1.1 | Yes | No |
| Roof Insulation at Roof Replacement | Alteration | See section 2.1.1.2 | Yes | No |
| Electric Space Heating Replacements | Alteration | See section 3.1.1.1 | Yes | No |
| Electric Water Heating Replacements | Alteration | See section 3.1.1.2 | Yes | No |
| Duct Insulation | Alteration | See section 4.1.1 | Yes | No |

| Measure | Alteration/ Addition | Climate Zones | Changes to Standard Design | New Features |
|---|---|---|---|---|
| Duct Sealing & 40 Foot Extension Trigger | Addition & Alteration | All | Yes | No |
| Attic Insulation for Alterations | Alteration | See section 5.1.1.1 | Yes | No |
| Attic Insulation for Additions | Addition | See section 5.1.1.2 | Yes | No |
| Revised Blower Door/Air Infiltration Compliance Credit | Alteration | All | No | No |
| Fireplace Removal Compliance Credit | Alteration | All | No | Yes |
| QII for Alterations Compliance Credit | Alteration | All | No | Yes |

**Existing CBECC-Res Modeling Capabilities**

To validate the current capabilities of the compliance software described in this section, simulations were conducted using the 2022 Research Version of CBECC-Res.

### *Cool Roofs at Roof Replacement*

A new distinction was added to the 2019 CBECC-Res software for addition and/or alteration projects which distinguishes the attic and cathedral roof status between *Altered* and *Altered Roof Surface*. This distinction is not defined the CBECC-Res 2019 User Manual (California Energy Commission 2019b), but the Statewide CASE Team interprets an *Altered Roof Surface* to indicate a roof replacement with no work conducted below the roof deck. An *Altered* roof is interpreted to cover projects that include roof replacement as well as work below the roof deck.

For attic spaces, there are no requirements for below roof deck insulation for alterations under any conditions. Therefore, there should not be any differences between how the Standard Design is modeled for these two status types. Status for the ceiling below attic is input separately in the software. Therefore, when an attic roof is assigned a status of either *Altered* or *Altered Roof Surface*, the Standard Design should reflect the aged solar reflectance and thermal emissivity requirements of Section 150.2(b)1I with no other changes.

For cathedral ceilings, Section 150.0(a)1 requires that rafter roofs in an alteration be insulated to R-19. When a cathedral roof is assigned a status of *Altered Roof Surface*, the Standard Design should reflect the aged solar reflectance and thermal emissivity requirements of Section 150.2(b)1I with no other changes. When a cathedral roof is assigned a status of *Altered*, in addition to the aged solar reflectance and thermal emissivity requirements the assembly should be modeled with R-19 insulation in all climate zones.

The Statewide CASE Team conducted testing in CBECC-Res 2022 in Climate Zone 12 with an asphalt shingle roof and found that when either an attic or cathedral roof is assigned an *Altered Roof Surface* status, the Standard Design incorrectly matches the Proposed Design for aged solar reflectance and thermal emissivity regardless of the values selected for the Proposed Design. This does not match Table 150.2-C of the Standards or Table 26 of the ACM Reference Manual.

When an attic roof is assigned an *Altered* status, the Standard Design is incorrectly modeled with an attic system that meets new construction standards per Table 150.1-A. Specifically, the Standard Design is evaluated with R-38 attic insulation, R-19 below deck roof insulation, and a tile roof with a 0.20 aged solar reflectance. This does not match Table 150.2-C of the Standards or Table 26 of the ACM Reference Manual. It is noted that Table 26 of the ACM Reference Manual should be revised to correct reflect that there are no requirements for roof deck insulation for alterations.

When a cathedral roof is assigned an *Altered* status, an attic is added to the Standard Design and the system is modeled to meet the new construction standards per Table 150.1-A, the same as with the attic roof case described in the paragraph above. This does not match Table 150.2-C of the Standards or Table 26 of the ACM Reference Manual.

#### *Roof Insulation at Low-Slope Roof Replacement*

See description above under Cool Roofs at Roof Replacement.

#### *Electric Space Heating Equipment*

Table 32 of the ACM Reference Manual references the new construction requirements in Section 2.4, which does not specify what the Standard Design shall be if the Proposed Design is an electric resistance heater. Section 3.6.4 of this CASE Report proposes language changes to Section 2.4 of the ACM Reference Manual to clarify that the Standard Design for new construction shall be a heat pump whenever the Proposed Design heating fuel is electric. The Statewide CASE Team conducted testing in Climate Zone 12 and found that the Standard Design reflects a heat pump with refrigerant charge verification.

In the case of verified existing conditions, Table 32 of the ACM Reference Manual states that the Standard Design shall be based on the existing heating fuel type and equipment efficiency. In CBECC-Res when an existing electric resistance heater is specified as both the verified existing equipment and the altered equipment, the Standard Design continues to reflect a heat pump and does not follow the ACM

Reference Manual. When an existing electric resistance is specified as the verified existing equipment with a heat pump as the altered equipment CBECC-Res does not run and reports an error that the zone has “incompatible altered and existing HVAC system assignments. To get compliance credit, altered and verified system types must be consistent.”

### *Electric Water Heating Equipment*

Table 32 of the ACM Reference Manual states that for an altered system without verified existing conditions the Standard Design shall be of the existing fuel type and the proposed tank type. Without verified existing conditions the existing fuel type would not be known if a project switches fuel types for the water heater. It’s unclear what the Standard Design water heater type should be if the proposed fuel is electric (electric resistance or HPWH). With verified existing conditions Table 32 states that the Standard Design shall be the existing water heater type and efficiency.

The Statewide CASE Team conducted testing in Climate Zone 12 and found that when the Proposed Design has an altered water heater which is electric, either electric resistance or a HPWH, the Standard Design reflects a gas storage water heater and does not follow the ACM Reference Manual.

With existing conditions verified and an electric resistance storage water heater for both the existing and the altered equipment, the Standard Design does not change and remains a gas storage water heater. With existing conditions verified, an electric resistance storage water heater for the existing equipment and a HPWH for the altered equipment, the Standard Design does reflect the energy use of the existing electric resistance water heater.

In addition, the Statewide CASE Team found what appears to be a bug in the CBECC-Res software where if an altered water heater system without verified existing conditions has an electric water heater defined as the first water heater CBECC-Res would not run and reports error code 22 “Undefined data: left side of ‘>=’”. Only when the electric water heater is defined as the second water heater as is shown in Figure 7 does the software run successfully.

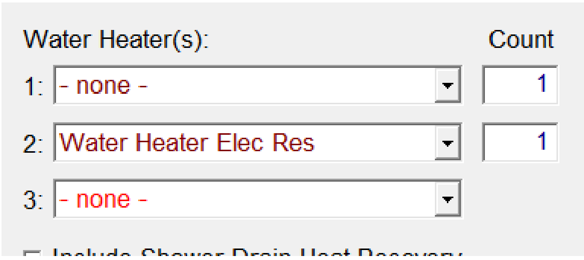


**Figure 7: Altered water heating system configuration – bug details.**

### *Duct Sealing*

According to Table 33 of the ACM Reference Manual all extended and altered ducts are evaluated with 15 percent leakage in the Standard Design. Test simulations in CBECC-Res were conducted to verify this, the results are described in Table 172.

**Table 172: Standard Design Assignments for Duct Leakage by Distribution System Status**

| Distribution System Status | Standard Design Leakage per ACM | CBECC-Res Standard Design Leakage | CBECC-Res Proposed Design Leakage |
|---|---|---|---|
| Existing | n/a | 15% | 15% (user cannot enter leakage rate) |
| Altered | 15% | 7% | 7% or value entered by user |
| Existing + New | 15% | 15% | 15% (user cannot enter leakage rate) |
| Existing + New <40ft | 15% | 15% | 7% (user cannot enter leakage rate) |
| Verified Altered | 15% | 7% | 7% or value entered by user |

### *Duct Insulation*

According to Table 33 of the ACM Reference Manual duct system insulation is evaluated based on the prescriptive requirement for new or replacement ducts unless existing conditions are HERS verified. Test simulations in CBECC-Res were conducted to verify this, the results are described in Table 173.

**Table 173: Standard Design Assignments for Duct Insulation by Distribution System Status**

| Distribution System Status | Standard Design R-value per ACM | CBECC-Res Standard Design R-value | CBECC-Res Proposed Design R-value |
|---|---|---|---|
| Existing | n/a | Existing duct R-value | Existing duct R-value |
| Altered | | Per ACM | Proposed duct R-value |

| Distribution System Status | Standard Design R-value per ACM | CBECC-Res Standard Design R-value | CBECC-Res Proposed Design R-value |
|---|---|---|---|
| Existing + New | R-6: CZ1-10, 12-13<br>R-8: CZ11, 14-16 | Existing duct R-value | Existing duct R-value (ignores proposed duct R-value) |
| Existing + New <40ft | | Existing duct R-value | Existing duct R-value (ignores proposed duct R-value) |
| Verified Altered (with default duct leakage) | Existing duct R-value | Per ACM | Proposed duct R-value |
| Verified Altered (user entered duct leakage) | Existing duct R-value | Proposed duct R-value for supply duct.<br>Existing duct R-value for return duct | Proposed duct R-value |

### *Attic Insulation for Alterations*

When a ceiling below attic is altered in an addition and/or alteration project the Standard Design should be modeled with R-19 attic insulation per Section 150.0(a)1. The Statewide CASE Team tested this in both Climate Zone 7 and 12 and found that the Standard Design in both instances is incorrectly modeled with R-30 attic insulation, which does not match Table 150.2-C of the Standards or Table 26 of the ACM Reference Manual.

### *Attic Insulation for Additions*

Based on Table 26 of the ACM Reference Manual the Standard Design for additions less than or equal to 700 square feet is R-30 ceiling insulation in Climate Zones 2 through 8 and R-38 elsewhere.

### *Revised Blower Door/Air Infiltration Compliance Credit*

Table 31 of the ACM Reference Manual states that Standard Design infiltration is 5 ACH50 unless existing conditions are HERS verified, in which case it is the lesser of 7 ACH50 or the HERS Rater tested value. Test simulations in CBECC-Res using Climate Zone 12 were conducted to verify this and found that without existing conditions verification the Standard Design infiltration is 5 ACH50 as indicated in Table 31. However, the Statewide CASE Team found that with verified existing conditions, the Standard Design reflects the HERS Rater pre-retrofit tested value unless the post-retrofit tested value is greater than 5 ACH50, in which case the Standard Design is set at 5 ACH50. For example, in a simulation with pre-retrofit and post-retrofit tested values of 7 and 6, respectively, there is a compliance penalty because the Standard Design is evaluated at 5 ACH50 and the Proposed Design at 7 ACH50.

#### *Fireplace Removal Compliance Credit*

CBECC-Res currently has no capabilities directly related to fireplace removal.

#### *Quality Insulation Installation for Alterations Compliance Credit*

CBECC-Res is currently not able to evaluate QII for alterations. QII is only allowed for new construction and additions.

### Summary of Proposed Revisions to CBECC-Res

#### *Cool Roofs at Roof Replacement*

CBECC-Res would need to be revised so the Standard Design properly reflects the requirements of Table 150.2-C of the Standards and Table 26 of the ACM Reference Manual as well as the new proposed code change requirements for aged solar reflectance and thermal emissivity in Section 150.2(b)1I. In addition, for attic roofs it's recommended that the two status' *Altered* and *Altered Roof Status* be combined into a single status. A definition of *Altered Roof Status* for cathedral ceilings should be added to the CBECC-Res User Manual.

In addition, it is proposed that the capability to indicate if a radiant barrier is installed over spaced sheathing be added as is described in section 2.6.6.1 of the ACM Reference Manual.

#### *Roof Insulation at Low-Slope Roof Replacement*

CBECC-Res would need to be revised so the Standard Design properly reflects the requirements of Table 150.2-C of the Standards and Table 26 of the ACM Reference Manual as well as the new proposed code change requirements for above roof deck insulation in Section 150.2(b)1I. A definition of *Altered Roof Status* for cathedral ceilings should be added to the CBECC-Res User Manual.

#### *Electric Space Heating Equipment*

CBECC-Res should be revised so that in the case of verified existing conditions Table 32 of the ACM Reference Manual is followed and the Standard Design is based on the existing fuel type and efficiency for existing electric resistance equipment. It should also be revised to be able to model the case where the existing and altered equipment are different system types. No changes are necessary without verified existing conditions since in all cases the Standard Design reflects a heat pump if the Proposed Design heating fuel is electric.

### *Electric Water Heating Equipment*

CBECC-Res should be revised so that the proposed changes to Table 32 of the ACM Reference Manual (see Section 3.6.4) is followed, and the Standard Design is defined appropriately. The proposed changes recommend that the Standard Design align with the new construction requirements and reflect a HPWH for proposed electric water heaters, unless verified existing conditions are met. With verified existing conditions the Standard Design should reflect the existing water heat type and efficiency. CBECC-Res should also be revised to fix the apparent bug with altered electric water heating systems described above.

### *Duct Leakage & Insulation*

CBECC-Res needs to be revised to reflect the proposed code changes for the duct leakage and insulation submeasures. Table 174 details the Statewide CASE Team's recommendations, which includes combining the available status categories from six (Existing, Altered, Verified Altered, New, Existing + New, Existing + New <=40ft) to four (Existing, Altered, Verified Altered, New). The default Proposed Design duct leakage is proposed to be revised to 30 percent unless the user inputs the duct leakage indicating that the prescriptive duct sealing requirements are done. This is recommended so that projects that do not comply with the prescriptive requirements are penalized; currently the software does not differentiate between projects that do or do not incorporate prescriptive duct sealing. A justification of the 30 percent is discussed in Section 4.1.3.3.

**Table 174: Proposed Revisions to CBECC-Res for Duct Leakage and Insulation**

| | Duct Leakage | | Duct Insulation | |
|---|---|---|---|---|
| **Distribution System Status** | **Standard Design** | **Proposed Design** | **Standard Design** | **Proposed Design** |
| Existing (including extended system with <=25ft) | 30% | 30% | Existing duct R-value | Existing duct R-value |
| Altered (including extended systems with >25ft & existing duct system with altered space- | 10% single family<br>15% multifamily | 30% or proposed duct leakage entered by user | R-6: CZ3, 5-7<br>R-8: CZ1-2, 4, 8-16 | Proposed duct R-value |

| | Duct Leakage | | Duct Insulation | |
|---|---|---|---|---|
| conditioning system) | | | | |
| Verified Altered | The lesser of existing duct leakage entered by user or 30% | Proposed duct leakage entered by user | Existing duct R-value | Proposed duct R-value |
| New | 5% single family 12% multifamily | 5% single family 12% multifamily or proposed duct leakage entered by user | R-6: CZ3, 5-7 R-8: CZ1-2, 4, 8-16 | Proposed duct R-value |

### *Attic Insulation for Alterations*

CBECC-Res needs to be revised so that the Standard Design reflects the addition of a R-49 prescriptive attic insulation requirement in Climate Zones 1 through 4, 6, and 8 through 16 for single family buildings and Climate Zones 1 through 4, and 8 through 16 for multifamily buildings. It is not proposed that the impacts of the air sealing requirement of this code change proposal are evaluated in the CBECC-Res Standard Design.

### *Attic Insulation for Additions*

CBECC-Res needs to be revised so that the Standard Design reflects the increase in prescriptive attic insulation from R-30 to R-38 for Climate Zones 2, 4, and 8 through 10 for additions less than or equal to 700 square feet.

### *Revised Blower Door/Air Infiltration Compliance Credit*

CBECC-Res needs to be revised to reflect the proposal in Section 6.6.4.1. The default infiltration rate would be increased to 10 ACH50 from 5 and 7 ACH50 for single family and multifamily buildings, respectively. With HERS verified existing conditions, the Standard Design infiltration would reflect the pre-retrofit tested ACH50 value.

### *Fireplace Removal Compliance Credit*

CBECC-Res needs to be revised to add a checkbox for a user to indicate when an existing masonry wood burning fireplace is removed meeting the requirements of RA4.XX – Masonry Fireplace Removal in an Alteration. When checked, infiltration would be reduced by 12 percent relative to the Standard Design of 10 ACH50, or 8.8 ACH50.

### *Quality Insulation Installation for Alterations Compliance Credit*

CBECC-Res needs to be revised to account for QII credit for altered assemblies. Table 175 presents the proposed modeling rules for QII credit for altered assemblies compared to the QII credit for new construction.

**Table 175: QII for Alterations Proposed Modeling Rules**

| Component | No QII | Alteration – QII | New Construction or Addition – QII |
|---|---|---|---|
| Walls, Floors, Attic Roofs, Cathedral Ceilings | Multiply the cavity insulation R-value/inch by 0.7. | Multiply the cavity insulation R-value/inch by 0.94. | No adjustment to R-value |
| Ceilings Below Attic | Multiply the blown and batt insulation R-value/inch by 0.96-0.00347*R. | Multiply the blown and batt insulation R-value/inch by 0.992-0.00069*R. | No adjustment to R-value |
| Ceilings Below Attic | Add a heat flow from the conditioned zone to the attic of 0.015 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space. | Add a heat flow from the conditioned zone to the attic of 0.003 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space. | No heat flow added |

## User Inputs to CBECC-Res

There are no changes to CBECC-Res user inputs for most of the proposed code changes. Where changes to user inputs are required, they are described below.

### *Cool Roofs at Roof Replacement*

The Statewide CASE Team recommends that a checkbox be added to the Construction Assembly for Attic Roofs that allows the user to indicate if the radiant barrier is installed over existing spaced sheathing. When the checkbox is checked the radiant barrier would be modeled with a 0.5 emittance value instead of 0.05, as is described in subsection 2.6.6.1 of the ACM Reference Manual.

### *Duct Leakage & Insulation*

Table 176 describes the recommended changes to the CBECC-Res user interface for the duct leakage and insulation submeasures.

**Table 176: Revisions to CBECC-Res User Inputs for Duct Proposals**

| Input Screen | Parameter Name | Revision |
|---|---|---|
| Distribution System: AirDistributionSystem | Status | Revise to remove “Existing + New” option. Clarify that an “Altered” system covers whenever the prescriptive duct sealing requirements are triggered (>=25ft of new or replacement ductwork; altered space-conditioning system) |
| Distribution System: AirDistributionSystem | Duct Leakage | Allow the user to enter duct leakage target without selecting “Low Leakage Air Handler” |
| Distribution System: AirDistributionSystem | Verify Existing Distribution System | Allow user to enter existing duct leakage |

### *Fireplace Removal Compliance Credit*

Table 177 lists the recommended CBECC-Res user inputs for the fireplace removal compliance credit.

**Table 177: Additional User Inputs Relevant to Fireplace Removal**

| Input Screen | Data Type | Units | User Editable | Recommended Label |
|---|---|---|---|---|
| Project: Building | Checkbox | N/A | Yes | Existing Fireplace Removed |

### *Quality Insulation Installation for Alterations Compliance Credit*

Table 178 lists the recommended CBECC-Res user inputs for the altered assembly QII compliance credit.

**Table 178: Additional User Inputs Relevant to QII for Altered Assemblies**

| Input Screen | Data Type | Units | User Editable | Recommended Label |
|---|---|---|---|---|
| Exterior Wall; Underground Wall; Interior Wall; Cathedral Ceiling; Ceiling (below attic); Exterior Floor; | Checkbox (only present if Surface Status = Altered) | N/A | Yes | QII for Altered Assembly |

| Input Screen | Data Type | Units | User Editable | Recommended Label |
|---|---|---|---|---|
| Floor over Crawlspace; Interior Floor | | | | |

## Simulation Engine Inputs

There are no recommended changes to how CBECC-Res translates user inputs for any of the proposed prescriptive code changes. Recommended changes for the compliance options are described below.

### *Revised Blower Door/Air Infiltration Compliance Credit*

When this credit it taken and pre- and post- retrofit air leakage is tested by a HERS Rater the area of low vent, izALo, for each condition should be calculated based on the user entered ACH50 values. No change to the calculation approach is proposed.

### *Fireplace Removal Compliance Credit*

When the fireplace removal credit checkbox is checked and tested air leakage is not entered, all of the six IZXFER infiltration objects for the conditioned zone in the Proposed Design should be revised to reflect an area of low vent, izALo, 12 percent less than that calculated based on the default air leakage rate. In the case of a building with an attic the IZXFER object representing infiltration between the conditioned zone and the attic should similarly be revised.

### *Quality Insulation Installation for Alterations Compliance Credit*

See Section 6.6.4.2 and discussion above for details on the proposed modeling rules for this submeasure. The calculation approach would remain the same as with the current QII process, with different derate factors applied to the assembly components.

## Simulation Engine Output Variables

All of the proposed code changes rely on existing algorithms and modeling processes within CBECC-Res. The simulation outputs that are currently used to debug a building energy model may continue to be used.

## Compliance Report

There are no recommended changes to the compliance reports for any of the proposed prescriptive code changes. Recommended changes for the compliance options are described below.

### *Fireplace Removal Compliance Credit*

It's recommended that when the fireplace removal checkbox credit is taken this be indicated in the Required Special Features section of the compliance report. If pre- and post- retrofit air leakage is tested by a HERS Rater there is no recommended reporting change.

### *Quality Insulation Installation for Alterations Compliance Credit*

A new column would need to be added to the Opaque Surfaces section of the compliance report, where details on walls, floors and ceilings are reported, which indicates whether an altered surface is taking the QII credit.

## Compliance Verification

All of the proposed prescriptive code changes already have compliance verification processes in place, there would be no change from the current process. Changes for the compliance options are described below.

### *Revised Blower Door/Air Infiltration Compliance Credit*

Blower door testing would be verified by a HERS rater and the process is the same as the current process for reduced infiltration testing in both new construction and alterations. Pre-retrofit blower door test results would be reported on a revised existing conditions verification form, CF3R-EXC-20-H. Post-retrofit blower door test would be reported as they currently are.

### *Fireplace Removal Compliance Credit*

For the fireplace removal checkbox credit, the authority having jurisdiction would verify this similar to how certain other energy efficiency features are required to be verified, such as radiant barrier.

### *Quality Insulation Installation for Alterations Compliance Credit*

QII would be verified by a HERS Rater, while some of the requirements would differ the process would be the same.

## Testing and Confirming CBECC-Res Modeling

Testing of CBECC-Res should be conducted to confirm that the correct efficiency assumptions are applied to the Standard Design for each of the proposed prescriptive code changes. Testing should also be done to confirm that the impact for the proposed compliance options is as expected.

Testing can be completed with the alteration and addition prototypes that are defined in the ACM Approval Manual.

## Description of Changes to ACM Reference Manual

See sections 2.6.4, 3.6.4, 4.6.4, 5.6.4, and 6.6.4 of this report for specific proposed changes to the ACM Reference Manual.

# Appendix F: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Sections 2.1.5, 3.1.5, 4.1.5, and 5.1.5, could impact various market actors. Table 179 through Table 182 identify the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in the following tables 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 G summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

**Table 179: Roles of Market Actors in the Proposed Compliance Process: Roof Replacement, Cool Roofs and Insulation**

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| Roofing Contractors | • Identify relevant requirements and/or compliance path and install products to meet requirements.<br>• Complete required compliance documents for permit application. | • Quickly and easily determine requirements based on scope and meet schedule.<br>• Demonstrate compliance with code requirements.<br>• Clearly communicate performance requirements to building owner.<br>• Complete compliance documents required for permit sign-off. | • Would need to document compliance with new requirement, not currently being documented.<br>• Low-slope roof insulation requirements at roof replacement now exists where it was not required before. | • Revise compliance documents to automate compliance requirements based on roof type and climate zone.<br>• Updated fact sheets available for distribution at local building department offices and websites. |
| Building Inspector/Plans Examiners | • Understand code requirement and confirm data on documents is compliant.<br>• Confirm plans / specifications match data on compliance documents.<br>• Provide correction comments if necessary. | • Quickly and easily determine requirements based on scope and climate zone.<br>• Quickly and easily determine if data in documents meets requirements.<br>• Quickly and easily determine if plans/specs match compliance documents.<br>• Quickly and easily provide correction comments that would resolve issue. | • Would need to verify new proposed projects are compliant.<br>• If project is applying for an exception would need to verify if this is acceptable. | • Compliance documents could auto-verify data is compliant with standards.<br>• Provide fact sheets available for distribution at local building department offices and websites to distribute to all projects applying for residential re-roof permit. |

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| Building Owner | Little direct involvement unless responsible for pulling permit. | If pulling permit, obtain necessary compliance documents from contractor | Could impact cost of reroofing. | Provide homeowner educational materials on comfort and utility bill impacts |

**Table 180: Roles of Market Actors in the Proposed Compliance Process: Electric Equipment Replacements**

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| HVAC & DHW Contractors | • Identify relevant requirements and/or compliance path and install products to meet requirements.<br>• Coordinate design with other team members as needed.<br>• Complete compliance documents for permit application.<br>• Coordinate with commissioning HERS Rater (HVAC only). | • Quickly and easily determine requirements based on scope and meet schedule.<br>• Clearly demonstrate compliance with code requirements.<br>• Clearly communicate system requirements to building owner.<br>• Complete compliance documents required for permit sign-off. | • Would need to coordinate additional time and potentially other subcontractors.<br>• Minimal impact for space heating measure. | Revise compliance document to automate compliance calculations. |
| Building Inspector/Plans Examiners | • Understand code requirement and confirm data on documents is compliant. | • Quickly and easily determine requirements based on scope.<br>• Quickly and easily determine if data in | • Would need to verify new proposed projects are compliant.<br>• If project is applying for an exception would need | Compliance document could auto-verify data is compliant with standards. |

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| | • Confirm plans/specifications match data on documents.<br>• Provide correction comments if necessary. | documents meets requirements.<br>• Quickly and easily determine if plans/specs match documents.<br>• Quickly and easily provide correction comments that would resolve issue. | to verify if this is acceptable. | |
| Building Owner | Little direct involvement unless responsible for pulling permit. | If pulling permit, obtain necessary compliance documents from contractor and ensure that contractor is meeting code | None | N/A |

Table 181: Roles of Market Actors in the Proposed Compliance Process: Duct Sealing & Insulation

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| HVAC Contractors | • Identify relevant requirements and/or compliance path and install products to meet requirements.<br>• Coordinate design with other team members as needed. | • Quickly and easily determine requirements based on scope and meet schedule.<br>• Demonstrate compliance with code requirements.<br>• Streamline coordination with other team members. | • May need to spend additional time sealing ducts and conducting a smoke test.<br>• Must seal to leakage rate based on measured air flow when air flow | Proposed documentation methodology uses components already produced as part of the design/construction process. No additional |

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| | • Complete compliance documents for permit application.<br>• Coordinate with HERS Rater. | • Clearly communicate system requirements to installation crew.<br>• Complete compliance documents required for HERS Rater and permit sign-off. | measurement is taken for code compliance. | documentation necessary. |
| HERS Rater | • Identify relevant testing and code requirements<br>• Perform required testing to confirm compliance.<br>• Verify performance meets code requirements | • Demonstrate compliance by ensuring calculations on compliance documents meet testing requirements in code.<br>• Recommend potential fixes in case requirements are not met. | Impact is minimal | N/A |
| Building Inspector/Plans Examiners | • Understand code requirement and confirm data on documents is compliant.<br>• Confirm HERS testing documents confirm compliance.<br>• Provide correction comments if necessary. | • Quickly and easily determine requirements based on scope.<br>• Quickly and easily determine if data in documents meets requirements.<br>• Quickly and easily determine if plans/specs match documents.<br>• Quickly and easily provide correction comments that would resolve issue. | Impact is minimal | N/A |

Table 182: Roles of Market Actors in the Proposed Compliance Process: Attic Insulation

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| Insulation / HVAC Contractors | • Identify relevant requirements and/or compliance path, install products, and complete work to meet requirements.<br>• Coordinate work with other contractors as needed.<br>• Complete required compliance documents for permit application.<br>• Coordinate with HERS Rater. | • Quickly and easily determine requirements based on scope and meet schedule.<br>• Demonstrate compliance with code requirements.<br>• Streamline coordination with other contractors.<br>• Clearly communicate system requirements to general contractor and building owner.<br>• Complete compliance documents required for HERS Rater and permit sign-off. | • Coordinate with HVAC trade.<br>• Would need to take additional time to conduct air sealing work and recessed can replacement before installing insulation or coordinate with subcontractor to complete the work.<br>• Coordinate HERS rater for air sealing inspection prior to installing insulation. | • Provide guidance on scheduling HERS Rater to combine air sealing inspection with other HERS tests like duct leakage testing.<br>• HVAC contractor expand into home performance work to include air sealing and insulation services into their portfolio. |
| HERS Rater | • Identify relevant testing and inspections required<br>• Perform required inspections to confirm compliance.<br>• Coordinate with HVAC / insulation contractor for additional HERS inspection requirement. | • Demonstrate compliance by ensuring calculations on compliance documents meet testing requirements in code.<br>• Ensure that client understands the stage of construction that HERS inspection is needed.<br>• Recommend potential fixes in case requires are not met. | • Would need to verify testing is meeting new requirements.<br>• Need to incorporate QII air sealing inspection for altered ceilings in addition to other HERS inspection requirements for | Coordinate with contractor teams to minimize number of site visits. |

| Market Actor | Task(s) In Compliance Process | Objective(s) in Completing Compliance Tasks | How Proposed Code Change Could Impact Work Flow | Opportunities to Minimize Negative Impacts of Compliance Requirement |
|---|---|---|---|---|
| | | | HVAC replacements. | |
| Building Inspector/Plans Examiners | • Understand code requirement and confirm data on documents is compliant.<br>• Confirm plans / specifications match data on documents.<br>• Ensure contractor / building owner are aware of additional requirements associated with this measure.<br>• Provide correction comments if necessary. | • Quickly and easily determine requirements based on scope and climate zone.<br>• Quickly and easily determine if data in documents meets requirements.<br>• Quickly and easily determine that project team is aware of additional tasks and inspections required.<br>• Quickly and easily determine if plans/specs match documents.<br>• Quickly and easily provide correction comments that would resolve issue. | • Would need to verify new proposed projects are compliant.<br>• Would need to ensure additional CF2R and CF3R forms are provided.<br>• If project is applying for an exception would need to verify if this is acceptable.<br>• Would need to verify new insulation levels meet code requirements. | • Compliance documents could auto-verify data is compliant with standards.<br>• Compliance documents could easily identify which requirements apply to the specific project. |
| Building Owner | Little direct involvement unless responsible for pulling permit. | If pulling permit, obtain necessary compliance documents from contractor. | Impact cost of work due to additional required scope. | |

# Appendix G: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this 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 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

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

The Statewide CASE Team hosted two stakeholder meetings for the submeasures via webinar. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting. Such as slide presentations, proposal summaries with code language, and meeting, are included in the bibliography section of this report.

| | | |
|---|---|---|
| First Round of Single Family Whole Building Utility-Sponsored Stakeholder Meeting | Tuesday, November 12, 2019 | https://title24stakeholders.com/event/single-family-whole-building-and-nonresidential-software-improvements-utility-sponsored-stakeholder-meeting/ |
| Second Round of Single Family Whole Building Utility-Sponsored Stakeholder Meeting | Thursday, March 5, 2020 | https://title24stakeholders.com/event/single-family-whole-building-utility-sponsored-stakeholder-meeting/ |

The first round of utility- sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from January to February 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost-effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[38] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted in to the listserv. Exported webinar meeting data captured attendance numbers and individual comments,

[38] Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/.

and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

## Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. Stakeholders included roofing contractors, mechanical contractors, plumbing contractors, designers and architects, general contractors & remodelers, roofing industry representatives, energy consultants, HERS Raters, manufacturers, utility representatives, and industry experts. The stakeholders with whom communication was successfully established are found in the Table 183.

**Table 183: List of Stakeholders Engaged during Outreach**

| Contact Name | Company | Role |
|---|---|---|
| Duane Knickerbocker | Brower Mechanical | HVAC Contractor |
| Larry Waters | A-1 Guaranteed Heating & Air | HVAC Contractor |
| Richard Hiteshew | A-1 Guaranteed Heating & Air | HVAC Contractor |
| David Krueger | Greiner | HVAC/DHW Contractor |
| Russ King | CalCERTS | HVAC Representative |
| Justin Sahota | Villara | HVAC Contractor |
| Mike Fischer | Asphalt Roofing Manufacturers Association | Roofing Industry Representative |
| Reed Hitchcock | Asphalt Roofing Manufacturers Association | Roofing Industry Representative |
| Bill Callahan | Associated Roofing Contractors of the Bay Area Counties | Roofing Industry Representative |
| Jason Scheurer | BEST Techs Contracting Design Build Remodel Inc. | Alteration Contractor |
| Jeff Steuben | Cool Roof Rating Council | Roofing Industry Representative |
| Mischa Egolf | Cool Roof Rating Council | Roofing Industry Representative |
| Mike MacFarland | Energy Docs | Home Performance Contractor |
| Steve Reardon | Enterprise Roofing Service | Roofing Contractor |
| Clay Johnson | Johnson Design | High Performance Designer |
| Ronnen Levinson | Lawrence Berkeley National Lab | Cool Roof Expert |
| Charlie Snowden | Low-E | Manufacturer of Roof Board Insulation Product |

| Contact Name | Company | Role |
|---|---|---|
| Tom Miller | Low-E | Manufacturer of Roof Board Insulation Product |
| Paul Mcilwee | Low-E | Manufacturer of Roof Board Insulation Product |
| Carlos Rodriquez | Mr. Roofing | Roofing Contractor |
| Allen Gilliland | One Sky Homes | Builder, Existing Homes |
| Phil Ligon | Premier Building Systems (SIPS) | Roofing Product Manufacturer |
| Fred Chacon | Rmax | Roofing Product Manufacturer |
| Steve Dubin | Rmax | Roofing Product Manufacturer |
| Nick Montanarelli | Rmax/Sika | Roofing Product Manufacturer |
| Marc Connerly | Roofing Contractors Association of California | Roofing Industry Representative |
| Scott Blunk | SMUD | Utility Representative & Previous Contractor |
| Bob Vezer | Vezer's Roofing | Roofing Contractor |
| Gary Smith | WedgeIt | Roofing Product Manufacturer |
| Will Pro | Will Pro Construction | Alteration Contractor |
| Kevin Burgeson | Burgeson's Heating & Air Conditioning | HVAC Contractor |
| Curt Yaeger | Yaeger Services | HVAC Contractor |
| Tom Cooper | TruTeam of California | Roofing Contractor |
| John Ficarra | Elite Roofing Supply | Roofing Supply/Distribution |
| Joshua Hussey | County of Los Angeles | Building Official |
| Chadwick Collins | Asphalt Roofing Manufacturers Association | Roofing Industry Representative |
| Richard Lawson | Lawson Roofing | Roofing Contractor |
| Mark Modera | UC Davis Western Cooling Efficiency Center | Technical Expert, HVAC |
| Meg Waltner | NRDC | Efficiency Advocate |
| Pierre Delforge | NRDC | Efficiency Advocate |
| Tom Paine | Consol | Energy Consultant |
| George Nesbitt | Environmental Design/Build | HERS Rater |
| Randy Young | Sheet Metal Workers | HVAC Union Representative |
| Nick Brown | Build Smart Group | Energy Consultant |

| Contact Name | Company | Role |
|---|---|---|
| Jeff Mang | Polyisocyanurate Insulation Manufacturers Association | Roofing Industry Representative |
| Brendan McGovern | Trane | HVAC Manufacturer |
| Luke Nolan | Central Coating Company | Roofing Contractor |
| Bruce Severance | Mitsubishi | HVAC Manufacturer |

## Stakeholder Survey

### Methodology

A stakeholder survey administered by Evergreen Economics was distributed via email to industry experts to understand any challenges they may experience with the 2016 and 2013 Title 24, Part 6 code as it relates to additions and alterations to existing residential buildings, and identify where they see opportunities to improve interpretation of the code, improve code compliance, and ultimately save energy in existing homes.

Distribution was done via listserves (such as CALBO, CABEC, and contacts from Title24Stakeholders.com) and emails were sent with a link to a web survey. A total of 59 people who responded to the survey worked on either additions or alterations, though only 26 completed the survey and responded to the final question.

### Participant Background

The majority of respondents worked on both additions and alterations (81%) with seven percent working on additions only, and 12 percent working on alterations only. The most common roles for respondents were plans reviewers and architect/designer (Figure 8).

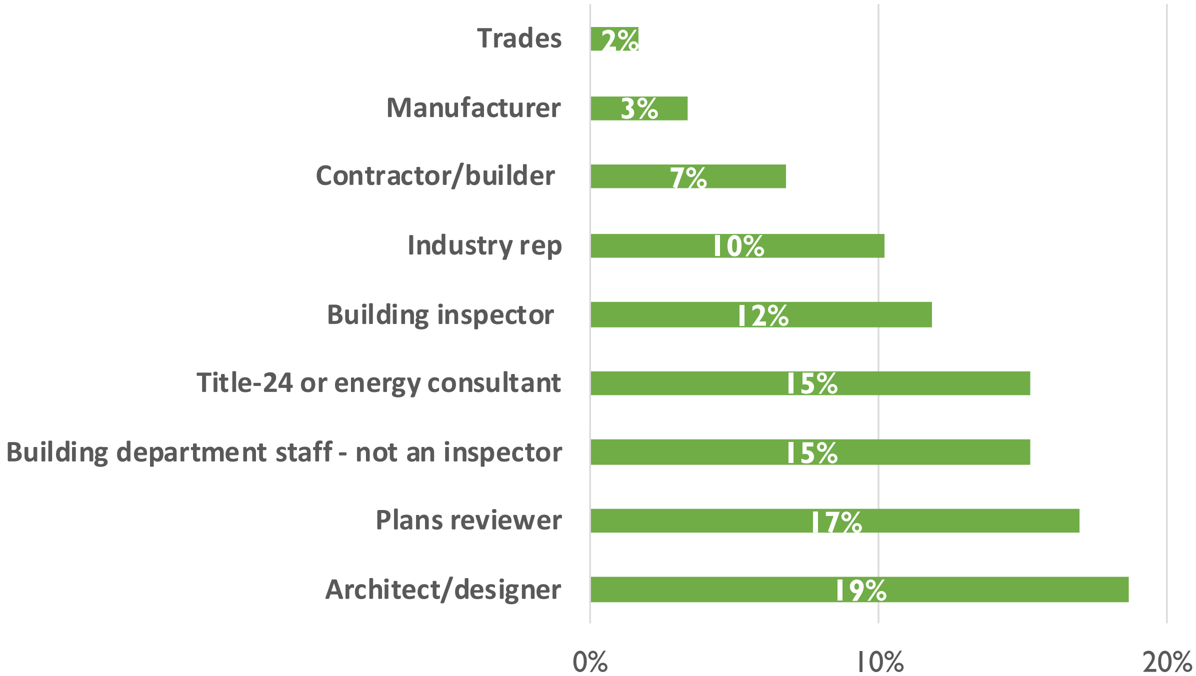


**Figure 8: Job type of respondents (n=59).**

Respondents worked on a variety of projects, though the most common project type was interior remodels. In addition to the project types shown in Figure 9, eight respondents added that they also worked on projects such as solar photovoltaics (n=5), pools (n=2), and ESS (n=2).

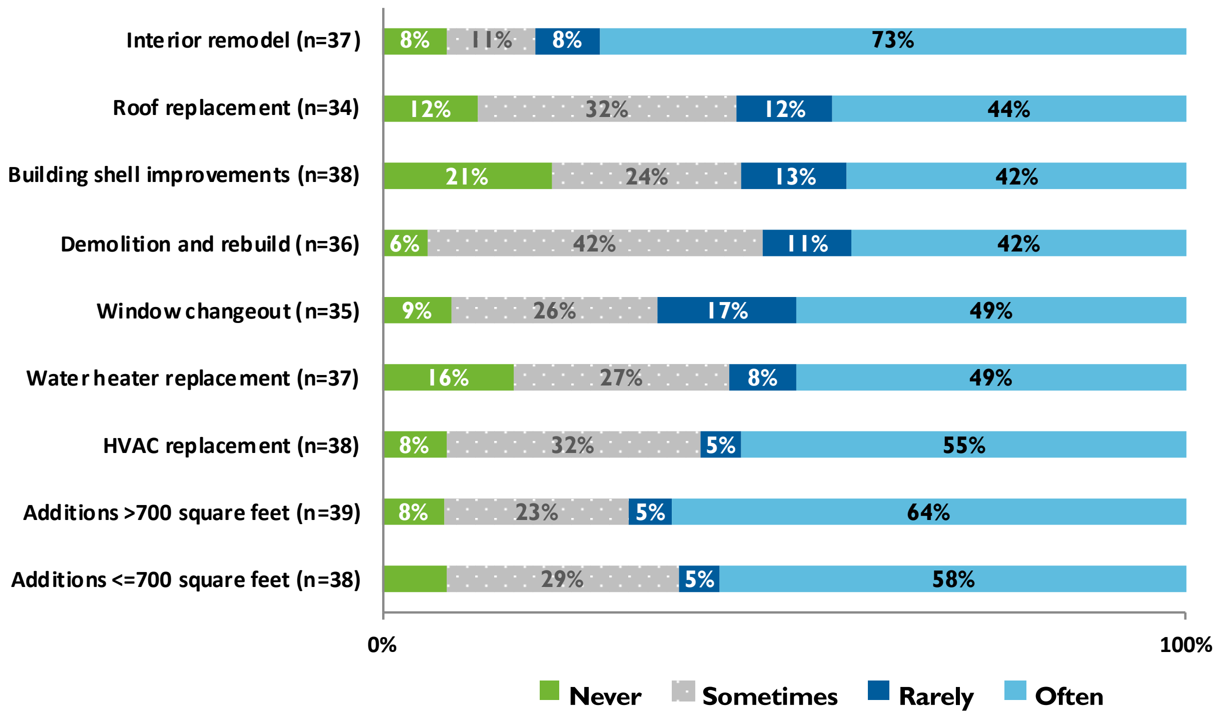


**Figure 9: How frequently respondents work on project types.**

### Implementer Findings

The findings in Figure 10 cover responses from implementers only, which included contractors/builders, trades, and architects/designers. These respondents varied in the number of additions and alterations projects they have done in the past two years.

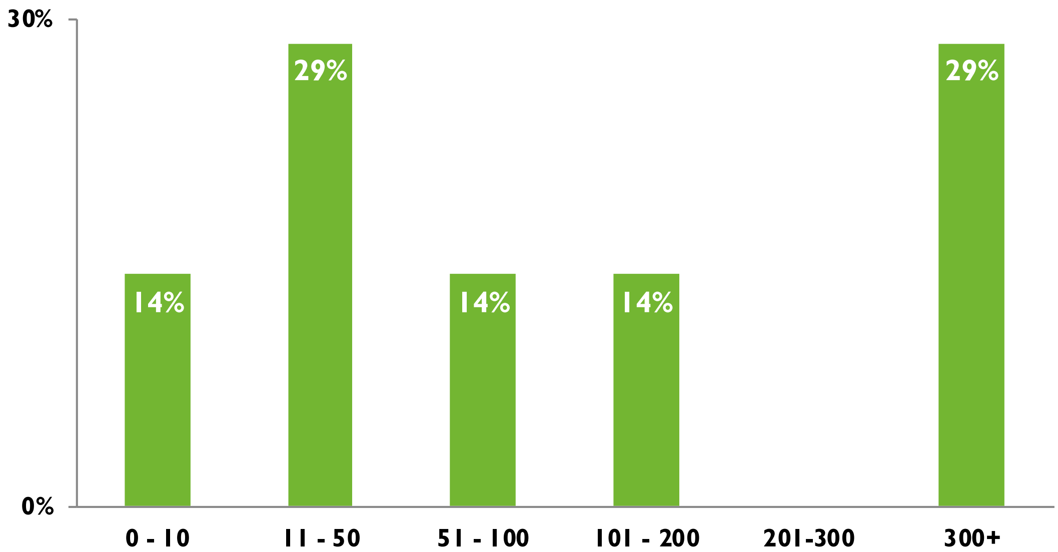


**Figure 10: Number of additions or alterations projects done in the past two years by implementers (n=14).**

The most frequently used resource used by implementer respondents to determine which code requirements apply to their residential projects is a Title 24 Consultant or a HERS Rater. Of the resources listed in Figure 11, Energy Code Ace was the least frequently used resource. In addition to the options given through the survey, respondents reported using the CEC website, EnergyPro, co-workers, utility trainings, and networking as a resource, though each of these was only mentioned by one respondent.

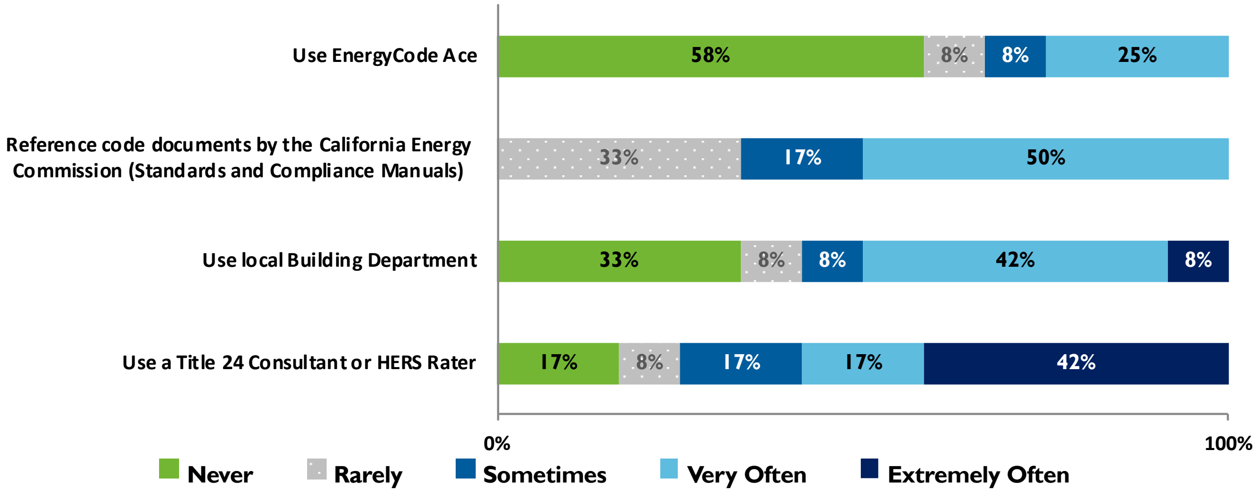


**Figure 11: Resources used to determine what energy code requirements apply to residential projects (n=12).**

There are two different paths for meeting code requirements. The performance path provides the most flexibility and involves an energy model such as with EnergyPro or CBECC. The prescriptive path is the simplest approach but requires that each individual component meet a prescribed energy requirement. When working on additions projects, two thirds of respondents (6/9) use the performance method.  For alterations projects, 8/10 use prescriptive, and 4/10 use the performance method with some overlap where respondents use both.

### Building Department Findings

We asked a specific set of questions of staff that work at a building department including building inspectors, plans reviews, and other building department staff.

Building inspectors and plans reviewers represented in this survey cover Northern California. Each bullet below represents one respondent unless otherwise noted.

- Palo Alto (n=4)
- Fremont (n=2)
- Sonoma, Napa, Marin counties
- San Ramon
- Salinas
- Mountain View
- Moorpark, Camarillo, Port Hueneme, Hidden hills, Cypress
- Dublin
- City of Visalia
- City of Roseville
- City of Pleasanton
- Anderson, CA

Seventy four percent of building department respondents reported seeing over 300 additions and alterations projects come through their offices over the past two years.

For additions projects, three quarters of the building department respondents see the performance method to demonstrate compliance with energy code via CF1R-PFR forms generated from Energy Pro or CBECC, and 10 percent use the prescriptive method (all other CF1R forms). The remaining fifteen percent utilize both.

Results were more split for alterations projects, with 58 percent of respondents seeing the prescriptive method being used, 21 percent seeing the performance method, and the remaining 21 percent seeing some combination of both.

These findings are consistent with what we heard from implementers, who reported that additions projects generally use the performance method and alterations projects generally use the prescriptive method.

While three respondents reported that there are no aspects of the energy code that they see frequently omitted from applications or improperly addressed, 12 respondents reported a wide variety of areas that they think are frequently omitted or not addressed:

- Insulation (n=3)
- Compliance Forms (n=3)
- Conditioned space addition areas (n=2)
- Window values, appliance efficiencies
- Missing skylights, building plan orientation
- Errors on the performance calculations
- Lighting
- HVAC
- Equipment specifications
- Duct design

Eight respondents had thoughts on what items are *entirely* omitted. This included:

- Insulation (n=3)
- HERs requirements (n=2)
- Window values, overhangs
- Tankless water heaters
- HVAC
- Equipment requirements
- Complying with energy “since it drives the cost up.”

Building department respondents reported that they are more confident that additions projects apply for permits, compared to alterations projects as shown in Figure 12.

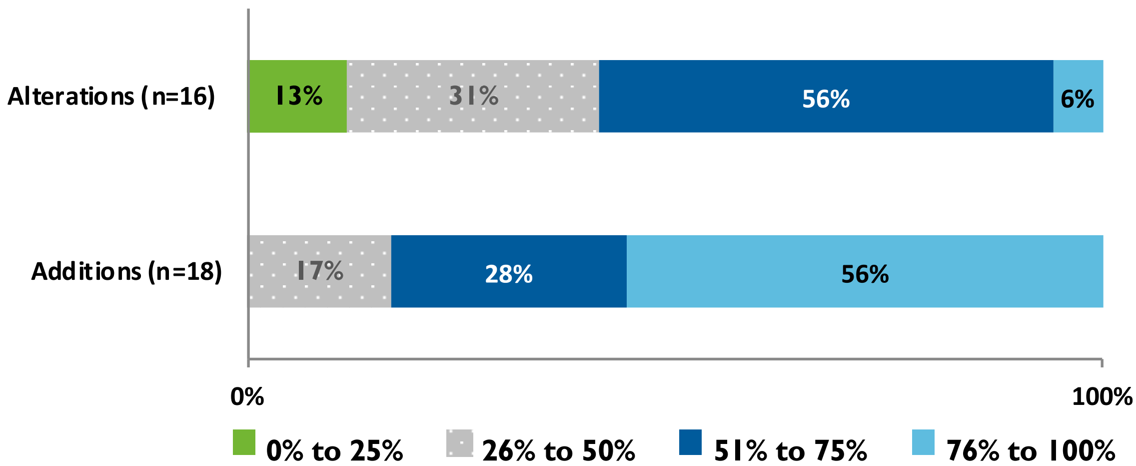


**Figure 12: Number of additions or alterations projects that apply for permits.**

We asked building department respondents about the primary compliance challenges in their jurisdictions. A total of 15 respondents gave their feedback, with almost half (7/15) reporting that the main challenge is the forms. One respondent said they were too confusing and difficult to understand and another respondent reported that the "energy code and all of its associated material are too complex and verbose for the average homeowner," that people "won't take the time to read pamphlets and compliance manuals," and that it "is difficult for staff to figure out which forms are required for different scope of works, because it is not incorporated into the building code requirements." To this last point, this respondent suggested that "the forms could be noted as an option and not a requirement to help alleviate this struggle."

Reach codes were the second most common challenge listed by building department respondents (4/15). Other challenges mentioned by at least two respondents each included:

- ADUs and their water heating systems
- Contractors (not getting testing done)
- Education for builders, architects and designers
- Solar PV

Some challenges were only mentioned by one respondent each including the following verbatim responses:

- All electric [buildings]
- All electric accessory dwelling units
- ECON-1
- Energy improvement
- Garage conversions
- HERs
- HVAC changeouts

- Keeping up with CEC changes
- Resources
- Variation in interpretation of codes from one jurisdiction to another
- Water heater changeouts

**Energy Consultant Findings**

A total of seven energy consultants responded to questions about additions and alterations work. Nearly half completed between 51-100 additions and alterations projects over the past two years, and nearly half completed 300 or more.

For additions projects, each respondent reported using the performance method to show compliance, and one person reported also using the prescriptive method. The same was true for alterations projects, though one additional respondent reported also using the prescriptive method. The additions findings are consistent with what we heard from building department officials and implementers.

In terms of issues referencing the energy code to determine requirements for residential *additions*, respondents shared three barriers for their clients:

- "Additions with 'extensions of existing walls,' etc. on and on."
- "No one wants to build their new walls with continuous insulation."
- "Additions alone can be very punitive."

When referencing energy code to determine requirements for residential *alterations* projects, respondents reported that they face the following issues:

- "Software CBECC-RES doesn't match code, e.g. U-value required for roof alteration; software treats most of it as new construction."
- "Some [clients] believe that their changes are trivial and do not think they should have to provide a CF1R."
- "Some minor alterations can be very costly to the client."

Energy consultants reported the following compliance challenges:

- Lack of enforcement of plumbing and HVAC energy code.
- Determining whether the new walls need to be 2x4 or 2x6: "If there [are] enough inherent credits in their design, they can get away with the new walls being 2x4."
- Projects that have code violations.
- When energy code does not always encourage the "best construction practices."
- [Unspecified issues in] climate zone 8-15.

Specific to the compliance software for residential additions, three of four respondents reported that they see problems including:

- "Wall extensions, second water heater in 2016 code, additions lower than 700 sf, I believe have lesser U-value requirements; 'Addition alone' in the software uses the standards for new construction regardless. The standard design never has skylights, although I get a prescriptive allowance for skylights in the code."

- "Need better/more accurate settings to define non-standard roofs: i.e. beams w/T&G then spray foam on the top side."
- "No credit for HERS verified Refrigerant Charge Measurement."
- "Forced to take a duct loss when modeling Mini-Split system."
- "VRF ductless heat pump systems calculations are way worse than a heat pump with ducts."
- "Unvented attics do not calculate properly."
- "No way to properly model:
    - Other lumber sizes for Trusses
    - Staggered studs
    - TJI framing
    - 4x framing
    - 5/8" sheetrock
    - Multiple layers of sheetrock
    - Walls adjacent to crawlspace
    - Existing heated slab with no slab edge insulation
    - Tyvek (No credit for perm 10 wrap)
    - Below grade unconditioned areas properly. Such as in the case of a basement or a below grade wall in a garage"
- "Work arounds have frequently been required, although this is improving."

Only one energy consultant reported that they faced any problems with the prescriptive compliance forms ("they are a pain to fill out") and no respondents reported any with the performance method. For the performance method, all four respondents reported that they either never, rarely or sometimes specify that existing conditions be verified by a HERS rater.

**Ideas for Improvement to the Energy Code**

Of the twenty-six respondents who answered the question about what changes they would make to improve understanding or implementation, nine respondents reported that they could think of none. The remaining respondents offered the following verbatim comments on improvement related to forms, simplification in general, and software:

- Specific to forms (n=5)
    - Reduce the forms and computer interface and make them easier for the contractor/homeowner to understand
    - Only [include] mandatory measures, no forms.
    - [Create] one simple form. Use for any project. More easy to understand regulations.
    - Fewer check boxes on the forms specifically related to fenestration, there are too many questions to answer.

    - We really need to simplify the process for homeowner, contractors and designers. There are too many forms, processes, methodologies, etc. to understand and track.
- Related to simplification (n=4):
    - Make less complicated.
    - I would remove all Title 24 form requirements which will be met by Title 20 standard compliance. I would simplify the requirements. If the compliance manual is needed to explain things, the code is too complex and needs to be simplified.
    - Get ride of it. All manufactures items are already compliant and legislation passed mandated only sales of compliant efficient energy saving items can only be sold so this regulation is just creating more work, expense and not providing any more compliance than we have without forms and Cal Green.
    - Get rid of the Database and align Title 20 with JA8.
- Specific to software (n=3):
    - [There are] too many exceptions to track, modeling software does not pick up mandatory measures
    - Make the software match the code; site enforcement of mandatory measures.
    - Fix the CBEC-Res software so that we can more accurately model the conditions specified on the plan.
- Related to small additions: simplify forms such as window change outs and reduce over penalization. (n=2)
- Allow for 'Duct Leakage to Outside' Measurement as passing standard for HERS tests.
- There needs to be a process to address unfeasible requirements that are inconsistent with existing conditions - such as a percentage of project cost toward conservation improvements, as is done with access improvements on commercial projects.

Respondents were split in half regarding portions of the code they think do *not* result in energy savings or improved quality of construction, despite the intent of the code. Half of respondents (15/31) reported that there are areas of the code that do *not* result in energy savings or improved quality of construction and identified the following areas. Verbatim responses are included below.

- Insulation:
    - Insulation of hot water lines in the conditioned space and using a tankless water heater.
    - The foam between studs.
    - QII requirement for quality insulation companies.
    - Rigid insulation on the exterior in seismic zone 4 in mild climates is a waste of money and leads to expensive design solutions.
- Documentation:

    - Some of the enforcement paperwork/computer work in documentation does not seem to be cost effective.
    - There are too many compliance forms required for plan review and inspection.
    - Reducing the paperwork and having only minimum compliance documentation will help.
- Ventilation:
    - Without balanced ventilation, the exhaust fan puts the home under negative pressure. Where it is warm outside and cool inside, this will lead to moisture condensation at the intake cracks and that leads to mold.
    - Exhaust only ventilation option.
    - Try burning a fire in a fireplace when a house is under negative pressure - when the fire starts to go out it will pull air down the chimney. IAQ fans in general are a waste of energy.
- HVAC compliance:
    - HERS ratings because HVAC contractors do not comply with Energy Code by not pulling a permit.
    - HVAC compliance should be done at the supplier level to ensure that contractors are permitting their work.
    - HERS testing of new units.
- Lighting:
    - The lighting in bathrooms should all be on vacancy sensors EXCEPT the vanity light which should be on a dimmer. Although shower lights on a vacancy sensor can pose problems with turning off in the middle of a shower if not located in view of the shower.
- Software:
    - The current software does not correctly model many advanced elements such as high performance non-ducted mini splits; hybrid water heaters; and unconventional insulation configurations.
- Aspects of the T24 points system.
- 150.H
- 150.K
- Using performance measures for additions to existing buildings.
- The same new construction requirements are applied to a 2,500 sf house and a standalone 250 sf accessory unit (ADU). The standards need to scale with the size of the house. The ADU's TDV budget is almost entirely water heating. The energy code is effectively regulating just the water heater, which already has federal efficiency requirements. Additional cost like HPW and HPR can't return the investment on a 250 sf house occupied by one person. If we omit the HPW, the ADU might fail by 15 percent, but this 15 percent might only represent 100 kWh per year or $28 in electricity. Thirty years of savings is $840, and we can not build HPW and HPR for a marginal $840. Conversely, I can pass a 6,000 sf house with electric resistance water heating, because the TDV budget is almost entirely space conditioning. The compliance feels upside down compared to the ADU. Finally, the EF of any water heater will vary with the daily water heating

load; a high efficiency water heater serving 1-2 people does not have the same cost effectiveness; the requirements need to scale.

We asked specifically about parts of the energy code that cause more work to be done without a permit. Respondents identified the following areas:

- HERS testing and HVAC replacements (n=6), though only a few respondents were specific about the barrier including the constant changes for window requirements and one respondent suggested that contractors should be required to pull a permit to purchase a piece of HVAC equipment.
- General compliance challenges including time and understanding complexity (n=4)
- Water heater change outs (mentioned by four respondents):
  - Yes, I recently had a SFD water heater form, and the water heater cut sheet was missing information. The applicant called the Title 24 1-800 number. They were very helpful but could not find the product information. The applicant then called the Title 20 800 number. They were able to help and found the product in compliance. This is way too much work for a simple water heater change out. Many people will attempt the process and then give up because the want to walk in, get a permit, and do the work.
  - If you want to replace a water heater, as part of a remodel, you need to replace with a tankless water heater, which do not have all the bugs worked out yet. A lot of maintenance required that people do not do. To avoid you need a HERS verification + T24 consultant + HERS rater and contractor verification, typically adding over $1,000 to construction cost for that alone. That is more than the cost of replacing the water heater.
- Lack of contractor education.
- The database and Title 20 does not match JA8

We also asked if there are opportunities for increased in compliance with *additions* specifically and respondents suggested that:

- “Depending on the size of the project and the age/efficiency of the existing equipment the equipment should be changed out.”
- “Air infiltration should be addressed whenever possible.”
- “[Provide an] incentive to the customer; and modeling software that actually predicts real energy use, not a 'black box' approach as is presently the case.”
- “Require a permit for HVAC equipment purchase.”

For improving compliance with *alterations*, respondents suggested:

- Working closer with certain staff:
  - “Outreach to contractors, better enforcement by AHJs and CSLB, contractor CEUs required by CSLB"
  - “Work with design, construction industries more closely.”
  - Host more utility trainings
- Focusing on manufacturer compliance:

  - “All manufactures items are already compliant and legislation passed mandated only sales of compliant efficient energy saving items can only be sold so this regulation is just creating more work, expense and not providing any more compliance than we have without forms and Cal Green.”
  - “I believe greater use of Title 20 would be easier for the expert manufacturer to comply with and help everyone purchasing the product. This would result in less paperwork for the homeowner doing a one-time repair who never needs to complete the process again for a decade or more.”
- “Air sealing, insulation of interstitial spaces, all can lighting should be AT, HVAC ducting and equipment should be changed, [add a] vapor barrier on dirt foundation"

Five respondents had the same suggestions across additions and alterations including improved enforcement at building departments, getting rid of forms, simplifying paperwork, embedding energy consultants at building departments, and focusing on building ADUs:

- “We don't need to save "energy" per se. The grid is 30 percent clean. We need to get fossil fuels out of buildings, and shift electric loads to midday. The code takes an antiquated approach by trying to "save" kilowatt hours. Just building infill housing has a climate benefit if we assume that these people are living closer to work. If energy creates a barrier to building ADUs, for example (HPW, HPR), then this is counterproductive. If code says I can not use a 40 gallon ER water heater in my garage conversion, I need to install tankless gas to pass code, then this is counterproductive.”

# Appendix H: Description of Prototypes

## Alteration Prototypes

The single family alteration prototype was developed from the alteration prototypes described in the ACM Approval Manual. The manual presents two prototypes, a 1,440 square foot existing alteration prototype and a second which is the same 1,440 square foot existing home with a 225 square foot addition. The average size of existing homes in the United States built in the 1970s was between 1,650 and 1,750 square feet, with size steadily increasing over time. To better represent the existing building stock, the alteration with addition prototype was revised to reflect a 1,665 square feet existing home. See Table 184 for a description of the prototype.

The total window area is 218 square feet, or 13.1 percent of the conditioned floor area, from 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). No attached garage was modeled per the descriptions in the ACM Approval Manual. However, a two-car attached garage was added for the electric water heater submeasure in order to evaluate the impact of the submeasure relative to water heater location.

**Table 184: Single Family Alteration Prototype Description**

| Building Component | Assumption |
|---|---|
| Conditioned Floor Area | 1,665 square feet<br>(~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 | None<br>(2-car garage added for electric water heater submeasure to evaluate water heaters located in a garage) |

The multifamily low-rise garden eight-unit 6,960 square foot two-story new construction prototype was used for the multifamily analysis.

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 the majority of 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 185 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 185: 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-slope) | 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) | CBECC-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<br>0.79 U-factor<br>0.70 SHGC CZ 1-7,16<br>0.40 SHGC CZ 8-15 | 2013 T24 Residential Vintage Table110.6-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 |

| Building Component Efficiency Feature | Baseline Assumption | Reference |
| --- | --- | --- |
| | | elsewhere. (California Energy Commission 2014)<br>Basis for selecting window types discussed in detail below. |
| Opaque Doors | 0.50 | CBECC-Res default |
| Quality Insulation Inspection Credit (HERS) | No | CBECC-Res default |
| House Infiltration | 10 ACH50 (single family)<br>7 ACH50 (multifamily) | 10 ACH50 Based on a literature review of blower door test data for existing homes. See detailed discussion below.<br>7 ACH50 is the CBECC-Res default for multifamily |
| **HVAC Equipment** | | |
| System Type & Description | Ducted FAU split system with gas furnace & A/C | Typical system for California homes |
| 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)<br>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 default |
| Verified Fan Watt Draw <= 0.58 W/cfm (HERS) | Single Speed PSC 0.58 | CBECC-Res default |
| **Water Heating Equipment** | | |

| Building Component Efficiency Feature | Baseline Assumption | Reference |
|---|---|---|
| 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 |

For specific submeasures, a small set of building attributes have been further evaluated for the basecase analysis to consider the range of configurations expected in the field. Table 186 summarizes the variations considered for specific characteristics in the analysis along with the basis for the selection of values.

**Table 186: Alterations Prototype Basecase Variations Considered in Analysis**

| Building Component Efficiency Feature | Variations for Cool Roof and Insulation Measures | Variations for Electric Heating Equipment Measure | Variations for Electric Water Heating Equipment Measure |
|---|---|---|---|
| **Envelope** | | | |
| Roof/Ceiling Insulation and Attic Type | 2 conditions:<br>1. R-19 (@ ceiling for attic & rafter for low-slope)<br>2. R-11 (@ ceiling for attic & rafter for low-slope) | | |
| **HVAC Equipment** | | | |
| System Type & Description | | Ducted FAU split system with electric resistance furnace & A/C | |
| Heating Efficiency | | Minimum efficiency for electric resistance | |

| | | | |
|---|---|---|---|
| Cooling Efficiency | | 14 SEER 11.7 EER [The federal minimum efficiency requirements that are in effect today, assuming cooling equipment is replaced with heating equipment.] | |
| Duct Location & Insulation | 2 conditions: 1. Attic, R-4.2, 15% leakage 2. Conditioned space | Attic, R-6/8 (per Table 150.2-A), 5% leakage. [Assuming duct system is replaced with heating equipment.] | |
| **Water Heating Equipment** | | | |
| System Type & Description | | | 2 conditions: 1. Electric resistance storage, in garage (single family only) 2. Electric resistance storage, in outside closet |
| Water Heater Efficiency | | | 0.92 UEF [The federal minimum efficiency requirements that are in effect today.] |

Three building characteristics—windows, air leakage, and duct leakage—merit a detailed discussion of assumptions and rationale:

**Windows**: The 2013 T24 Residential Vintage Table R3-50 recommends using the Standards Tables 110.6-A and 110.6-B for default U-factors and SHGC requirements for all vintages. These tables include U-factors and SHGC based on product type. According to data from the Residential Energy Consumption Survey (United States Energy Information Administration 2015) for the West Census region which is comprised of California, Washington, Oregon, and Alaska, windows in existing residential stock are split between aluminum (~50 percent) and wood and vinyl (~25 percent each). The same data also indicates an almost equal split between single-pane and double-pane windows. Per personal communication with Ken Nittler (Nittler 2019), vinyl windows started becoming more dominant after 1995 and double-pane metal windows are a reasonable assumption for the existing building stock. Thus, operable, double-panel metal windows without a thermal break are assumed in this analysis.

Low-E glass was just beginning to enter the market in the 1990s. The Standards included shading coefficient requirements for windows in Climates Zones 8 through 15 beginning with the 1985 code cycle. In the 1992 and 1995 code the shading coefficient requirement was 0.40 in Climate Zones 8 through 13 and 0.15 in Climate Zone 14 and 15. At this time there were not many products available that could meet a 0.15 SHGC, therefore a SHGC of 0.40 is assumed for all Climates Zones 8 through 15. Defaults from Standards Table 110.6-B are used elsewhere.

**Air Leakage**: There is a wide range in tested ACH50 values for single family homes in existing literature. A study by Max Sherman of Lawrence Berkeley National Laboratory (LBNL) (Sherman 2008) notes an infiltration rate of 12-30 ACH50 for existing homes in the U.S. with 24 ACH50 being the average for the stock. Data from the 2013 ASHRAE Handbook of Fundamentals indicates a range of 0 to 50 ACH50 for a sample of 2,080 existing single family homes in the United States based on a study conducted by Sherman and Dickeroff in 1998 (American Society of Heating, Refrigerating and Air-Conditioning Engineers 2013). Although a higher level is likely defensible, an air leakage level of 10 ACH50 is used as a conservative assumption in the present analysis

## Single Family Addition Prototype

The single family addition 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 225 square foot addition was extracted from the second prototype and evaluated as an addition alone project. See Table 187 for a description of the prototype.

**Table 187: Single Family Addition Prototype Description**

| Building Component | Assumption |
|---|---|
| Conditioned Floor Area | 225 square feet |
| Ceiling Height | 8 feet |
| Wall Area | 404 square feet |
| Window Area | 48 square feet |
| Opaque Door Area | 20 square feet |
| Number of Bedrooms | 0 |

# Appendix I: Additional Analysis

## Cool Roofs at Roof Replacement

Table 188 shows cost effectiveness analysis for the steep-slope cool roof submeasure for the single family prototype with ductwork located in conditioned space instead of the vented attic. These results inform Exception 1 TO 150.2(b)1Ii which exempts projects that have no ducts in the attic in most climate zones, except in Climate Zones 8, 11, 13, and 15 where installing the cool roof under these conditions is still cost effective.

**Table 188: Steep-Slope Cool Roof 30-Year Cost-Effectiveness for a Single Family Home with Ducts in Conditioned Space**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | -$228 | $460 | -0.49 |
| 2 | $239 | $460 | 0.52 |
| 3 | $52 | $460 | 0.11 |
| 4 | $311 | $460 | 0.68 |
| 5 | -$52 | $460 | -0.11 |
| 6 | $219 | $460 | 0.48 |
| 7 | $187 | $460 | 0.41 |
| 8 | $464 | $460 | 1.01 |
| 9 | $372 | $460 | 0.81 |
| 10 | $403 | $460 | 0.88 |
| 11 | $544 | $460 | 1.18 |
| 12 | $395 | $460 | 0.86 |
| 13 | $582 | $460 | 1.26 |
| 14 | $415 | $460 | 0.90 |
| 15 | $651 | $460 | 1.42 |
| 16 | $6 | $460 | 0.01 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

## Roof Insulation at Low-Slope Roof Replacement

Table 189 and Table 190 present cost effectiveness results for this submeasures for single family and multifamily buildings, respectively, with R-19 insulation in the roof cavity instead of R-11, the results for which are presented in the main body of this report. These results inform Exception 1 to Section 150.2(b)1Iiib which exempts projects in Climate Zones 1, 2, 4, and 8 through 10 for single family buildings and Climate Zones 1, 2, 4, 8 through 10, and 16 for multifamily buildings with at least R-19 roof cavity insulation, where the addition of roof insulation was not found to be cost effective.

**Table 189: Low-Slope Roof Insulation 30-Year Cost-Effectiveness for a Single Family Home with R-19 Cavity Insulation**

| **Climate Zone** | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | **Benefit-to-Cost Ratio** |
|---|---|---|---|
| 1 | $3,742 | $5,671 | 0.66 |
| 2 | $5,038 | $5,671 | 0.89 |
| 3 | $3,209 | $5,671 | 0.57 |
| 4 | $4,733 | $5,671 | 0.83 |
| 5 | $2,149 | $5,671 | 0.38 |
| 6 | $2,443 | $5,671 | 0.43 |
| 7 | $1,792 | $5,671 | 0.32 |
| 8 | $5,323 | $5,671 | 0.94 |
| 9 | $4,456 | $5,671 | 0.79 |
| 10 | $5,228 | $5,671 | 0.92 |
| 11 | $7,429 | $5,671 | 1.31 |
| 12 | $6,063 | $5,671 | 1.07 |
| 13 | $7,604 | $5,671 | 1.34 |
| 14 | $7,400 | $5,671 | 1.30 |
| 15 | $8,019 | $5,671 | 1.41 |
| 16 | $5,744 | $5,671 | 1.01 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the Benefit-to-Cost ratio is infinite.

### Table 190: Low-Slope Roof Insulation 30-Year Cost-Effectiveness for a Multifamily Home with R-19 Cavity Insulation

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $978 | $1,481 | 0.66 |
| 2 | $1,303 | $1,481 | 0.88 |
| 3 | $688 | $1,481 | 0.46 |
| 4 | $1,022 | $1,481 | 0.69 |
| 5 | $564 | $1,481 | 0.38 |
| 6 | $552 | $1,481 | 0.37 |
| 7 | $354 | $1,481 | 0.24 |
| 8 | $1,242 | $1,481 | 0.84 |
| 9 | $1,090 | $1,481 | 0.74 |
| 10 | $1,300 | $1,481 | 0.88 |
| 11 | $1,799 | $1,481 | 1.21 |
| 12 | $1,565 | $1,481 | 1.06 |
| 13 | $1,884 | $1,481 | 1.27 |
| 14 | $1,848 | $1,481 | 1.25 |
| 15 | $1,979 | $1,481 | 1.34 |
| 16 | $1,439 | $1,481 | 0.97 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

## Attic Insulation for Alterations

This section provides detailed cost effectiveness results for the attic insulation for alterations submeasure. Table 191 through Table 196 presents results for single family buildings and Table 197 through Table 201 presents results for multifamily buildings. Results for the package with R-49 attic insulation upgrade, air sealing, and recessed can upgrades are provided, in addition to results for just R-49 attic insulation with recessed can upgrades and R-49 attic insulation on its own. Results are presented relative to both an existing building with R-11 attic insulation as well as an existing building with R-19 attic insulation.

In the case of R-19 existing attic insulation this is an exception that requires HERS verification of existing conditions. In these cases, a HERS verification cost is included in the total incremental costs. For single family buildings this was assumed to be $100 per building. For multifamily buildings it was assumed to be $50 per apartment below an attic, with a total cost for the building of $300.

**Table 191: 30-Year Cost-Effectiveness for R-49 Attic Insulation, Air Sealing, & Recessed Can Upgrades on a Single Family Home with Existing R-11 Cavity Insulation**

| Climate Zone | Benefits<br>TDV Energy Cost Savings + Other PV Savings[a]<br>(2023 PV$) | Costs<br>Total Incremental PV Costs[b]<br>(2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $4,355 | $4,964 | 0.88 |
| 2 | $5,847 | $4,964 | 1.18 |
| 3 | $4,070 | $4,964 | 0.82 |
| 4 | $5,165 | $4,964 | 1.04 |
| 5 | $2,670 | $4,964 | 0.54 |
| 6 | $2,846 | $4,964 | 0.57 |
| 7 | $2,258 | $4,964 | 0.45 |
| 8 | $5,363 | $4,964 | 1.08 |
| 9 | $5,179 | $4,964 | 1.04 |
| 10 | $5,551 | $4,964 | 1.12 |
| 11 | $7,915 | $4,964 | 1.59 |
| 12 | $7,095 | $4,964 | 1.43 |
| 13 | $7,843 | $4,964 | 1.58 |
| 14 | $7,705 | $4,964 | 1.55 |
| 15 | $8,278 | $4,964 | 1.67 |
| 16 | $6,887 | $4,964 | 1.39 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 192: 30-Year Cost-Effectiveness for R-49 Attic Insulation & Recessed Can Upgrades on a Single Family Home with Existing R-11 Cavity Insulation

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $3,771 | $3,041 | 1.24 |
| 2 | $5,479 | $3,041 | 1.80 |
| 3 | $3,779 | $3,041 | 1.24 |
| 4 | $4,879 | $3,041 | 1.60 |
| 5 | $2,399 | $3,041 | 0.79 |
| 6 | $2,765 | $3,041 | 0.91 |
| 7 | $2,232 | $3,041 | 0.73 |
| 8 | $5,297 | $3,041 | 1.74 |
| 9 | $4,977 | $3,041 | 1.64 |
| 10 | $5,234 | $3,041 | 1.72 |
| 11 | $7,492 | $3,041 | 2.46 |
| 12 | $6,602 | $3,041 | 2.17 |
| 13 | $7,622 | $3,041 | 2.51 |
| 14 | $7,322 | $3,041 | 2.41 |
| 15 | $7,867 | $3,041 | 2.59 |
| 16 | $6,279 | $3,041 | 2.07 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 193: 30-Year Cost-Effectiveness for R-49 Attic Insulation Upgrade on a Single Family Home with Existing R-11 Cavity Insulation

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $3,771 | $2,560 | 1.47 |
| 2 | $5,479 | $2,560 | 2.14 |
| 3 | $3,779 | $2,560 | 1.48 |
| 4 | $4,879 | $2,560 | 1.91 |
| 5 | $2,399 | $2,560 | 0.94 |
| 6 | $2,765 | $2,560 | 1.08 |
| 7 | $2,232 | $2,560 | 0.87 |
| 8 | $5,297 | $2,560 | 2.07 |
| 9 | $4,977 | $2,560 | 1.94 |
| 10 | $5,234 | $2,560 | 2.04 |
| 11 | $7,492 | $2,560 | 2.93 |
| 12 | $6,602 | $2,560 | 2.58 |
| 13 | $7,622 | $2,560 | 2.98 |
| 14 | $7,322 | $2,560 | 2.86 |
| 15 | $7,867 | $2,560 | 3.07 |
| 16 | $6,279 | $2,560 | 2.45 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 194: 30-Year Cost-Effectiveness for R-49 Attic Insulation, Air Sealing, & Recessed Can Upgrades on a Single Family Home with Existing R-19 Cavity Insulation**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $2,414 | $4,964 | 0.49 |
| 2 | $3,140 | $4,964 | 0.63 |
| 3 | $2,267 | $4,964 | 0.46 |
| 4 | $2,846 | $4,964 | 0.57 |
| 5 | $1,535 | $4,964 | 0.31 |
| 6 | $1,492 | $4,964 | 0.30 |
| 7 | $1,089 | $4,964 | 0.22 |
| 8 | $2,878 | $4,964 | 0.58 |
| 9 | $2,829 | $4,964 | 0.57 |
| 10 | $3,007 | $4,964 | 0.61 |
| 11 | $4,177 | $4,964 | 0.84 |
| 12 | $3,724 | $4,964 | 0.75 |
| 13 | $4,263 | $4,964 | 0.86 |
| 14 | $4,254 | $4,964 | 0.86 |
| 15 | $4,341 | $4,964 | 0.87 |
| 16 | $3,713 | $4,964 | 0.75 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 195: 30-Year Cost-Effectiveness for R-49 Attic Insulation & Recessed Can Upgrades on a Single Family Home with Existing R-19 Cavity Insulation, HERS Verified**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,829 | $2,974 | 0.61 |
| 2 | $2,771 | $2,974 | 0.93 |
| 3 | $1,976 | $2,974 | 0.66 |
| 4 | $2,561 | $2,974 | 0.86 |
| 5 | $1,265 | $2,974 | 0.43 |
| 6 | $1,411 | $2,974 | 0.47 |
| 7 | $1,063 | $2,974 | 0.36 |
| 8 | $2,811 | $2,974 | 0.95 |
| 9 | $2,627 | $2,974 | 0.88 |
| 10 | $2,690 | $2,974 | 0.90 |
| 11 | $3,753 | $2,974 | 1.26 |
| 12 | $3,232 | $2,974 | 1.09 |
| 13 | $4,041 | $2,974 | 1.36 |
| 14 | $3,871 | $2,974 | 1.30 |
| 15 | $3,929 | $2,974 | 1.32 |
| 16 | $3,105 | $2,974 | 1.04 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 196: 30-Year Cost-Effectiveness for R-49 Attic Insulation Upgrade on a Single Family Home with Existing R-19 Cavity Insulation, HERS Verified**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,829 | $2,493 | 0.73 |
| 2 | $2,771 | $2,493 | 1.11 |
| 3 | $1,976 | $2,493 | 0.79 |
| 4 | $2,561 | $2,493 | 1.03 |
| 5 | $1,265 | $2,493 | 0.51 |
| 6 | $1,411 | $2,493 | 0.57 |
| 7 | $1,063 | $2,493 | 0.43 |
| 8 | $2,811 | $2,493 | 1.13 |
| 9 | $2,627 | $2,493 | 1.05 |
| 10 | $2,690 | $2,493 | 1.08 |
| 11 | $3,753 | $2,493 | 1.51 |
| 12 | $3,232 | $2,493 | 1.30 |
| 13 | $4,041 | $2,493 | 1.62 |
| 14 | $3,871 | $2,493 | 1.55 |
| 15 | $3,929 | $2,493 | 1.58 |
| 16 | $3,105 | $2,493 | 1.25 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

### Table 197: 30-Year Cost-Effectiveness for R-49 Attic Insulation, Air Sealing, & Recessed Can Upgrades on a Multifamily Home with Existing R-11 Cavity Insulation

| **Climate Zone** | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | **Benefit-to-Cost Ratio** |
|---|---|---|---|
| 1 | $1,116 | $1,297 | 0.86 |
| 2 | $1,378 | $1,297 | 1.06 |
| 3 | $855 | $1,297 | 0.66 |
| 4 | $1,230 | $1,297 | 0.95 |
| 5 | $669 | $1,297 | 0.52 |
| 6 | $653 | $1,297 | 0.50 |
| 7 | $499 | $1,297 | 0.38 |
| 8 | $1,293 | $1,297 | 1.00 |
| 9 | $1,137 | $1,297 | 0.88 |
| 10 | $1,286 | $1,297 | 0.99 |
| 11 | $1,777 | $1,297 | 1.37 |
| 12 | $1,652 | $1,297 | 1.27 |
| 13 | $1,836 | $1,297 | 1.42 |
| 14 | $1,743 | $1,297 | 1.34 |
| 15 | $1,882 | $1,297 | 1.45 |
| 16 | $1,642 | $1,297 | 1.27 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 198: 30-Year Cost-Effectiveness for R-49 Attic Insulation & Recessed Can Upgrades on a Multifamily Home with Existing R-11 Cavity Insulation**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,060 | $794 | 1.33 |
| 2 | $1,285 | $794 | 1.62 |
| 3 | $804 | $794 | 1.01 |
| 4 | $1,136 | $794 | 1.43 |
| 5 | $631 | $794 | 0.79 |
| 6 | $592 | $794 | 0.74 |
| 7 | $449 | $794 | 0.56 |
| 8 | $1,197 | $794 | 1.51 |
| 9 | $1,040 | $794 | 1.31 |
| 10 | $1,174 | $794 | 1.48 |
| 11 | $1,618 | $794 | 2.04 |
| 12 | $1,532 | $794 | 1.93 |
| 13 | $1,665 | $794 | 2.10 |
| 14 | $1,601 | $794 | 2.02 |
| 15 | $1,648 | $794 | 2.07 |
| 16 | $1,559 | $794 | 1.96 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 199: 30-Year Cost-Effectiveness for R-49 Attic Insulation Upgrade on a Multifamily Home with Existing R-11 Cavity Insulation**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $1,060 | $669 | 1.58 |
| 2 | $1,285 | $669 | 1.92 |
| 3 | $804 | $669 | 1.20 |
| 4 | $1,136 | $669 | 1.70 |
| 5 | $631 | $669 | 0.94 |
| 6 | $592 | $669 | 0.88 |
| 7 | $449 | $669 | 0.67 |
| 8 | $1,197 | $669 | 1.79 |
| 9 | $1,040 | $669 | 1.56 |
| 10 | $1,174 | $669 | 1.76 |
| 11 | $1,618 | $669 | 2.42 |
| 12 | $1,532 | $669 | 2.29 |
| 13 | $1,665 | $669 | 2.49 |
| 14 | $1,601 | $669 | 2.39 |
| 15 | $1,648 | $669 | 2.46 |
| 16 | $1,559 | $669 | 2.33 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 200: 30-Year Cost-Effectiveness for R-49 Attic Insulation & Recessed Can Upgrades on a Multifamily Home with Existing R-19 Cavity Insulation, HERS Verified**

| Climate Zone | **Benefits** TDV Energy Cost Savings + Other PV Savings[a] **(2023 PV$)** | **Costs** Total Incremental PV Costs[b] **(2023 PV$)** | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $533 | $776 | 0.69 |
| 2 | $692 | $776 | 0.89 |
| 3 | $405 | $776 | 0.52 |
| 4 | $623 | $776 | 0.80 |
| 5 | $316 | $776 | 0.41 |
| 6 | $298 | $776 | 0.38 |
| 7 | $223 | $776 | 0.29 |
| 8 | $676 | $776 | 0.87 |
| 9 | $569 | $776 | 0.73 |
| 10 | $629 | $776 | 0.81 |
| 11 | $864 | $776 | 1.11 |
| 12 | $831 | $776 | 1.07 |
| 13 | $927 | $776 | 1.19 |
| 14 | $862 | $776 | 1.11 |
| 15 | $873 | $776 | 1.13 |
| 16 | $780 | $776 | 1.00 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

**Table 201: 30-Year Cost-Effectiveness for R-49 Attic Insulation Upgrade on a Multifamily Home with Existing R-19 Cavity Insulation, HERS Verified**

| Climate Zone | Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$) | Costs Total Incremental PV Costs[b] (2023 PV$) | Benefit-to-Cost Ratio |
|---|---|---|---|
| 1 | $533 | $650 | 0.82 |
| 2 | $692 | $650 | 1.06 |
| 3 | $405 | $650 | 0.62 |
| 4 | $623 | $650 | 0.96 |
| 5 | $316 | $650 | 0.49 |
| 6 | $298 | $650 | 0.46 |
| 7 | $223 | $650 | 0.34 |
| 8 | $676 | $650 | 1.04 |
| 9 | $569 | $650 | 0.87 |
| 10 | $629 | $650 | 0.97 |
| 11 | $864 | $650 | 1.33 |
| 12 | $831 | $650 | 1.28 |
| 13 | $927 | $650 | 1.43 |
| 14 | $862 | $650 | 1.33 |
| 15 | $873 | $650 | 1.34 |
| 16 | $780 | $650 | 1.20 |

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) 3 percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) 3 percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.