TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Introduction

Overview

Please refer to Chapter 3.1 of the *2022 Single-Family Residential Compliance Manual*.

Navigating This Chapter

This chapter is organized by building envelope component as seen in the Table of Contents.

This chapter includes:

- An overview of changes to building envelope requirements for the 2025 Energy Code.
- A description of fenestration terminology, requirements and labeling, U-factor and solar heat gain coefficient (SHGC) requirements, and credits that can be used under the performance approach.
- Description of opaque envelope terminology, requirements related to insulation, roof products, radiant barriers, air barriers, vapor retarders, and attic ventilation.
- Compliance approaches for alternative construction assemblies such as log homes, straw bale, structural insulated panels (SIPs) and insulated concrete form (ICF) construction.

What's New for 2025

The *2025 Building Energy Efficiency Standards* for residential buildings include increased efficiencies for several envelope requirements, and there are improvements that have been made to better aid the designer, builder, and building official.

MANDATORY Section 150.0

- Exception to mandatory roof deck insulation in newly constructed attic systems in Climate Zones 4 and 8–16 to meet an area-weighted average U-factor no greater than 0.184 for ductless space-conditioning systems.(Section 150.0(a)1), for space-conditioning duct systems buried within insulation in an attic that complies using Section 150.1(b) and is verified according to RA 3.1.4.1.
- Increased mandatory required minimum wall insulation from R-13 to R-15 (overall assembly maximum U-0.095) for 2x4 wood framed assemblies, and R-20 to R-21 (overall assembly maximum U-0.069) for 2x6 assemblies (Section 150.0(c)).
- Mandatory maximum weighted average U-factor for fenestration products including skylight decreased to 0.40 (Section 150.0(q)).
- Fenestration installed in buildings located in fire hazard severity zones or wildland-urban interface (WUI) fire areas as designated by the local enforcement agency, is excepted from mandatory fenestration requirements (Section 150.0(q)).

PRESCRIPTIVE Section 150.1

- A new alternative prescriptive compliance pathway under Option C of Table 150.1-A, for cathedral ceilings in single-family new construction. Cathedral ceilings will require an R-value of 38 in all California climate zones. (Section 150.1(c)1Aiii).

- The prescriptive maximum U-factor requirements of window assemblies reduced from 0.30 to 0.27 in Climate Zones 1 through 5, 11 through 14, and 16. Climate Zones 6–10 and 15 remain at 0.30 U-factor. Exception 1 for new dwelling units that are 500 square feet or less in Climate Zone 5 allows maximum U-factor of 0.30 (Section 150.1(c)3A).

Fenestration (Window/Skylight/Glazed Door) and Opaque Doors

Please refer to Chapter 3.3 of the *2022 Single-Family Residential Compliance Manual*.

Fenestration Types

Windows and Glazed Doors

A *window* is a vertical fenestration product that is an assembled unit consisting of a frame and sash component holding one or more pieces of glazing. Window performance is measured with the U-factor and solar heat gain coefficient (SHGC).

Glazed doors are doors having a glazed area of 25 percent or more of the area of the door. Glazed doors are treated the same as windows and must meet the U-factor and SHGC requirements for windows. Most sliding glass doors, French doors, and some entry doors with large amounts of glazing will meet the definition to be treated as glazed doors.

Opaque Doors

Please refer to Chapter 3.3.1.2 of the *2022 Single-Family Residential Compliance Manual*.

Skylights and Tubular Daylight Devices

Please refer to Chapter 3.3.1.3 of the *2022 Single-Family Residential Compliance Manual*.

Fenestration Subcategories

Please refer to Chapter 3.3.1.4 of the *2022 Single-Family Residential Compliance Manual*.

Fenestration Definitions

- Center of glass U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT) are measured only through glass at least 2.5 inches from the edge of the glass or dividers.
- Clear glass has little, if any, observable tint with an insulated glass (IG) unit with an SHGC of 0.5 or greater.
- *Chromogenic* is a class of glazing that can change the optical properties by including active materials (e.g., electrochromic) and passive materials (e.g., photochromic and thermochromic) permanently integrated into the glazing assembly.
- *Electrochromatic* is a class of glazing that tints on demand using a small amount of electricity.
- Divider (muntin). An element that physically or visually divides different lites of glass. (See Definition K.) It may be a true divided lite, between the panes, or applied to the exterior or interior of the glazing.
- Double-pane window. *Double-pane* (or dual-pane) *glazing* is made of two panes of glass (or other glazing material) separated by space (generally ¼" [6 mm] to ¾" [18 mm]) filled

with air or other gas. Two panes of glazing laminated together do not constitute double-pane glazing

- Dynamic glazing. Glazing systems that have the ability to reversibly change the performance properties, including U-factor, solar heat gain coefficient (SHGC), or visible transmittance (VT), or both between well-defined end points. Includes active materials (e.g., electrochromic) and passive materials (e.g., photochromic and thermochromic) permanently integrated into the glazing assembly.

  With appropriate controls, electrochromic glass can be darkened or lightened to adjust the levels of daylight and solar heat gain. These products have the ability to reversibly change the SHGC and VT between well-defined endpoints.

- Integrated shading systems is a class of fenestration products including an active layer (e.g., shades, louvers, blinds, or other materials) permanently integrated between two or more glazing layers and that has the ability to reversibly change performance properties, including U-factor, SHGC, or VT between well-defined end points, or a combination.
- Fixed. The fenestration product cannot be opened.
- Gap width. The distance between glazing in multiglazed systems (e.g., double or triple glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit thickness, which is measured from outside surface to outside surface.
- Grille. See Divider.
- Insulating glass unit (IG unit or IG). An IG unit includes the glazing, coatings, tinting, spacer(s), films (if any), gas infills, and edge caulking.
- Light or lite. A layer of glazing material, especially in a multilayered IG unit. Referred to as panes in Section 110.6 when the lites are separated by a spacer from inside to outside of the fenestration.
- Low-emissivity (Low-e) coatings. Low-e coatings are special coatings applied to the second, third, or fourth surfaces in double- or triple-glazed windows or skylights. As the name implies, the surface has a low emittance, meaning that radiation from that surface to the surface it “looks at” is reduced. Since radiation transfer from the hot side to the cool side of the window is a major component of heat transfer in glazing, low-e coatings are very effective in reducing the U-factor. They do nothing, however, to reduce losses through the frame.

  Low-e coatings can be engineered to have different levels of solar heat gain. Generally, there are two kinds of low-e coatings:

  - Low-solar-gain low-e coatings are formulated to reduce air-conditioning loads. Fenestration products with low-solar-gain low-e coatings typically have an SHGC of 0.40 or less. Low-solar-gain low-e coatings are sometimes called *spectrally selective coatings* because they filter much of the infrared and ultraviolet portions of the sun’s radiation while allowing visible light to pass through.
  - High-solar-gain low-e coatings, by contrast, are formulated to maximize solar gains. Such coatings would be preferable in passive solar applications or where there is little air conditioning.

Another advantage of low-e coatings, especially low-solar-gain low-e coatings, is that when they filter the sun's energy, they generally remove between 80 percent and 85 percent of the ultraviolet light that would otherwise pass through the window and damage fabrics and other interior furnishings. This is a major advantage for homeowners and can be a selling point for builders.

- Mullion. A frame member that is used to join two windows into one fenestration unit.
- Muntin. See Dividers.
- Nonmetal frame includes vinyl, wood, fiberglass, and other low-conductance materials. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics. Nonmetal frames may have metal strengthening bars entirely inside the frame extrusions or metal cladding only on the surface.
- Operable. The fenestration product can be opened for ventilation.
- Solar heat gain coefficient (SHGC). A measure of the relative amount of heat gain from sunlight that passes through a fenestration product. SHGC is a number between zero and one that represents the ratio of solar heat that passes through the fenestration product to the total solar heat that is incident on the outside of the window. A low SHGC number (closer to 0) means that the fenestration product keeps out most solar heat. A higher SHGC number (closer to 1) means that the fenestration product lets in most of the solar heat.
- *SHGC* or $SHGC_t$ is the SHGC for the total fenestration product and is the value used for compliance with the Energy Code.
- Spacer or gap space. A material that separates multiple panes of glass in an IG unit.
- Thermal break frame includes metal frames that are not solid metal from the inside to the outside but are separated in the middle by a material with a significantly lower conductivity.
- Tinted. Glazing products formulated to have the appearance of color that alters the solar heat gain and visible transmittance. Common colors include gray, bronze, green, and blue. Some coatings can also appear tinted.
- Triple-pane window. Triple-pane glazing is made of three panes of glass (or other glazing material) separated by space (generally ¼" [6 mm] to ¾" [18 mm]) filled with air or other gas. Three panes of glazing laminated together do not constitute triple-pane glazing.
- U-factor. A measure of how much heat can pass through a construction assembly or a fenestration product. The lower the U-factor, the more energy efficient the product is. The units for U-factor are British thermal units (Btu) of heat loss each hour per square foot (ft^2) of window area per degree Fahrenheit (°F) of temperature difference (Btu/hr-ft^2-°F). U-factor is the inverse of R-value.

  The U-factor considers the entire product, including losses through the center of glass, at the edge of glass where a metal spacer typically separates the double-glazing panes, losses through the frame, and through the mullions. For metal-framed fenestration products, the frame losses can be significant.
- Visible transmittance (VT) is the ratio of visible light transmitted through the fenestration. The higher the VT rating, the more light is allowed through a window.

- Window films are composed of a polyester substrate to which a special scratch-resistant coating is applied on one side, with a mounting adhesive layer and protective release liner applied to the other side.

Mandatory Requirements Section 10-111, Section 10-112, Section 110.6, and Section 150.0(q)

Please refer to Chapter 3.3.2.1 of the *2022 Single-Family Residential Compliance Manual*.

Certified Product Labels: Temporary and Permanent

Please refer to Chapter 3.3.2.2 of the *2022 Single-Family Residential Compliance Manual*.

Default Label: Temporary

Please refer to Chapter 3.3.2.3 of the *2022 Single-Family Residential Compliance Manual*.

Fenestration Products Section 150.0(q)

A weighted maximum weighted average U-factor of 0.40 is required for fenestration products separating conditioned and unconditioned spaces or outdoors. Several exceptions to this requirement are provided as these scenarios are not expected to result in enough heat transfer between conditioned and unconditioned spaces or outdoors to support the costs. These exceptions are based on the fenestration area, the use of dual-glazed greenhouse or garden windows up to 30 square feet, or if the building meets Part 7 of the California Building Code, California Wildland-Urban Interface Code.

U-Factor and SHGC Ratings Section 110.6(a), Table 110.6-A, and Table 110.6-B

Determining U-Factor and SHGC

The Energy Code requires that U-factor and solar heat gain coefficient (SHGC) be calculated using standardized procedures to ensure that the thermal performance or efficiency data for fenestration products is accurate. The data provided by different manufacturers within each fenestration type (i.e., windows, doors, skylights) can easily be compared to others within that type and can be verified independently. Acceptable methods of determining U-factor and SHGC are shown in Table 3-2.

Table 3-1: Methods for Determining U-Factor and SHGC

U-Factor/SHGC Determination Method	Manufactured Windows and Doors	Manufactured Skylights	Site-Built Fenestration (Vertical & Skylight)	Field-Fabricated Fenestration	Glass Block
NFRC-100 (U-Factor) NFRC-200 (SHGC)	X	X	X	N/A	N/A
Energy Code Default Table 110.6-A (U-Factor) Table 110.6-B (SHGC)	X	X	X	X	X
NFRC's Component Modeling Approach (CMA)[1]	N/A	N/A	N/A	N/A	N/A
NA6[2]	N/A	N/A	X	N/A	N/A

The NFRC CMA method is limited to nonresidential and is not approved for residential use.

The Alternative Default U-factors and SHGCs from Reference Appendices, Nonresidential Appendix NA6 may be used only for total site-built vertical fenestration plus skylights up to 250 ft^2 or 5 percent of the conditioned floor area, whichever is larger. Residential area allowances are defined in NA6.1(b).

Source: California Energy Commission

Note for architects/designers: When the alternative procedure from NA6 for unrated site-built fenestration is used in a residential application, it may not meet the mandatory or prescriptive values as required by Section 150.0(q) and Table 150.1-A, respectively, even if area-weighted averaging is implemented. If NA6 glazing meets mandatory, but not prescriptive values, then it would be necessary to use the performance approach to meet energy compliance.

Example 3-1: Multiple Window Types in a Project

Question:

My new home will have a combination of window types, including fixed, operable, wood, metal, and so forth, some of which are field-fabricated. What are the options for showing compliance with the Energy Code?

Answer:

All windows must meet the mandatory requirements of Section 110.6 and Section 110.7 and the mandatory maximum area-weighted average U-factor of 0.40 from Section 150.0(q), unless exempted. For field-fabricated windows, you must select U-factors and SHGC values from the default tables (Table 110.6-A and Table 110.6-B of the Energy Code). Windows that are not field-fabricated must be labeled with NFRC-certified or default efficiencies. No fenestration products in the default tables meet the mandatory maximum U-factor of 0.40 individually. If the area-weighted average U-factors or SHGC values do not comply with the prescriptive requirements, the performance method must be used. To simplify data entry into the compliance software, you may choose the U-factor from Table 110.6-A of the Energy Code that is the highest of any of the windows planned to be installed and use this for all windows for compliance. However, you must use the appropriate SHGC from Table 110.6-B for each window type being installed.

Example 3-2: Glass Block

Question:

Which U-factor is used for an operable metal-framed glass block?

Answer:

For glass block, use the U-factor from Table 110.6-A of the Energy Code for the frame type in which the glass blocks are installed and for the fenestration product type. The U-factor for operable metal-framed glass block from Table 110.6-A is 0.87.

Example 3-3

Question:

Which SHGC is used for clear glass block, and can it be used for tinted glass block?

Answer 2: Use the default SHGC values from Table 110.6-B, depending upon whether the glass block has a metal or nonmetal frame and whether it is operable or fixed. The default SHGC table does not include tinted glass block, so use the clear glass block SHGC as the default for both clear and tinted glass block.

Example 3-4

Question:

Does it need a label?

Answer:

Glass block is considered a field-fabricated product and may be installed only if compliance is demonstrated on the compliance documents. Temporary labels described in Default Label: Temporary above must be applied to the installation for review by the building inspector, with corresponding values in the compliance report.

Example 3-5: Sunrooms

Question:

Is there a default U-factor for the glass in sunrooms?

Answer:

If the sunroom is part of the conditioned floor area, then yes. For the horizontal or sloped portions of the sunroom glazing, use the U-factor for skylights. For the vertical portions, use the U-factors for fixed windows, operable windows, or doors, as appropriate. As a simple alternative, the manufacturer may label the entire sunroom with the highest U-factor of any of the fenestration types within the assembly.

Example 3-6: Glazed Doors

Question:

How are exterior glazed doors treated in compliance documentation for U- factor and SHGC?

Answer:

All doors with glass area greater than or equal to 25 percent of the door area, which includes French doors, are defined as fenestration products and are covered by the NFRC Rating and Certification Program. The U-factor and SHGC for doors with 25 percent or more glass area may be determined in one of two ways:

- Use the NFRC rated and labeled values.
- Refer to Table 110.6-A and 110.6-B of the Energy Code. The values are based upon glazing and framing type.

In special cases where site-built fenestration is being installed in a residential application, the site-built windows and glazed doors can use an alternative method to calculate the U- factor and the SHGC by using the manufacturer's center-of-glass values (COG). The COG values are calculated in accordance with Reference Appendices, Nonresidential Appendix NA6. To use this calculation, the maximum allowed site-built fenestration is 250 ft^2 or 5 percent of the conditioned floor area, whichever is larger.

Example 3-7:

Question:

How can I determine a U-factor and SHGC for doors when less than 25 percent of the door area is glass?

Answer:

Doors with less than 25 percent glass area are treated as opaque exterior doors. For prescriptive or performance approaches, only the U-factor is used for this product type. Use one of the following options for U-factor of the door:

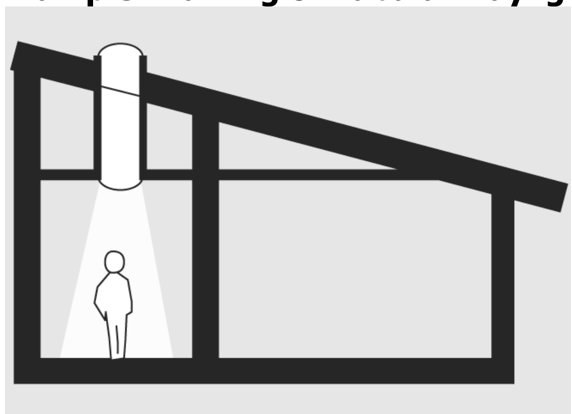
- The NFRC label if one is available
- The default values from Table JA4.5.1 of the Reference Appendices
- Tubular daylighting device with single-pane diffuser

Example 3-8:

Question:

A tubular daylighting device (TDD) will be used to get daylight into a house. The skylight has a clear plastic dome exterior to the roof, a single-pane ¼-inch (6 mm)- thick acrylic diffuser mounted at the ceiling, and a metal tube connecting the two. How are U-factor and SHGC determined for the performance approach to comply with the Energy Code, if U_c is 1.20 and $SHGC_c$ is 0.85?

Figure 3-1: Example Drawing of Tubular Daylighting Device



Source: California Energy Commission

Answer:

There are three methods available for determining the U-factor for TDD:

- Use the NFRC label if the product has been tested and certified under NFRC procedures. This requires a label that states: "Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures NFRC 100," followed by the U-factor.
- Use the default U-factor from Table 110.6-A of the Energy Code. This tubular product would be considered a metal frame, fixed, single-pane skylight resulting in a U-factor of 1.19, which must appear on a label preceded by the words "CEC Default U-factor." (A tubular daylighting device would have to have two panes of glazing with an air space of less than 2 inches [50 mm] between them at the plane of the ceiling insulation for it to be considered double-pane.)
- Determine the U-factor from Reference Appendices, Nonresidential Appendix NA6, Equation NA6-1. The U-factor for this tubular daylighting device would be based on metal with no curb (Table NA6-5). The U-factor for this skylight, using Equation NA6-1, is 1.25, where U_t = (0.195 + (0.882 x 1.20)). This must appear on a label stated as "CEC Default U-factor 1.25."

There also are three methods available for determining SHGC for TDD:

- Use the NFRC label if the skylight has been tested and certified under NFRC procedures and requires a label that states: "Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures."
- Use the default table SHGC in Table 110.6-B of the Energy Code. This tubular daylight device would be considered a metal-frame, fixed, clear, single-pane skylight resulting in an SHGC of 0.83, which must appear on a label stated as "CEC Default SHGC 0.83."
- Determine the SHGC from Reference Appendices, Nonresidential Appendix NA6, Equation NA6-2. The SHGC for this skylight using Equation NA6-2 is 0.81, where $SHGC_t$ = (0.08 + (0.86 x 0.85)). This must appear on a label stated as "CEC Default SHGC 0.81."

Example 3-9: Tubular Daylighting Device With Dual-Pane Diffuser

Question:

How are the U-factor and the SHGC determined if the TDD in the previous example has a dual-pane diffuser (instead of single-pane) mounted at the ceiling?

Answer:

The procedure would be the same as Example 3-8, except that the double-pane U-factor and SHGC values from Tables 110.6-A and 110.6-B of the Energy Code would be used instead of single-pane values. Up to 3 ft^2 of tubular daylighting device with a dual-pane diffuser is assumed to have the prescriptive U-factor and SHGC from Table 150.1-A for compliance calculations (Exception 1 to Section 150.1(c)3A).

Air Leakage Section 110.6(a)1, Section 110.7

Please refer to Chapter 3.3.4 of the *2022 Single-Family Residential Compliance Manual*.

Prescriptive Requirements Section 150.1(c)3, Section 150.1(c)4, Section 150.1(c)5, and Table 150.1-A

Fenestration

Prescriptive requirements described in this chapter typically refer to Table 150.1-A. The maximum fenestration U-factor required prescriptively is 0.27 for Climate Zones 1 through 5, 11 through 14, and 16, and 0.30 for all other climate zones. Newly constructed homes with a conditioned floor area of 500 square feet or less in Climate Zone 5 may comply with a maximum U-factor of 0.30. The maximum SHGC is 0.23 for single-family homes in Climate Zones 2, 4, and 6–14. The maximum SHGC is 0.20 for single-family homes in Climate Zone 15. Single-family homes in Climate Zones 1, 3, 5, and 16 have no SHGC prescriptive requirements.

The requirements apply to fenestration products without consideration of insect screens or interior shading devices. With some exceptions, some fenestration products may exceed the prescriptive requirement as long as the U-factor and SHGC of windows, glazed doors, and skylights can be area weight-averaged together to meet the prescriptive requirement using the CF1R-ENV-02-E compliance document in Appendix A of this manual.

Opaque Doors

An *opaque door* is an installed swinging door separating conditioned space from outside or adjacent unconditioned space with less than 25 percent glazed area. A door that has 25 percent or more glazed area is considered a glazed door and is treated like a fenestration product (Section 3.5.8).

Opaque doors are prescriptively required to have an area-weighted average U-factor no greater than U-0.20, per Table 150.1-A. Swinging doors between the garage and conditioned space that are required to have fire protection are exempt from the prescriptive requirement. The U-factor must be rated in accordance with NFRC 100, or the applicable default U-factor defined in Reference Appendices, Joint Appendix Table JA4.5.1 must be used.

Note for Building Inspectors: At the field inspection, the field inspector verifies that the door U-factor meets the energy compliance values by checking the NFRC label sticker on the product. When manufacturers do not rate the thermal efficiencies by NFRC procedures, the

Energy Commission default values must be used and documented on a temporary default label (Figure 3-3).

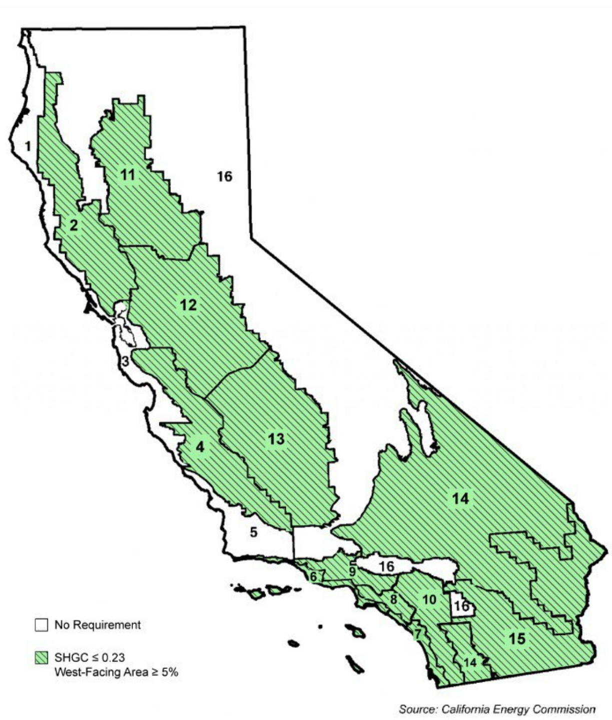
Table 3-2: Maximum U-Factors, SHGC, and Fenestration Area by Climate Zone in the Prescriptive Package

Climate Zone	1,3,5,16	2,4,11-14	6-10	15
Maximum Fenestration U-Factor	0.27*	0.27	0.30	0.30
Maximum Fenestration SHGC	NR	0.23	0.23	0.20
Maximum Fenestration Area	20%	20%	20%	20%
Maximum West-Facing Fenestration Area	NR	5%	5%	5%
Maximum Opaque Door U-Factor	0.20	0.20	0.20	0.20

***In Climate Zone 5, newly constructed homes with a conditioned floor area of 500 square feet or less may install U-0.30 windows.**

Source: California Energy Commission

Figure 3-2: Prescriptive Package, SHGC, and West-Facing Area Criteria by Climate Zone



Source: California Energy Commission

Fenestration and Opaque Door Prescriptive and Mandatory Exceptions

Glazed Doors

Any door that is more than 25 percent or greater glass is considered a glazed door and must comply with the mandatory requirements and other requirements applicable to a fenestration product. Up to 3 ft^2 of glass in a door is exempt from the U-factor and SHGC requirements (or can be considered equivalent to the prescriptive package values). The U-factor and SHGC shall be based on either the NFRC values for the entire door, including glass area, or use default values in Table 110.6-A for the U-factor and Table 110.6-B for the SGHC. If the door has less than 25 percent glazing, the glazing portion of the door is ignored in the prescriptive approach.

Tubular Daylighting Device (TDD)

In each dwelling unit, up to 3 ft^2 of tubular daylighting devices area with dual-pane diffusers at the ceiling are exempt from the prescriptive U-factor and SHGC requirements, where the TDD area is included in the maximum of 20 percent fenestration area. However, the U-factor shall not exceed a maximum of 0.40. See Section 150.0(q) and Exception 1 of Section 150.1(c)3A.

Opaque Doors

Opaque doors between the garage and conditioned space that are required to have fire protection are not required to meet the prescriptive U-factor requirement of 0.20. See Exception to Section 150.1(c)5.

Skylights

Each new dwelling unit in Climate Zones 2, 4, 6–15, may have up to 16 square feet of skylight area with a maximum 0.40 U-factor and a maximum SHGC of 0.30. The total area of skylights is included in the maximum of 20 percent fenestration area. In Climate Zones 1, 3, 5, and 16, there is no SHGC prescriptive requirement. See Exception 3 of Section 150.1(c)3A.

Aside from the specific exceptions to the fenestration prescriptive requirements, the area weight-averaged U-factor and SHGC must not exceed the U-factor specified in Table 150.1-A and cannot be greater than the SHGC specified in Table 150.1-A when large numbers of skylights are used for prescriptive compliance. Alternatively, the performance approach may be used to meet energy compliance.

Dynamic Glazing

If a dwelling unit includes a type of dynamic glazing that is electrochromatic, chromogenic, or an integrated shading device and the glazing is automatically controlled, use the lowest U-factor and lowest SHGC to determine compliance with prescriptive package fenestration requirements. Since this type of product has compliance ratings that vary, it cannot be weight-averaged with nonchromogenic products as per Exception 3 of Section 150.1(c)3A.

Site-Built Fenestration

When a dwelling unit contains a combination of manufactured and site-built fenestration, only the site-built fenestration values can be determined by using Reference Appendices, Nonresidential Appendix NA6. All fenestration, including site-built, can default to Table 110.6-A and Table 110.6-B.

Maximum Area

The prescriptive requirements limit total glass area to a maximum of 20 percent of the conditioned floor area in all climate zones.

Note: There are exceptions to the prescriptive requirements for alterations in Section 150.2(b)1A that allow additional glass area beyond the 20 percent limitation, including west-facing glass. See Chapter 9 for more information on alterations.

Greenhouse Windows/Garden Windows

Compared to other fenestration products, the NFRC-rated U-factor for greenhouse windows are comparatively high. Section 150.0(q) includes an exception from the U-factor requirement for dual-glazed greenhouse or garden windows that total up to 30 ft^2 of fenestration area.

Prescriptive Credit for Exterior Shading Devices Section 150.1(c)4

Please refer to Chapter 3.3.5.2 of the *2022 Single-Family Residential Compliance Manual*.

Fenestration in the Performance Approach Section 150.1(b)

Please refer to Chapter 3.3.6 of the *2022 Single-Family Residential Compliance Manual*.

Fenestration Area and Orientation

The performance approach includes consideration of the fenestration area and orientation, which can have a big effect on energy use. Compliance is determined by comparing the proposed fenestration to the standard design fenestration.

For buildings with glazing areas less than or equal to 20 percent of the conditioned floor area (CFA), the standard design fenestration fora newly constructed building is modeled with the same glazing area as the proposed home with one-quarter of the window area on the north, east, south, and west orientations.

For buildings with more than 20 percent of the CFA, the standard design is limited to 20 percent glass area.

The effects of orientation, the fenestration product performance levels and other building features like overhangs, judging the particular area, orientation, and performance level should be considered when determining performance approach calculations.

Improved Fenestration Performance

The fenestration weighted average U-factor in the standard design for newly constructed buildings is 0.27 in Climate Zones 1 through 5, 11–14, and 16, and is 0.30 in all other climate zone. Choosing high-performance fenestration that performs better than the prescriptive requirements level can earn significant credit through the performance method. For example, in warmer climates (e.g., Climate Zones 8–15), choosing a window with a lower SHGC can reduce the cooling loads compared to the standard design. In colder climates (e.g., Climate Zones 1, 3, 5 and 16) where there are no prescriptive SHGC requirements, choosing a window with an SHGC of 0.35 or lower can increase the heating loads compared to the standard design.

The magnitude of the effect will vary by climate zone. In mild coastal climates, the benefit from reducing fenestration U-factor will be smaller than in cold, mountain climates. Several factors affect window performance. For fenestration with NFRC ratings, the following performance features are accounted for in the U-factor and SHGC ratings:

- Frame materials, design, and configuration (including cross-sectional characteristics). Fenestration can be framed in many materials. The most common include wood, aluminum, vinyl, fiberglass, or composites of these materials. Frames made of low-conductance materials like wood, vinyl, and fiberglass are better insulators than metal. Some aluminum-framed units have thermal breaks that reduce the conductive heat transfer through the framing element compared with similar units having no such conductive thermal break.
- Number of panes of glazing, low-emissivity coatings, tints, fill gases, cavity dimensions, and spacer construction. Windows compliant with the prescriptive requirements are likely to have at least double-glazing with a low-emissivity coating and argon gas fill with an improved spacer. The choice of low-emissivity coating is particularly important as cooling climates will generally benefit from a low SHGC coating, while heating climates may benefit from a high SHGC coating. There are many ways to improve performance beyond the prescriptive levels. Adding glazing layers such as triple glazing and low-emissivity coatings such as those facing the conditioned space are two likely improvements.

Dynamic glazing with appropriate controls may also offer opportunities for improving performance.

Fixed Permanent Shading Devices

Please refer to Chapter 3.3.6.3 of the *2022 Single-Family Residential Compliance Manual*.

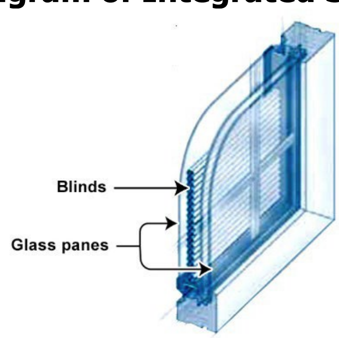
Interior Shading Devices

Please refer to Chapter 3.3.6.4 of the *2022 Single-Family Residential Compliance Manual*.

Dynamic Glazing

Dynamic glazing products are either integrated shading systems or electrochromatic devices and are considered a fenestration product.

Figure 3-3: Diagram of Integrated Shading System



Source: NFRC Dynamic Glazing Products Fact Sheet

Integrated shading systems. These systems include blinds positioned between glass panes that can be opened and closed using automatic controls. See Figure 3-5.

The labels for integrated shading systems will reflect the endpoints of the product performance for U-factor and SHGC (Figure 3-4: Example of Integrated Shading System NFRC Label). The unique rating "variable arrow" identifier helps consumers understand the "dynamics" of the product and allows comparison with other similar dynamic fenestration products.

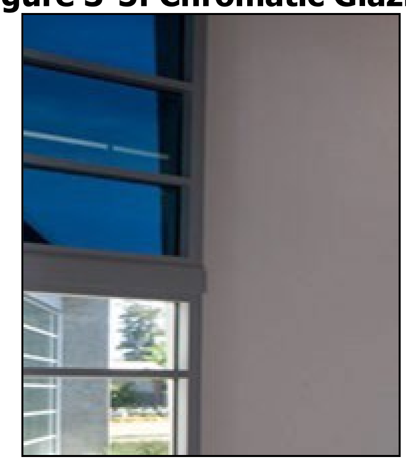
If the fenestration product can operate at intermediate states, a dual directional arrow (↔) with the word "Variable" will appear on the label. Some dynamic glazing can adjust to intermediate states, allowing for a performance level between the endpoints.

Figure 3-4: Example of Integrated Shading System NFRC Label

Source: NFRC Dynamic Glazing Products Fact Sheet

In Figure 3-4: Example of Integrated Shading System NFRC Label, the low value rating is displayed to the left (in the closed or darker position), and the high value rating is displayed to the right (in the open or lighter position). These value ratings let the consumer know at a glance the best and worst case performance of the product and the default performance level. To use the high-performance values for integrated shading systems, the product must have an NFRC Certified Label sticker. Otherwise, the default values from Tables 110.6-A and 110.6-B must be used.

Figure 3-5: Chromatic Glazing



Source: Sage Electrochromics

Chromatic glazing. One type of dynamic glazing product uses a chromatic type of glass that can change the performance properties, allowing occupants to control their environment manually or automatically by tinting or darkening a glass with the flip of a switch. Some fenestration products can change performance automatically with the use of an automatic control or environmental signals. These high-performance windows can reduce energy costs because of controlled daylighting and unwanted heat gain or heat loss.

A view of chromatic glazing in the open (off) and closed (on) position is shown in Figure 3-5: Chromatic Glazing. Best-rated performance values may be used for compliance with an NFRC Certified Label sticker and when automatic controls are installed.

- If the window includes either an NFRC label or automatic controls, but not both, then default to Table 150.1-A maximum U-factors and maximum SHGC values.

If neither an NFRC label nor automatic controls are included, then the default values from Tables 110.6-A and 110.6-B of the Energy Code must be used.

Window Films Section 150.1(b)
Please refer to Chapter 3.3.6.6 of the *2022 Single-Family Residential Compliance Manual*.

Bay Windows Section 150.1(b)
Please refer to Chapter 3.3.6.7 of the *2022 Single-Family Residential Compliance Manual*.

Opaque Envelope

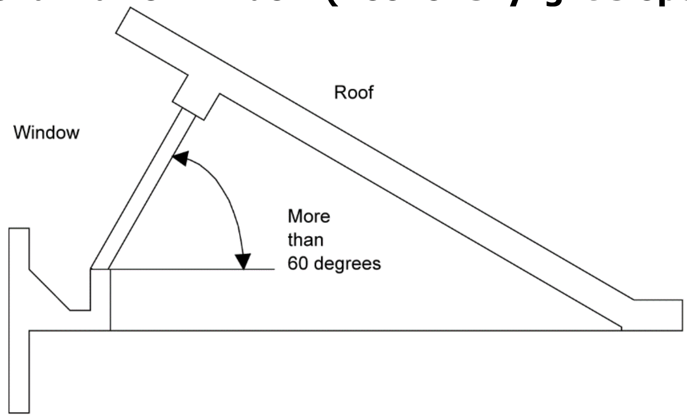
Please refer to Chapter 3.4 of the *2022 Single-Family Residential Compliance Manual*.

Opaque Envelope Definitions

Opaque elements of the building envelope significantly contribute to the related energy efficiency. Components of the building envelope include walls, floors, soffits, roofs, and ceilings. Envelope and other building components definitions are listed in Section 100.1(b) of the Energy Code and the Reference Appendices, Joint Appendix JA1.

- The *exterior partition* is an opaque, translucent, or transparent solid barrier that separates conditioned space from ambient air or unconditioned space.
- The *demising partition* is a wall, fenestration, floor, or ceiling that separates conditioned space from enclosed unconditioned space.
- The *conditioned space* is an enclosed space within a building that is either directly conditioned or indirectly conditioned.
- *Unconditioned space* is enclosed space within a building that is neither directly conditioned nor indirectly conditioned.
- *Plenum* is an air compartment or chamber, including uninhabited crawl space, areas above a ceiling or below a floor, or attic spaces, to which one or more ducts are connected and that forms part of either the supply-air, return-air, or exhaust air system, other than the occupied space being conditioned.
- *Attic* is an enclosed space directly below the roof deck and above the ceiling.
- Sloping surfaces are considered either a wall or a roof, depending on the slope. (See Figure 3-6: Slope of a Wall or Window (Roof or Skylight Slope Is Less Than 60°).) If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including windows in walls and any skylight types in roofs.

Figure 3-6: Slope of a Wall or Window (Roof or Skylight Slope Is Less Than 60°)



Source: California Energy Commission

- The *exterior roof* is an exterior partition that has a slope less than 60 degrees from horizontal, that has conditioned space below, and that is not an exterior door or skylight.
- The *roof deck* is the surface that supports the roofing material. Typically made of plywood or OSB, it is supported by the roof framing members such as rafters or trusses.
- *Exterior floor/soffit* is a horizontal exterior partition, or a horizontal demising partition, under conditioned space.
- *Vapor retarder* or *vapor barrier* is a material or assembly designed to limit the amount of vapor moisture that passes through that material or assembly.
- *Roofing products* are the top layer of the roof that is exposed to the outside, which has properties including, but not limited to, solar reflectance, thermal emittance, and mass.
- *Cool roof* is a roofing material with high thermal emittance and high solar reflectance, or low thermal emittance and exceptionally high solar reflectance, as specified in Part 6, that reduces heat gain through the roof.
- *Solar reflectance* is the fraction of solar energy that is reflected by the roof surface.
- *Thermal emittance* is the fraction of thermal energy that is emitted from the roof surface.
- A *low-sloped roof* is a surface with a pitch less than 2:12 (less than 9.5 degrees from the horizon).
- A *steep-sloped roof* is a surface with a pitch greater than or equal to 2:12 (9.5 degrees or greater from the horizontal).
- *Air leakage* is a measurement of heat loss and gain by infiltration and exfiltration through gaps and cracks in the envelope.
- *Infiltration* is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It can be a major component of heating and cooling loads. Infiltration can occur through holes and cracks in the building envelope and around doors and fenestration framing areas. Reducing infiltration in the building envelope can result in significant energy savings, especially in climates with severe winter and summer conditions. It also can result in improved occupant comfort, reduced moisture intrusion, and fewer air pollutants. Infiltration is balanced with an equal amount of exfiltration.

- *Exfiltration* is uncontrolled outward air leakage from inside a building, including leakage through cracks, joints, and intersections; around windows and doors; and through any other exterior partition or duct penetration. Exfiltration is balanced by an equal amount of infiltration.
- *Ventilation* is the *intentional* replacement of conditioned air with unconditioned air through open windows and skylights or mechanical systems.

Air Sealing and Air Leakage Section 110.7, Section 150.0

Joints and Other Openings Section 110.7

Please refer to Chapter 3.4.2.1 of the *2022 Single-Family Residential Compliance Manual*.

Fireplaces, Decorative Gas Appliances, and Gas Logs Section 150.0(e)

Please refer to Chapter 3.4.2.2 of the *2022 Single-Family Residential Compliance Manual*.

Roofing Products Section 10-113, Section 110.8(i), Section 150.1(c)11

Please refer to Chapter 3.4.3 of the *2022 Single-Family Residential Compliance Manual*.

Product Labels Section 10-113

Figure 3-7: Sample CRRC Product Label and Information shows a sample Cool Roof Rating Council product label. The label includes solar reflectance and thermal emittance values.

Figure 3-7: Sample CRRC Product Label and Information

CRRC
COOL ROOF RATING COUNCIL ®

	Initial	Weathered
Solar Reflectance	0.00	Pending
Thermal Emittance	0.00	Pending

Rated Product ID Number	_ _ _ _
Licensed Seller ID Number	_ _ _ _
Classification	Production Line

Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary.

Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.

Source: Cool Roof Rating Council

Solar reflectance and thermal emittance are measured from 0 to 1; the higher the value, the "cooler" the roof. There are numerous roofing materials in a wide range of colors that have adequate cool roof properties. Reducing heat gains through the roof will reduce the cooling load of the home, resulting in reduced air-conditioned energy needed to maintain occupant comfort. High-emitting roof surfaces reject absorbed heat quickly (upward and out of the building) than roof surfaces with low- emitting properties.

Solar reflectance (SR). There are three solar reflectance measurements:

- Initial solar reflectance
- Three-year aged solar reflectance
- Accelerated aged solar reflectance

All requirements of the Energy Code are based on the three-year aged solar reflectance (SR). If the aged SR value is not available in the CRRC's Rated Product Directory, then the aged value shall be derived from the CRRC aged value equation (using the initial value for solar reflectance) or an accelerated process. Until the appropriate aged-rated value for the reflectance is posted in the directory, the equation below can be used to calculate the aged rated solar reflectance, or a new method of testing is used to find the accelerated solar reflectance.

Calculating Aged Solar Reflectance from Initial Reflectance

$$Aged\ Reflectance = 0.2 + \beta \times (\rho_{initial} - 0.2)$$

Where,

- $\rho_{initial}$ = Initial reflectance listed in the CRRC rated product directory
- β = soiling resistance is 0.65 for field applied coating or 0.70 for other

Thermal emittance (TE). The Energy Code does not distinguish between initial and aged thermal emittance, meaning either value can be used to demonstrate compliance with the Energy Code.

Note for contractors/installers: What is the solar reflectance index (SRI)?

An alternative to the aged solar reflectance and thermal emittance required values is to use the solar reflectance index (SRI) to show compliance. A calculation worksheet is available to calculate the SRI by inputting the three-year aged solar reflectance and thermal emittance of the desired roofing material.

The calculation worksheet can be found at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency.

By using the SRI alternative, a cool roof may comply with a lower emittance, as long as the aged reflectance is higher, and vice versa.

Example 3-10: ENERGY STAR® Roofing Products

Question:

I am a salesperson who represents several roofing products. Many of them are on the ENERGY STAR® list published by the U.S. Environmental Protection Agency (EPA) for cool roofing materials. Is this sufficient to meet the Energy Code?

Answer:

No. ENERGY STAR has different requirements than the Energy Code for reflectance and no requirements for emittance. Per Section 10-113, the Cool Roof Rating Council (www.coolroofs.org) is the only entity recognized by the California Energy Commission to determine what qualifies as a cool roof.

Example 3-11: Certifying Products With the Cool Roof Rating Council (CRRC)

Question:

How does a product get CRRC cool roof certification?

Answer:

CRRC publishes its certification procedures in the CRRC-1 Program Manual, available for free at www.coolroofs.org or by calling CRRC at (866) 465-2523 (toll free within the USA) or (510) 485-7176. Anyone new to the certification process and wishing to have one or more products certified should contact CRRC by phone or by email at info@coolroofs.org. Working with CRRC is strongly recommended; staff walks interested parties through the procedures.

Example 3-12: Reflectance vs. Emittance

Question:

I understand reflectance, but what is emittance?

Answer:

Material that reflects the sun's energy will still absorb some of that energy as heat; there are no perfectly reflecting materials being used for roofing. The absorbed heat is given off (emitted) to the environment in varying amounts depending on the materials and surface types. This emittance is given a value between 0 and 1, and this value represents a comparison (ratio) between what a given material or surface emits and what a perfect blackbody emitter would emit at the same temperature.

A higher emittance value means more energy is released from the material or surface; scientists refer to this emitted energy as *thermal radiation*. *Emittance* is a measure of the relative efficiency with which a material, surface, or body can cool itself by radiation.

Lower-emitting materials become relatively hotter due to holding in heat. Roof materials with low emittance hold onto more solar energy as heat, and that held heat can be given off downward into the building. More heat in the building increases the need for air conditioning for comfort. A cool roof system that reflects solar radiation (has high reflectance) and emits thermal radiation well (has high emittance) will result in a cooler roof and a cooler building with lower air-conditioning costs.

Mandatory Requirements

Please refer to Chapter 3.4.3.2 of the *2022 Single-Family Residential Compliance Manual*.

Prescriptive Requirements Section 150.1(c)11

Steep-sloped and low-sloped energy-efficient cool roofs are prescriptively required in some climate zones. The prescriptive requirement is based on an aged solar reflectance and thermal emittance tested value from the Cool Roof Rating Council (CRRC). If a cool roof is being installed to comply with the Energy Code, it must meet mandatory product and labeling requirements.

Table 3-3: Prescriptive Cool Roof Requirements

Roof Type	Climate Zone	Minimum Three-Year Aged Solar Reflectance	Minimum Thermal Emittance	Minimum SRI
Steep-sloped	10 through 15	0.20	0.75	16
Low-sloped	13 and 15	0.63	0.75	75

Source: California Energy Commission

There are two exceptions to meeting these prescriptive requirements:

- Roof area with building-integrated photovoltaic panels or building-integrated solar thermal panels. *Building-integrated photovoltaics* are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades.
- Roof constructions that have a weight of at least 25 lb/ft².

The project could choose to pursue the performance approach and trade off the prescriptive cool roof requirements. See Opaque Envelope in the Performance Approach and Chapter 8 for more on the performance approach.

Compliance and Enforcement

Please refer to Chapter 3.4.3.4 of the *2022 Single-Family Residential Compliance Manual*.

Radiant Barriers Section 110.8(j), Section 150.1(c)2

Please refer to Chapter 3.4.4 of the *2022 Single-Family Residential Compliance Manual*.

Mandatory Requirements Section 110.8(j)

Please refer to Chapter 3.4.4.1 of the *2022 Single-Family Residential Compliance Manual*.

Prescriptive Requirements Section 150.1(c)2, RA4.2.1

The prescriptive requirements call for a radiant barrier under Option C for vented attics in Climate Zones 2–15. The same requirement applies to cathedral ceilings under Option C if an air gap is present between the roof deck and the roof insulation. Option B vented attics only require a radiant barrier in Climate Zones 2, 3, and 5–7. There also needs to be ventilation to the outside to reduce moisture effects on the deck.

Installation. The most common way of meeting the radiant barrier requirement is to use roof sheathing that has a radiant barrier bonded to it by the manufacturer. Some oriented strand board (OSB) products have a factory-applied radiant barrier. The sheathing is installed with the radiant barrier (shiny side) facing down toward the attic space.

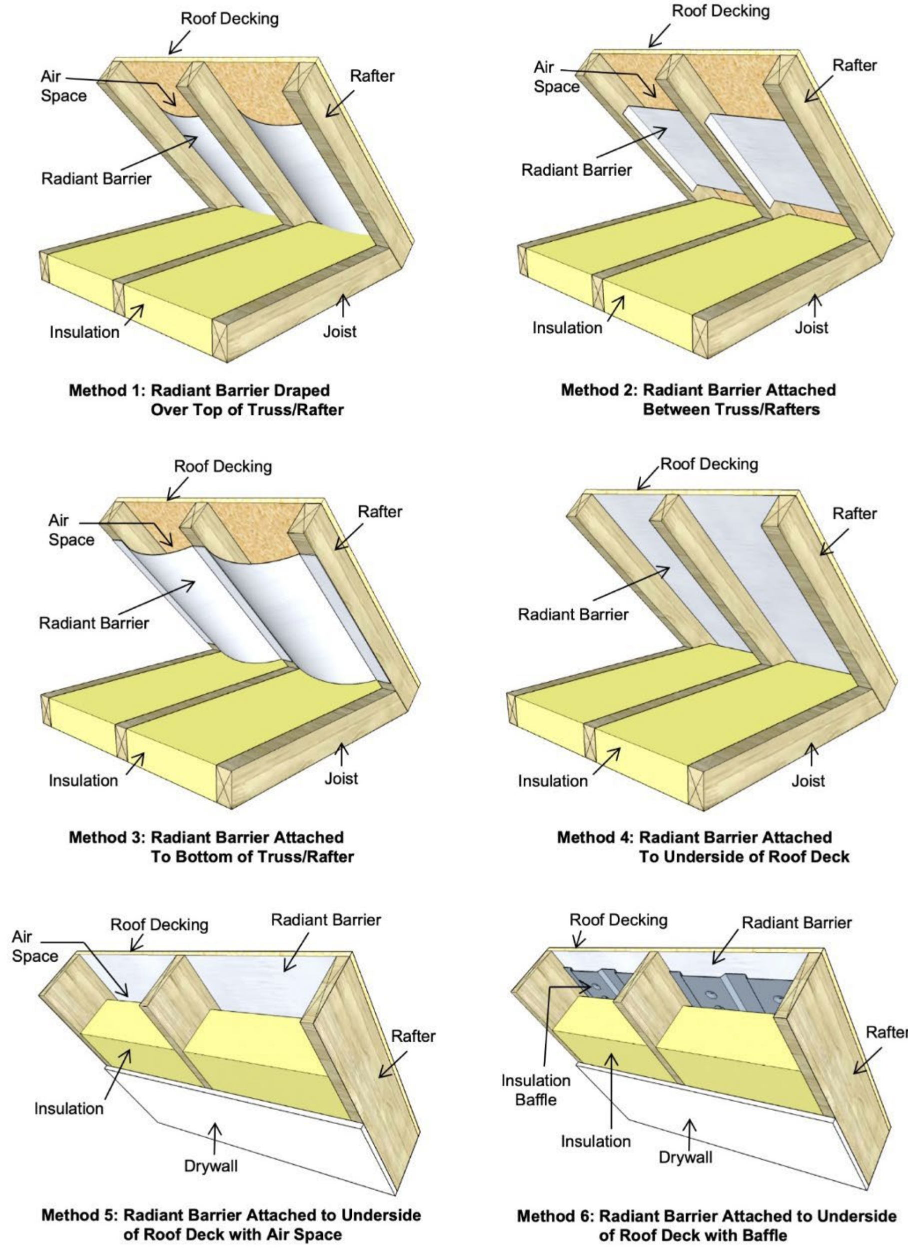
Alternatively, a radiant barrier material that meets the same ASTM test and moisture perforation requirements that apply to factory-laminated foil can be field-laminated. Field lamination must use a secure mechanical means of holding the foil-type material to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material. Roofs with gable ends must have a radiant barrier installed on the gable ends to meet the radiant barrier requirement.

Other acceptable methods are to drape a foil type radiant barrier over the top of the top chords before the sheathing is installed, stapling the radiant barrier between the top chords after the sheathing is installed, and stapling the radiant barrier to the underside of the truss/rafters (top chord). For these installation methods, the foil must be installed with spacing requirements as described in Reference Appendices, Residential Appendix RA4.2.1.

Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces, particularly when roof sheathing is installed that does not include a laminated foil-type radiant barrier. Radiant barrier foil material may be field-laminated after the sheathing has been installed by "laminating" the foil to the roof sheathing between framing members. This construction type is described in the Reference Appendices, Residential Appendix RA4.2.1.1. See Figure 3-8: Methods of Installation for Radiant Barriers for drawings of radiant barrier installation methods.

For closed rafter spaces, such as a cathedral ceiling, the required air space for radiant barriers shall be provided and must meet the ventilation requirements of California Residential Code (CRC), Title 24, Part 2.5, Section R806.1.

Figure 3-8: Methods of Installation for Radiant Barriers



Source: California Energy Commission

Radiant Barriers in the Performance Approach

In the performance approach, radiant barriers are modeled apart from the U-factor. The duct efficiency also is affected by the presence of a radiant barrier when using the performance approach. See more in Opaque Envelope in the Performance Approach and Chapter 8.

Vapor Retarder Section 150.0(g) and RA4.5.1

When is a vapor retarder required?

In Climate Zones 14 and 16, a continuous Class I or Class II vapor retarder, lapped or joint sealed, must be installed on the conditioned-space side of all insulation in all exterior walls, on the roof decks of vented attics with above-deck or below-deck air-permeable insulation, and in unvented attics with air-permeable insulation.

Buildings that are unvented in all climates zones must have a Class I or Class II vapor retarder placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with Reference Appendices, Residential Appendix RA4.5.1.

Product Requirements

Please refer to Chapter 3.4.5.1 of the *2022 Single-Family Residential Compliance Manual*.

Insulation Products

The Energy Code encourages the use of energy-saving techniques and designs for showing compliance. Insulation is one of the least expensive requirements to improve building energy efficiency. Insulation requires no maintenance, helps improve indoor comfort, and provides excellent sound control. Adding extra insulation later is more expensive than maximizing insulation levels at the beginning of construction. Innovative construction techniques and building products are being used more often by designers and builders who recognize the value of energy-efficient, high-performance buildings.

When the performance compliance method is used, an energy credit can be taken for design strategies that reduce building energy use below the standard design energy budget (compliance credit). Some strategies may require third-party verification by an Energy Code Compliance (ECC)-Rater; others do not. For more on the performance method, see Opaque Envelope in the Performance Approach and Chapter 8.

Table 3-4: Relevant Sections in the Energy Code

	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Insulation	Section 110.8(a) - (d), Section 110.8(g) - (h), Section 150.0(a) - (d), Section 150.0(f)	Section 150.1(c)1 Table 150.1-A	Section 150.1(a), Section 150.1(b)

Source: California Energy Commission

Types of Insulation Products

Please refer to Chapter 3.5.1 of the *2022 Single-Family Residential Compliance Manual*.

Batt and Blanket

Please refer to Chapter 3.5.1.1 of the *2022 Single-Family Residential Compliance Manual*.

Loose-Fill Insulation

Please refer to Chapter 3.5.1.2 of the *2022 Single-Family Residential Compliance Manual*.

Spray Polyurethane Foam (SPF)

Please refer to Chapter 3.5.1.3 of the *2022 Single-Family Residential Compliance Manual*.

Rigid Insulation

Rigid board insulation sheathing is made from fiberglass, mineral wool, expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate (ISO), or polyurethane (PUR). It varies in thickness, and some products can provide up to R-6 per inch of thickness.

Figure 3-9: Properly Installed Rigid Insulation With Sealant Tape

Source: U.S. Environmental Protection Agency

This type of insulation is used for above-roof decks, exterior walls, cathedral ceilings, basement walls; as perimeter insulation at concrete slab edges; and to insulate special framing situations such as window and door headers and around metal seismic bracing. Rigid board insulation may also be integral to exterior siding materials. Properly sealed rigid insulation can be used continuously across an envelope surface to reduce air infiltration and exfiltration and thermal bridging at framing.

Note for contractors/installers: Proper installation of continuous rigid insulation may include button cap nails, furring strips, flashing, sealant tape, and design of the drainage plane. See Figure 3-9: Properly Installed Rigid Insulation With Sealant Tape.

The 2025 California Residential Code (CRC) provides guidance on fastener penetration depth, diameter, and spacing for exterior foam sheathing in Section R703.15.

Insulation Product Requirements Section 110.8(a)

Please refer to Chapter 3.5.2 of the *2022 Single-Family Residential Compliance Manual*.

Urea Formaldehyde Foam Insulation Section 110.8(b)

Please refer to Chapter 3.5.2.1 of the *2022 Single-Family Residential Compliance Manual*.

Flame Spread Rating of Insulation Section 110.8(c)

Please refer to Chapter 3.5.2.2 of the *2022 Single-Family Residential Compliance Manual*.

Ceiling and Roof Insulation Section 110.8(d), Section 150(a)

Loose Fill Insulation in the Attic Section 150.0(b)

Please refer to Chapter 3.5.3.1 of the *2022 Single-Family Residential Compliance Manual*.

Wet Insulation Systems Section 110.8(h)

Please refer to Chapter 3.5.3.2 of the *2022 Single-Family Residential Compliance Manual*.

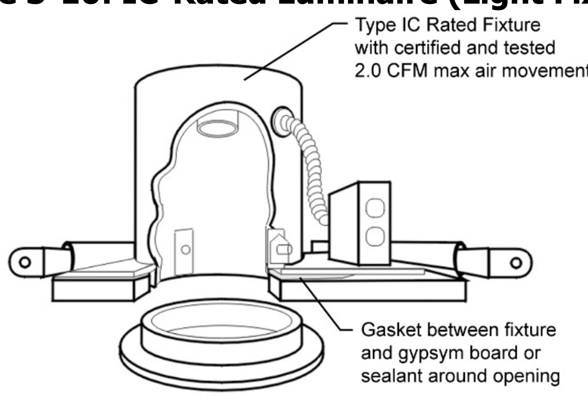
Recessed Luminaires Section 150.0(k)1C

Luminaires recessed in ceilings can create thermal bridging through the assembly. Not only does this degrade the performance of the ceiling assembly, but it can permit condensation on a cold surface of the luminaire if exposed to moist air, as in a bathroom. Refer to the Lighting Chapter 6 for more information regarding the applicable requirements for recessed luminaires.

Luminaires recessed in ceilings must meet three requirements.

- They must be listed as defined in the Article 100 of the California Electric Code for zero clearance insulation contact (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Code Council (ICC). This enables insulation to be in direct contact with the luminaire.
- The luminaire must have a label certified as per Section 150.0(k)1Cii for airtight (AT) construction. Airtight construction means that leakage through the luminaire will not exceed 2.0 cfm when exposed to a 75 Pa pressure difference, when tested in accordance with ASTM E283.
- The luminaire must be sealed with a gasket or caulk between the housing and ceiling.

Figure 3-10: IC-Rated Luminaire (Light Fixture)



Source: California Energy Commission

Mandatory Requirements

Wood-framed roof/ceiling construction assemblies must have at least R-22 insulation or a maximum U-factor of 0.043 based on 16-inch-on-center wood-framed rafter roofs, as determined from Reference Appendices, Joint Appendix JA4. Some areas of the roof/ceiling can be greater than the maximum U-factor if other areas have a U-factor lower than the requirement and the weighted average U-factor for the overall ceiling/roof is 0.043 or less.

Metal-framed and roof/ceiling constructions other than wood-framed must have a U-factor of 0.043 or less to comply with the mandatory requirement. If the insulation is not penetrated by framing, such as rigid insulation laid over a structural deck, then the rigid insulation can actually have a rated R-value of less than R-22 so long as the total roof/ceiling assembly U-factor is not greater than U-0.043.

Newly constructed attics above conditioned space must have roof deck insulation in Climate Zones 4 and 8–16. Insulation may either be above or below the roof deck so long as the area-weighted average U-factor of the roof assembly is not greater than 0.184. This is equivalent to

R-3 or R-4 insulation depending on the location of the insulation (above or below the roof deck) and the roof type. See Table 3-5: Examples of Wood-Framed Roof Assemblies and U-Factors, Assuming a Vented Attic for examples of assemblies that can be constructed to meet the requirement.

Exceptions to the mandatory roof deck insulation include:

- If the space-conditioning system air handler and ducts are located entirely in conditioned space below the ceiling separating occupiable space from the attic. (NOTE: Duct systems located in conditioned space can be uninsulated if specific conditions are met, as explained in Section 4.4.1 (Section 150.0(m)1B))
- If no greater than 12 linear feet of supply duct, including the air handler and plenum, are located in unconditioned space with all other portions of the supply ducts located in conditioned space below the ceiling separating the occupiable space from the attic.
- The space-conditioning system is ductless.
- Space-conditioning ducts system are buried within insulation in an attic that complies using Section 150.1(b) and is verified according to RA 3.1.4.1.

Table 3-5: Examples of Wood-Framed Roof Assemblies and U-Factors, Assuming a Vented Attic

Roofing	Above Deck Continuous Insulation	Below Deck Cavity Insulation	U-Factor[1]
Tile (10 PSF w/ airgap)	R-3	n/a	0.180
Tile (10 PSF w/ airgap)	n/a	R-3	0.184
Tile (10 PSF no airgap)	R-4	n/a	0.175
Tile (10 PSF no airgap)	n/a	R-4	0.181
Asphalt Shingle	R-4	n/a	0.178
Asphalt Shingle	n/a	R-4	0.184
Metal Tile	R-3	n/a	0.182
Metal Tile	n/a	R-4	0.159

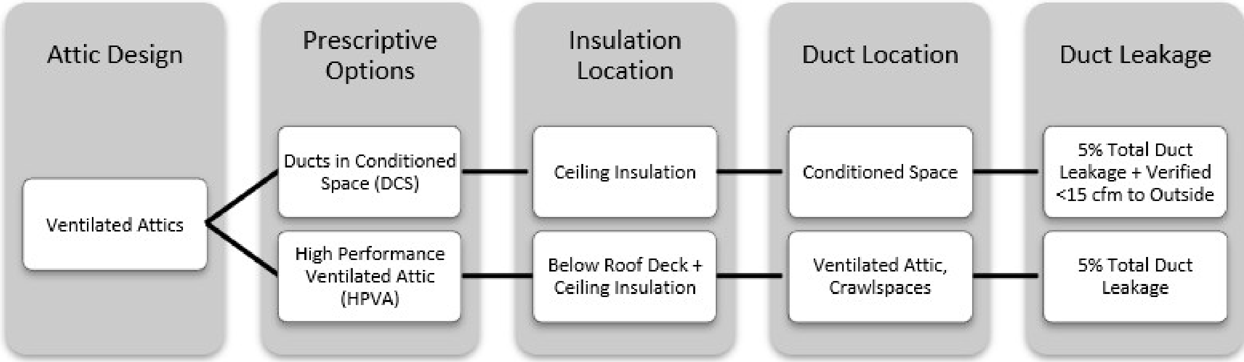
1. **U-factor based on 2x4 at 24 inch on-center roof framing.**

Source: California Energy Commission

Prescriptive Requirements Section 150.1(c) and Table 150.1-A

The 2025 Energy Code is designed to offer flexibility to the builders and designers of residential newly constructed buildings in terms of achieving the intended energy efficiency targets. As such, the Energy Code offers several options for achieving one of two design objectives related to improving energy performance of homes built with ventilated attics in Climate Zones 4, 8-16, as shown in Figure 3-11: Ventilated Attic Prescriptive Compliance Choices.

Figure 3-11: Ventilated Attic Prescriptive Compliance Choices



Source: California Energy Commission

High-performance ventilated attic (HPVA). This approach reduces temperature differences between the attic space and the conditioned air being transported through ductwork in the attic. The package consists of insulation below the roof deck (Option B) in addition to insulation at the ceiling, R-6 or R-8 ducts, and 5 percent total duct leakage of the nominal air handler airflow.

Ducts in conditioned space (DCS). Ducts and air handlers are within the thermal and air barrier envelope of the building.

Note for contractors/installers: The ducts in conditioned space (Option C) requires field verification by a ECC Rater to meet the prescriptive requirement.

All the prescriptive requirements for HPVA or DCS are based on the assumption that the home is built with the following construction practices:

- The attic is ventilated with an appropriate free vent area as described below.
    - The roof is constructed with standard wood rafters and trusses.
    - For HPVA, the outermost layer of the roof construction is either tiles or a roofing product installed with an air gap between it and the roof deck.
    - The air handler and ducts are in the ventilated attic for HPVA and are in conditioned space for DCS.
- The air barrier is located at the ceiling.

If a building design does not meet all of these specifications, it must comply through the performance approach.

Example 3-13: Cathedral Ceilings

Question:

If 5 percent of a roof will be a cathedral ceiling, can it still comply under the prescriptive requirements?

Answer:

Yes. The 2025 Energy Code adds a prescriptive alternative for cathedral ceilings under Option C. In all climate zones, a cathedral ceiling will comply with R-38 cavity insulation.

Example 3-14: Unventilated Attics

Question:

Does an unventilated attic with insulation at the roof deck comply under the prescriptive requirements?

Answer:

No. The entire attic must be a ventilated space with the building air barrier located at the ceiling with standard wood rafter trusses to comply with the prescriptive requirements. This project must comply through the performance approach.

Example 3-15: Insulation Above the Roof Deck

Question:

Does a ventilated attic with insulation above the roof deck comply under the prescriptive requirements?

Answer:

No. The insulation must be located below the roof deck between the roof rafters to comply with the prescriptive requirements. If insulation is above the roof deck, the project must comply through the performance approach.

Example 3-16: Asphalt Shingles

Question:

A home with asphalt shingle roofing, having no air gap, has a ventilated attic with insulation installed below the roof deck between the roof rafters (HPVA) and at the ceiling meeting prescriptive insulation levels. Does this home comply with the prescriptive requirements?

Answer:

No. The roofing product must be of a type that is installed with an air gap between the product and the roof deck, such as concrete tile, or have an air gap built into the assembly between the product and the roof deck to comply with the prescriptive requirements. If a roofing product with no air gap between the product and the roof deck is installed, the project must comply through the performance approach.

Example 3-17: Gable Ends in High Performance Ventilated Attics

Question:

In addition to the roof underdeck, do gable end walls in high performance ventilated attics (HPVA) need to be insulated?

Answer:

No. Gable end walls do not need to be insulated when designing and installing a HPVA.

Example 3-18: Attic Insulation Placement

Question:

When installing roof/ceiling insulation, does the insulation need to be installed on the entire roof/ceiling, including areas over unconditioned space?

Answer:

It depends. The insulation should be installed at the roof/ceiling in one of the following ways:

- If the attic is an open or undivided space, then the entire roof/ceiling should be insulated. This includes portions of the roof/ceiling over an unconditioned space such as a garage.
- If the attic has a continuous air barrier separating the attic over unconditioned space from the attic over conditioned space, then only the portions of the roof/ceiling over conditioned space should be insulated. It is recommended, but not required, that the air barrier also be insulated.

High Performance Ventilated Attics Section 150.1(c).1

This section describes the prescriptive requirements and approaches necessary for HPVA as they relate to roof/ceiling insulation. HVAC aspects of the HPVA including duct insulation and duct leakage are described in Chapter 4. Requirements and approaches to meet the ducts in conditioned space (DCS) are described in Chapter 4 of this manual.

Section 150.1(c).1 requires different values of roof and ceiling insulation, depending on whether the HPVA (Option B) or DCS (Option C) is chosen. Table 3-6: Prescriptive Insulation Options shows a prescriptive requirements checklist for each option based on Tables 150.1-A. For additions and alterations please see chapter 9.

Table 3-6: Prescriptive Insulation Options

High Performance Ventilated Attics Option B1	Ducts in Conditioned Space Option C
R-19 (CZ 4, 8 – 16) below roof deck batt, spray in cellulose/fiberglass secured with netting, or spray foam R-38 (CZ 1, 2, 4, 8 – 16) ceiling insulation or R-30 (CZ 3, 5 – 7) Radiant barrier (CZ 2, 3, 5 – 7) Air space between roofing and the roof deck R-6 or R-8 duct insulation (climate zone specific) 5% total duct leakage	<u>Vented attic</u> R-38 (CZ 1, 8 – 16) ceiling insulation or R-30 (CZ 2 – 7) R-6 or R-8 ducts (climate zone-specific) Radiant barrier (CZ 2 – 15) Air space between roofing and the roof deck ECC-verified ducts in conditioned space (5% Total Duct Leakage + Verified <25 cfm to Outside) <u>Cathedral Ceiling</u> R-38 roof deck insulation in all climate zones

	ECC-verified ducts in conditioned space (5% Total Duct Leakage + Verified <25 cfm to Outside)
Table 150.1-A Assembly Option B	Table 150.1-A Assembly Option C

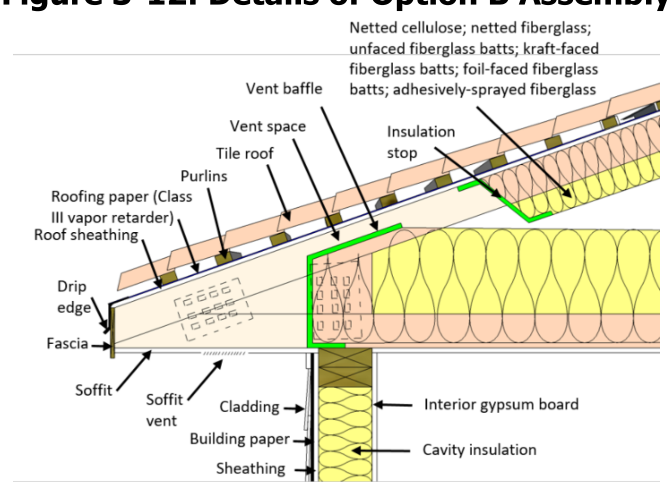
Note: 1 Option B is the standard design used to set the energy budget for the performance approach.

Source: California Energy Commission

Below Roof Deck Insulation Option B. In a vented attic, air-permeable or air- impermeable insulation (batt, spray foam, loose-fill cellulose, or fiberglass) should be placed directly below the roof deck between the truss members and secured in place to provide a thermal break for the attic space. Insulation must be in direct contact with the roof deck and secured by the insulation adhesion, facing, mechanical fasteners, wire systems, a membrane material, or netting. Batts supported with cabling or other mechanical methods from below shall have supports that are less than or equal to 16" apart and no farther than 8" from the end of the batt.

- When batt thickness exceeds the depth of the roof framing members, full-width batts must be used to fit snugly and allow batts to expand beyond the framing members. Full coverage of the top chord framing members by insulation is recommended as best practice but is not required.

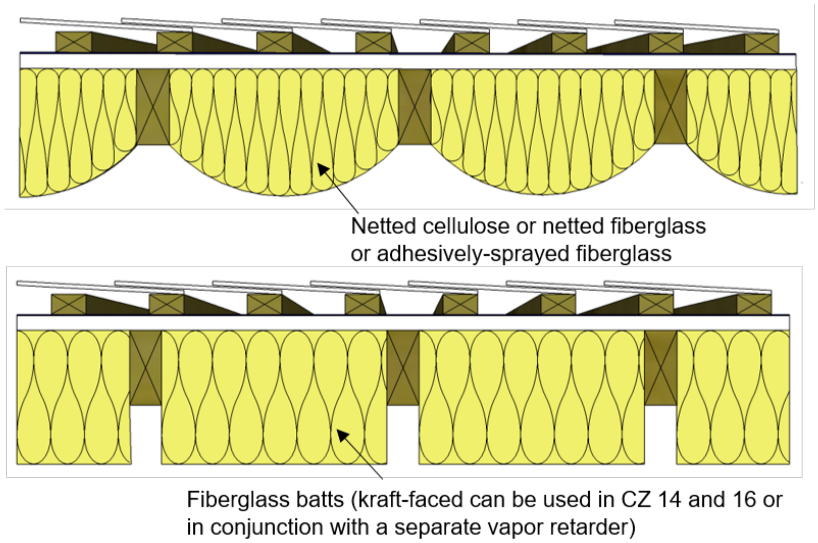
Figure 3-12: Details of Option B Assembly



Note: In order to comply with CRC 806.3, where eave or cornice vents are installed, blocking, bridging and insulation shall not block the free flow of air. Not less than a 1-inch (25 mm) space shall be provided between the insulation and the roof sheathing and at the location of the vent.

Source: California Energy Commission

Figure 3-13: Placement of Insulation Below the Roof Deck



Source: California Energy Commission

When insulation is installed below the roof deck to meet the prescriptive requirements of Option B, a radiant barrier is not required. However, a draped radiant barrier may be installed to receive performance credit.

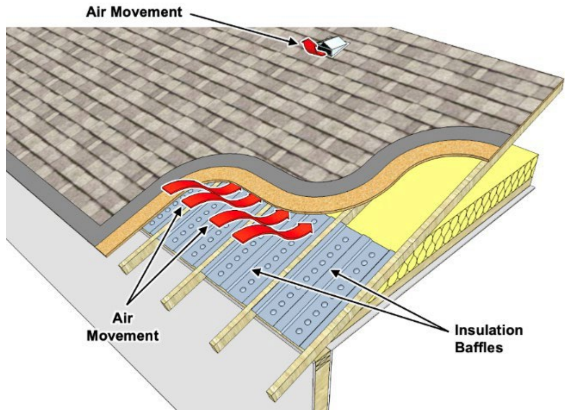
Vapor Retarders (Option B). Attic vapor retarders are not required by the Energy Code in most climates when using spray foam, blown-in insulation, or unfaced batts, and when sufficient attic ventilation is maintained. Although not required, the use of vapor retarders can provide additional security against possible moisture buildup in attic and framed assemblies. In climate zones 14 and 16, a Class I or Class II vapor retarder must be used to manage moisture as stated in California Building Code (CBC), Title 24, Part 2.5, Section R806.2.

Attic Ventilation (Options B and C)

When venting an attic according to CRC 806, ridge or eyebrow venting (if installed) must be maintained, as shown in Figure 3-14: Insulation Air Baffles.

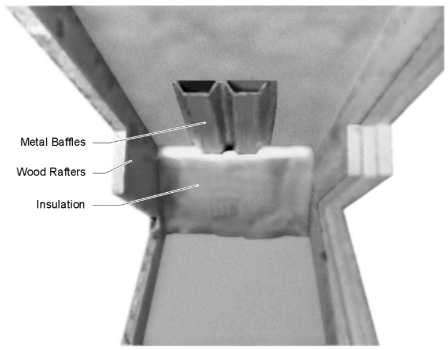
When installing insulation below the roof deck, vent baffles and insulation barriers should be used to maintain proper ventilation space. Proper airflow through the space helps remove moisture and prevents any associated issues.

Figure 3-14: Insulation Air Baffles



Source: Building Science Corporation

Figure 3-15: Baffles at the Eave in Attics



Source: California Energy Commission

Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation. (See Figure 3-15: Baffles at the Eave in Attics.) The baffle should extend beyond the height of the ceiling insulation and should have sufficient clearance between the baffle and roof deck at the top. There are several acceptable methods for maintaining ventilation air, including preformed baffles made of either cardboard or plastic. In some cases, plywood or rigid foam baffles are used.

The California Building Code (CBC) requires a minimum vent area to be provided in roofs with attics, including enclosed rafter roofs creating cathedral or vaulted ceilings. Check with the local building jurisdiction to determine which of the two CBC ventilation requirements are to be followed:

- CBC, Title 24, Part 2, Vol. 1, Section 1202.2 requires that the net-free ventilating area shall not be less than 1/300 of the area of the space ventilated.
- CBC, Title 24, Part 2.5, Section R806.2 requires that the net-free ventilating area shall not be less than 1/150 of the area of the space ventilated. This ratio may be reduced to 1/300 if a ceiling vapor retarder is installed in climate zones 14 and 16. If meeting Option 1 above, a minimum of 40 percent and not more than 50 percent of the vents must be located in the upper portion of the space being ventilated at least 3 feet above the eave or cornice vents.

Insulation shall not block the free flow of air, and a minimum 1-inch air space shall be provided between the insulation and the roof sheathing and at the location of the vent.

Ventilated openings are covered with corrosion-resistant wire cloth screening or similar mesh material. When part of the vent area is blocked by meshes or louvers, the resulting "net-free area" of the vent must be considered to determine if ventilation requirements are met.

Many jurisdictions in California are covered by Wildland Urban Interface (WUI) regulations where specific requirements for construction materials must be used to improve fire resistance for the building. These regulations require special vents that are expressly tested to resist the intrusion of flames and burning embers. Check with the building department to ensure compliance with local codes.

Note for Contractors/Installers: Tips for Successfully Implementing the High Performance Attics Requirements.

- Commit to a compliance strategy early in the building design process.
- Have a kick-off meeting with builder, subcontractor, designer, energy consultant, and ECC Rater to set expectations and express the value of the design.
- Communicate strategy and schedule to subcontractors and other team members early.
- Include insulation specifications according to the CF1R on the building plans.
- Insulation contractor will install insulation below roof deck (ideally at the same time as ceiling insulation).
- All relevant subcontractors must be aware of where the air barrier is located and be conscious of where they make penetrations, especially if designing for verified ducts in conditioned space or reduced building envelope leakage.
- Duct and Air Handlers Located in Conditioned Space Option C.

Allows a project to place and verify that ducts are located in conditioned space instead of installing insulation at the roof deck. If complying with this option, ceiling and duct insulation must be installed at the values specified in Table 150.1-A for Option C, and a radiant barrier is required in most climate zones.

ECC-Verification (Option C). Simply locating ducts in conditioned space does not qualify for this requirement; a ECC Rater must test and verify for low leakage ducts within conditioned space and that the ducts are insulated to a level required in Table 150.1-A of the Energy Code and Section 150.1(c)9B.

Note for Architects/Designers*:* Design strategies that can be used to prescriptively comply with Option C include dropped ceilings (dropped soffit), plenum or scissor truss to create a conditioned plenum box, and open-web floor truss. The key is that the ducts and equipment are placed within the thermal air barrier of the building. Locating ducts within an unvented attic does not meet Option C requirements.

Ceiling Insulation (Options B and C). Insulation coverage should extend far enough to the outside walls to cover the bottom chord of the truss. However, insulation should not block eave vents in attics because the flow of air through the attic space helps remove moisture that can build up in the attic and condense on the underside of the roof deck. This can cause structural damage and reduce the effectiveness of the insulation.

Based on area-weighted averaging, ceiling insulation may be tapered near the eave, but it must be applied at a rate to cover the entire ceiling at the specified level. An elevated truss is not required but may be desirable in some applications.

Example 3-19: Installation Doesn't Match Compliant Design Option

Question:

A newly constructed building project in climate zone 12 with HVAC ducts in the attic was designed to meet the prescriptive requirements for below roof deck and ceiling insulation. Due to miscommunication amongst the team, the roof deck insulation was not installed, and R-49 attic ceiling insulation was installed instead. Does this project still comply?

Answer:

This project no longer meets the prescriptive requirements and must follow the performance approach. For future projects, clearly communicating the project expectations to all team members early in the construction process is the key to succeeding at this design strategy. Having a project initiation meeting with all subcontractors and team members is a best practice, at least for the first few projects, until the entire team is aware of the design needs.

Note: If the design was changed so that the roof deck has a radiant barrier and the HVAC equipment and ducts are verified to be in conditioned space, the altered design will meet the prescriptive requirements under Option C.

Wall Insulation

Mandatory Requirements Section 150.0(c)

- 2x4 inch wood-framed walls above grade. Shall have a U-factor not exceeding U-0.095. In a wood-framed wall assembly, this requirement is met with at least R-15 insulation installed between 16 inch-on-center framing members. Tables found in JA4 can also provide U-factors for other wall assemblies.
- 2x6 inch or greater wood-framed walls above grade. Shall have a U-factor not exceeding U-0.069. In a wood-framed wall assembly, this requirement is met with at least R-21 insulation installed between 16 inch-on-center framing members. Tables found in JA4 can also provide U-factors for other wall assemblies.
- Mass and Masonry walls above grade. Must be insulated to meet the prescriptive requirements in Table 150.1-A for mass walls.

  Note: a mass wall is defined as a wall with a heat capacity greater than or equal to 7.0 Btu/h-ft2 per footnote 5 of Table 150.1-A
- Opaque non-framed wall assemblies. Must meet a maximum U-factor of U-0.102.
- Demising partitions and knee walls. Demising and knee walls must meet or exceed minimum insulation requirements listed above, depending on wall type.

Exceptions: There are several cases where the mandatory requirements for wall insulation do not apply or apply in a special way. For best practice, the following should be implemented:

- The mandatory requirements apply to foundation walls of heated basements and heated crawl space walls where they are above grade, but not to the portion that is located below grade. Note that Prescriptive requirements will apply to below grade walls.
- For additions to existing buildings, existing wood-framed walls that are not being altered and are already insulated to a U-factor of 0.110 or lower, or that have existing R-11 insulation need not comply with the mandatory R-15 wall insulation. For more on additions and altered walls see Chapter 9.
- Altered wood-framed walls where the existing siding is not being removed or replaced may meet the requirement with insulation between framing members are covered in Chapter 9.
- Rim joists between floors of a multistory building will comply with these mandatory requirements if they have R-15 insulation installed on the inside of the rim joist and are properly installed between intersecting joist members.

Demising Partitions and Knee Walls

Demising partitions and knee walls are not required to meet the prescriptive requirements in Table 150.1-A. Demising partitions and knee walls shall meet the mandatory minimum wall insulation requirements from Section 150.0(c).

Prescriptive Requirements (Table 150.1-A)

Please refer to Chapter 3.5.4.2 of the *2022 Single-family Residential Compliance Manual*.

Raised-Floor Insulation Section 150.0(d)

Mandatory Requirements

Please refer to Chapter 3.5.5.1 of the *2022 Single-family Residential Compliance Manual*.

Prescriptive Requirements

While the requirements for framed floors are the same in all climate zones, the requirements for concrete raised floors differ.

Framed Raised Floors. Table 150.1-A (prescriptive requirements) call for a minimum of R-19 insulation installed between wood framing or an overall assembly U-factor of 0.037 for framed raised floors in all climate zones. The requirement may be satisfied by installing the specified amount of insulation in a wood-framed floor or by meeting an equivalent U-factor. U-factors for raised floor assemblies are listed in Reference Appendices, Joint Appendix JA4.4.

Table 3-7: Wood-Framed Raised Floor Constructions Meeting Prescriptive Requirements

Insulation R-Value	Crawlspace?	Reference Joint Appendix JA4 Construction and Table Cell Entry	Equivalent U-Factor
R-19	No	4.4.2 A4	0.049
R-19	Yes	4.4.1 A4	0.037

Source: California Energy Commission

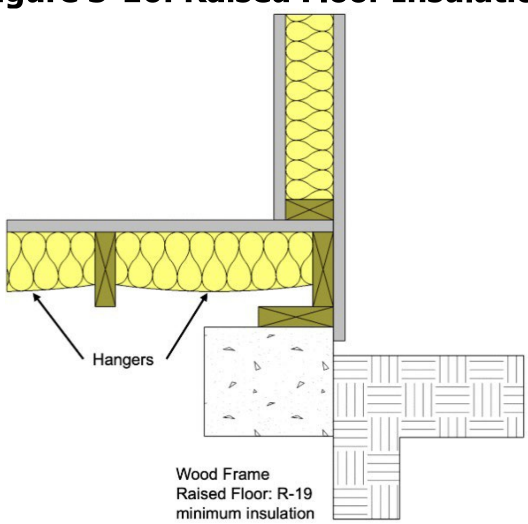
Concrete Raised Floors. Insulation requirements for concrete raised floors differ by climate zone, summarized in Table 3-8: Insulation Requirements for Concrete Raised Floors per Table 150.1-A.

Table 3-8: Insulation Requirements for Concrete Raised Floors per Table 150.1-A

Climate Zone	1,2,11,13,14,16	12,15	3-10
U-Factor	≤ 0.092	≤ 0.138	≤ 0.269
R-Value of Continuous Insulation	≥ R-8	≥ R-4	No Req.

Source: California Energy Commission

Figure 3-16: Raised Floor Insulation



Source: California Energy Commission

Installation. Cavity floor insulation should be installed in direct contact with the air barrier, which is typically the subfloor. If the air barrier is the subfloor, then cavity insulation should be installed so that there is no air space between the insulation and the floor. Support is typically needed for friction fit cavity insulation to prevent the insulation from falling, sagging, or deteriorating.

Options for support include netting stapled to the underside of floor joists, insulation hangers running perpendicular to the joists, or other suitable means. Insulation hangers should be spaced at 18 inches or less before rolling out the insulation. See Figure 3-16: Raised Floor Insulation. Insulation hangers are heavy wires up to 48 inches long with pointed ends, which provide positive wood penetration. Netting or mesh should be nailed or stapled to the underside of the joists. Floor insulation should not cover foundation vents.

Slab Insulation

Mandatory Requirements Section 150.0(f)

Slab Insulation Products

The mandatory requirements state that the insulation material must be suitable for the application. Insulation material in direct contact with soil, such as perimeter insulation, must have a water absorption rate no greater than 0.3 percent when tested in accordance with ASTM C272 Test Method A, 24-Hour Immersion, and a vapor permeance no greater than 2.0 perm/inch when tested in accordance with ASTM E96.

The insulation must be protected from physical and UV degradation by either installing a water-resistant protection board, extending sheet metal flashing below grade, choosing an insulation product that has a hard durable surface on one side, or by other suitable means.

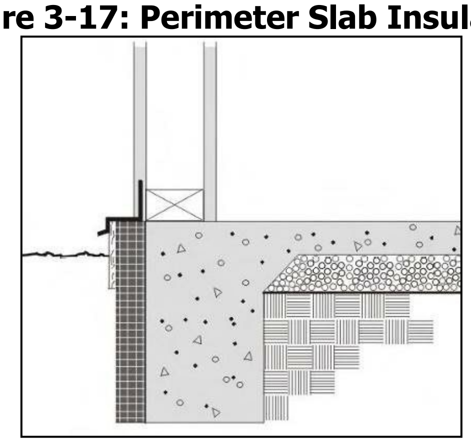
In addition, the California Residential code CRC 318.4 has requirements for foam plastic insulation in Very High Termite areas.

A common location for the slab insulation is on the foundation perimeter (Figure 3-17: Perimeter Slab Insulation). Insulation that extends downward to the top of the footing is acceptable.

Otherwise, the insulation must extend downward from the level of the top of the slab, down 16 inches (40 cm) or to the frost line, whichever is greater.

For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.

Figure 3-17: Perimeter Slab Insulation



Source: California Energy Commission

Heated Slab Floor Insulation Section 110.8(g)

Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A and Table 3-9: Slab Insulation Requirements for Heated Slab Floors.

One option is to install the insulation between the heated slab and foundation wall. In this case, insulation must extend downward to the top of the footing and then extend horizontally inward four feet toward the center of the slab. R-5 vertical insulation is required in all climates except climate zone 16, which requires R-10 of vertical insulation and R-7 horizontal insulation.

Table 3-9: Slab Insulation Requirements for Heated Slab Floors

Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Value
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop at the top of the footing, where this is less than the required depth. For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.	1 – 15 16	5 10
Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plain view.	1 – 15 16	5 10 vertical and 7 horizontal

Source: California Energy Commission

Prescriptive Requirements

Please refer to Chapter 3.5.6.2 of the *2022 Single-family Residential Compliance Manual*.

Thermal Mass

Please refer to Chapter 3.5.7 of the *2022 Single-family Residential Compliance Manual*.

Quality Insulation Installation (QII) RA 3.5

Prescriptive Requirements (Table 150.1-A)

The prescriptive requirements shown in Table 150.1-A calls for QII in all climate zones for newly constructed buildings and additions greater than 700 square feet.

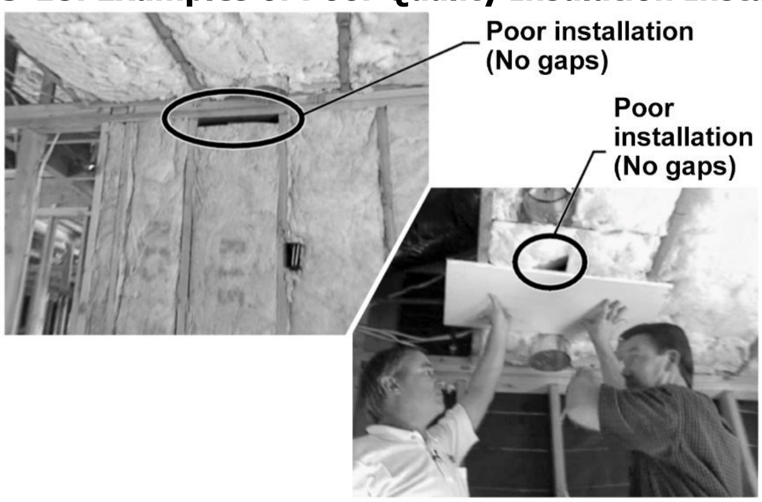
All insulation shall be installed properly throughout the building. A third-party ECC-Rater is required to verify the integrity of the installed insulation. The installer shall provide evidence to the ECC-Rater using compliance documentation that all insulation specified is installed to meet specified R-values and assembly U-factors.

To meet QII, two primary installation criteria must be adhered to, and they both must be field-verified by a ECC Rater. They include air sealing of the building enclosure (including walls, ceiling/roof, and floors), as well as proper installation of insulation. Refer to Reference Appendices, Residential Appendix RA3.5 for more details.

Many residential insulation installations have flaws that degrade thermal performance. Four problems are generally responsible for this degradation:

- There is an inadequate air barrier in the building envelope or holes and gaps within the air barrier system that inhibit the ability to limit air leakage.
- Insulation is not in contact with the air barrier, creating air spaces that short- circuit the thermal break of the insulation when the air barrier is not limiting air leakage properly.
- The insulation has voids or gaps, resulting in portions of the construction assembly that are not properly insulated and, therefore, have less thermal resistance than other portions of the assembly (Figure 3-18: Examples of Poor Quality Insulation Installation).
- The insulation is compressed, creating a gap near the air barrier and/or reducing the thickness of the insulation.

Figure 3-18: Examples of Poor Quality Insulation Installation



Source: California Energy Commission

QII requires third-party ECC inspection to verify that an air barrier and insulation are installed correctly to eliminate or reduce common problems associated with poor installation. Guidance for QII is provided in Reference Appendices, Residential Appendix RA3.5. QII applies to framed and non-framed assemblies.

Framed assemblies include wood and steel construction insulated with batts of mineral fiber, mineral and natural wool, or cellulose; loose-fill insulation of mineral fiber, mineral and natural wool, cellulose, or spray polyurethane foam (SPF). Rigid board insulation may be used on the exterior or interior of framed or non-framed assemblies.

Non-framed assemblies include structural insulated panels (SIP), insulated concrete forms (ICF), and mass walls of masonry, concrete and concrete sandwich panels, log walls, and straw bale.

Tips for implementing QII:

- QII applies to the whole building - roof/ceilings, walls, and floors - and requires field verification by a third-party ECC Rater.
- If slab edge insulation is installed, then the integrity of the slab edge insulation must also be field-verified in addition to the air barrier and insulation system for walls and the roof/ceiling.
- Combinations of insulation types (hybrid systems) are allowed.
- An air barrier shall be installed for the entire envelope. Air barrier must be verified prior to insulation being installed.
- QII is prescriptively required for additions to existing buildings more than 700 square feet. Refer to Chapter 9 for additional information specific to additions.
- Headers shall meet one of the following criteria for QII:
    - Two-member header with insulation in between. The header and insulation must fill the wall cavity. There are prefabricated products available that meet this assembly. Example: a 2x4 wall with two 2x nominal headers, or a 2x6 wall with a 4x nominal header and a 2x nominal header. Insulation is required to fill the wall cavity and must be installed between the headers.
    - Two-member header, less than the wall width, with insulation on the interior face. The header and insulation must fill the wall cavity. Example: a 2x6 wall with two 2x nominal headers. Insulation is required to fill the wall cavity and must be installed to the interior face of the wall.
    - Single-member header, less than the wall width, with insulation on the interior face. The header and insulation must fill the wall cavity. Example: a 2x4 wall with a 3-1/8-inch-wide header, or 2x6 wall with a 4x nominal header. Insulation is required to fill the wall cavity and must be installed to the interior face of the wall. Note: 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.
    - Single-member header, same width as wall. The header must fill the wall cavity. Example: a 2x4 wall with a 4x nominal header or a 2x6 wall with a 6x nominal header. No additional insulation is required provided that the entire wall has at least R-2 continuous rigid insulation installed on the exterior.
- Wood structural panel box headers may also be used as load-bearing headers in exterior wall construction, when built in accordance with California Residential Code (CRC) Figure R602.7.3 and Table R602.7.3.
- Metal bracing, tie-downs, or steel structural framing can be used to connect to wood framing for structural or seismic purposes, and comply with QII if:
    - Metal bracing, tie-downs, or steel structural framing is identified on the structural plans.
    - Insulation is installed in a manner that minimizes the thermal bridging through the structural framing assembly.

  - Insulation fills the entire cavity and/or adheres to all six sides and ends of structural assemblies that separate conditioned from unconditioned space.
  - The structural portions of assemblies are airtight.

QII in the Compliance Modeling Software. QII is not a mandatory requirement; therefore, when using the performance approach, QII may be traded off with other efficiency requirements. However, the compliance modeling software assumes QII and full insulation effectiveness in the standard design. The compliance modeling software automatically reduces the effectiveness of insulation for the proposed design in projects that do not pursue QII. The effect of a poorly installed air barrier system and envelope insulation results in higher wall heat loss and heat gain than standard R-value and U-factor calculations would indicate. Similar increases in heat loss and heat gain are experienced for roof/ceilings where construction and installation flaws are present. The reduction in effectiveness reflects standard industry installation practices and allows for full insulation credit to be taken for ECC verified quality insulation installation.

Air Barrier RA3.5.2

An air barrier shall be installed enclosing the entire building. The air barrier must be installed in a continuous manner across all components of framed and non-framed envelope assemblies. The installer shall provide evidence with compliance documentation that the air barrier system meets one or more of the air barrier requirements. More detailed explanation is provided in Reference Appendices, Residential Appendix RA3.5.

Documentation for the air barrier includes product data sheets and manufacturer specifications and installation guidelines.

Note for ECC Raters: For QII, a third-party ECC-Rater is required to verify that the air barrier has been installed properly and is integral with the insulation being used throughout the building.

Note for Contractors/Installers: Continuous Air Barrier Requirements

A combination of interconnected materials and assemblies are joined and sealed together to provide a continuous barrier to air leakage through the building envelope separating conditioned from unconditioned space or adjoining conditioned spaces of different occupancies or uses. An air barrier must meet one of the following:

- Using materials that have an air permeance not exceeding
- 0.004 cfm/ft2 under a pressure differential of 0.3 in. w.g. (1.57 psf) (0.02 L/s.m2 at 75 pa) when tested in accordance with ASTM E2178.
- Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft2 under a pressure differential of 0.3 in. w.g (1.57 psf) (0.2 L/s.m2 at 75 pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680 or ASTM E283.
- Testing the completed building and demonstrating that the air leakage rate of the building envelope does not exceed 0.40 cfm/ft2 at a pressure differential of 0.3 in w.g. (1.57 psf) (2.0 L/s.m2 at 75 pa) in accordance with ASTM E779 or an equivalent approved method.

The following materials meet the air permeance testing performance levels of 1 above. Manufacturers of these and other product types must provide a specification or product data sheet showing compliance to the ASTM testing requirements to be considered as an air barrier.

- Plywood – minimum 3/8 inch
- Oriented strand board – minimum 3/8 inches
- Extruded polystyrene insulation board – minimum 1/2 inch
- Foil-backed polyisocyanurate insulation board – minimum 1/2 inch
- Foil-backed urethane foam insulation – 1 inch
- Closed-cell spray polyurethane foam (ccSPF) with a minimum density of 2.0 pcf and a minimum thickness of 2.0 inches. Alternatively, ccSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m2 at 75 Pa pressure differential when tested in accordance with ASTM E2178 or ASTM E283.
- Open cell spray polyurethane (ocSPF) foam with a minimum density of 0.4 to1.5 pcf and a minimum thickness of 5½ inches. Alternatively, ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m2 at 75 Pa pressure differential when tested in accordance with ASTM E2178 or ASTM E283.
- Exterior or interior gypsum board – minimum 1/2 inch
- Cement board – minimum 1/2 inch
- Built-up roofing membrane
- Modified bituminous roof membrane
- Particleboard – minimum 1/2 inch
- Fully adhered single-ply roof membrane
- Portland cement/sand parge, or gypsum plaster – minimum 5/8 inch
- Cast-in-place and precast concrete
- Fully grouted uninsulated and insulated concrete block masonry
- Sheet steel or aluminum

Materials and assemblies of materials that can demonstrate compliance with the air barrier testing requirements must be installed according to the manufacturer's instructions, and a ECC-Rater shall verify the integrity of the installation.

Opaque Envelope in the Performance Approach

Some residential projects may not wish to use or do not meet the requirements for prescriptive compliance. The performance approach offers increased flexibility as well as compliance credits for certain assemblies, usually those requiring ECC-Verification. The designs described below are examples of residential envelope strategies that can be implemented under the performance approach. The proposed design used under the performance approach is compared to the standard design, which is determined by the prescriptive requirements. Remember that when using the performance approach, all applicable mandatory requirements must still be met.

Advanced Assemblies. Common strategies for exceeding the minimum energy performance level set by the 2025 Energy Code include the use of better components such as:

- Higher insulation levels.
- More efficient fenestration.
- Reducing building infiltration.
- Use of cool roof products.
- Better framing techniques (such as the use of raised-heel trusses that accommodate more insulation).
- Reduced thermal bridging across framing members.
- Greater use of non-framed assemblies or panelized systems (such as SIPs and ICFs).
- More efficient heating, cooling, and water-heating equipment.

The performance approach encourages the use of energy-saving techniques for showing compliance with the Energy Code.

Advanced Building Design. The design of a building, floor plan, and site design layout all affect energy use. A passive design building uses elements of the building to heat and cool itself, in contrast to relying on mechanical systems to provide the thermal energy needs of the building. Passive solar strategies encompass several advanced high-performance envelope techniques, such as:

- Carefully choosing the size, type, and placement of fenestration and shading.
- Providing and controlling fresh air ventilation during the day and night.
- Having internal and external thermal mass components that help store useful heat and cooling energy.
- Having highly insulated envelope assemblies.
- Using high performing roofing materials (cool roofs) and radiant barriers.
- Having very low air leakage.

Some requirements designed as part of an advanced assembly system may require specific installation procedures or field verification and diagnostic testing to ensure proper performance. Field verification and diagnostic testing are ways to ensure that the energy efficiency features used in compliance calculations are realized as energy benefits to the occupants.

Unvented Attics

Please refer to Chapter 3.6.1 of the *2022 Single-family Residential Compliance Manual*.

Below-Roof Deck Netted Insulation in Unvented Attics

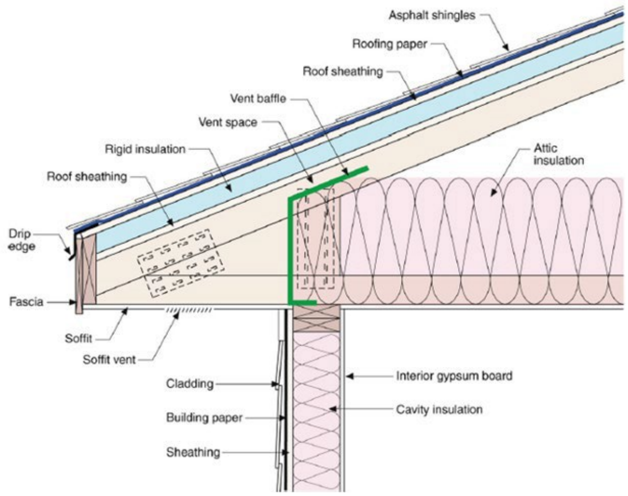
Please refer to Chapter 3.6.1.1 of the *2022 Single-family Residential Compliance Manual*.

Above-Roof Deck Insulation

A layer of continuous rigid insulation above and in direct contract with the roof deck (sheathing) increases the thermal integrity of the roof system. Continuous above-roof deck insulation is suitable for use with either asphalt shingles or clay/concrete tiles.

Required R-values for insulation installed above the roof deck are lower than R-values for insulation installed below the roof deck due to reduced thermal bridging when continuous insulation is applied directly above the roof deck. Further, an air space installed between the roof deck and the roofing tiles or shingles improves cooling of the roof assembly.

Figure 3-19: Detail of Above-Roof Deck Insulation

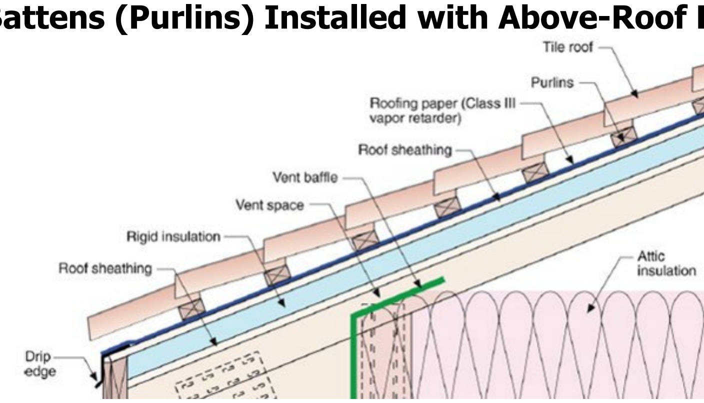


Source: Building Science Corporation

Note for ECC-Raters: Check manufacturer's specifications for proper nail schedules (fastening patterns); this will change depending on the roof pitch, truss spacing, and roofing material.

With concrete and clay tiles. Standard construction practice in California for concrete and clay tiles is to have an air gap between the tiles and roof deck because the tiles are installed over horizontal battens (or purlins). One option is to install continuous rigid insulation over the roof deck and a second layer of roof sheathing above the rigid insulation. If required by climate zone, a vapor retarder would be installed above the second sheathing layer to host the purlins with the tiles installed over them (Figure 3-20: Battens (Purlins) Installed with Above-Roof Deck Insulation).

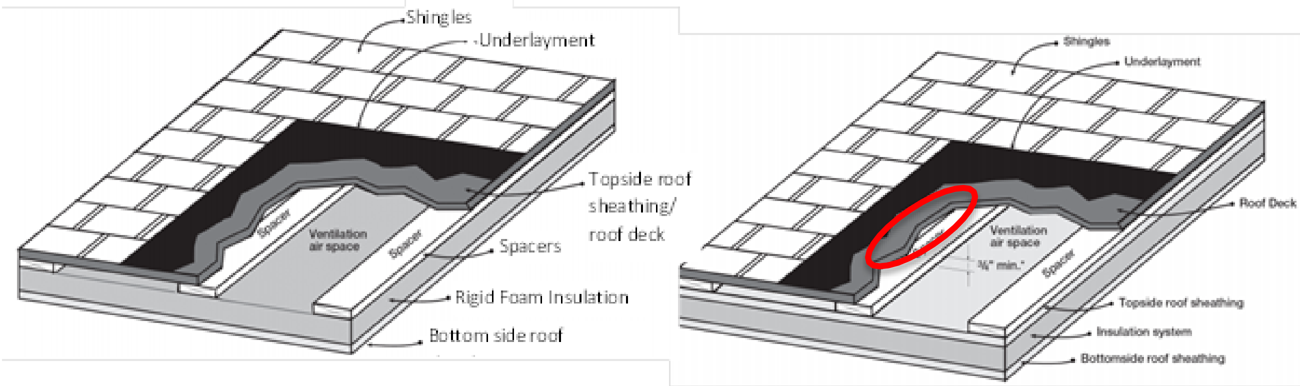
Figure 3-20: Battens (Purlins) Installed with Above-Roof Deck Insulation



Source: Building Science Corporation

With asphalt shingles. When installing asphalt shingles over above-roof deck insulation, it is best practice to ensure an air gap between the shingles and the top sheathing or insulation, as shown in Figure 3-21: Above-Roof Deck Insulation and Air Spaces with and without A Second Layer of Roof Sheathing, to mitigate the effect of high temperatures that reduce the effective life of roofing products.

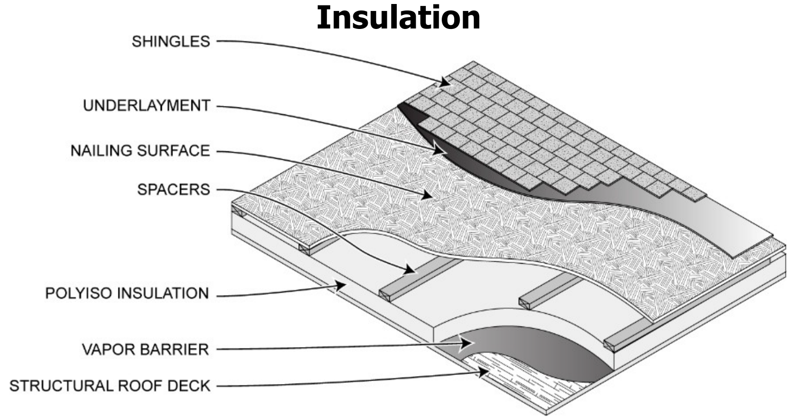
Figure 3-21: Above-Roof Deck Insulation and Air Spaces with and without A Second Layer of Roof Sheathing



Source: ARMA technical bulletin No. 211-RR-94

Spacers can be inserted above or below a second roof sheathing to provide roof deck ventilation and a nailable base for asphalt shingles (Figure 3-22: Asphalt Shingles and Spacers Installed with Above-Roof Deck Insulation). Prefabricated insulation products with spacers and top sheathing are available Check manufacturers' and trade association websites for a list of products that provide an air space and nailable base.

Figure 3-22: Asphalt Shingles and Spacers Installed with Above-Roof Deck Insulation



Source: PIMA Tech Bulletin #106

Example 3-20: Two Layers of Rigid Foam Board Above-Roof Deck

Question:

Can two layers of R-4 rigid foam board be installed as an equivalent performance to R8 rigid foam insulation above the roof deck? If so, are there best practices for installing the two layers of insulation?

Answer:

Yes, installing two R-4 rigid foam board layers is equivalent in performance to R-8. To prevent water infiltration, it is best to stagger the horizontal and vertical joints of the two layers and take care to seal each joint properly.

Example 3-21: Roof Material Directly Over Rigid insulation

Question:

A project plans to install R-6 rigid foam insulation above the roof deck with roofing material placed *directly* over the insulation. What are the best practices for installing the insulation?

Answer:

Insulation can be installed directly on the roof deck with no air gap, but performance is improved if an air gap is installed between the rigid insulation and the roofing material by using spacers or battens (purlins). Products exist that combine insulation, spacers, and additional sheathing for nailing asphalt shingles. Check with insulation manufacturers for available products.

Example 3-22: Fire Ratings Required by CBC, Chapter 15

Question:

Does a roof assembly using above-roof deck insulation meet Class A/B/C fire rating specifications, as determined by California Building Code (CBC), Chapter 15?

Answer:

Application of above-roof deck insulation affects the fire rating classification of roof covering products. Roof covering products are rated to Class A/B/C based on the ASTM E108 (NFPA 256, UL790) test. Class A/B/C ratings are done with specific roof assemblies, and ratings are valid only when the installation is the same as the assembly as rated. Under current building code requirement, tile roof products installed directly over the roof deck or over purlins are automatically rated Class A. Chapter 15 in the California Building Code (and International Building Code Section 1505 for Fire Classification) specify that certain roofing materials are Class A without having to test to ASTEM E108. These materials include slate, clay, concrete roof tile, an exposed concrete roof deck, and ferrous and copper shingles; however, asphalt shingles are not covered under this category.

Insulation products, on the other hand, are subject to a different fire test from roof- covering products. The California Building Code and International Building Code (Section 2603 for Foam Plastic Insulation) require foam plastic insulation to be tested to demonstrate a flame-spread index of not more than 75 and a smoke-developed index of not more than 450 according to ASTM E84 (UL723). The requirements apply to roof insulation products, including XPS/polyiso/polyurethane above-deck insulation and SPF below-deck insulation products.

To ensure that insulated roof assemblies meet the proper fire rating classification, roof product manufacturers and insulation manufacturers must test and develop assemblies that meet the CBC testing specifications.

Insulated Roof Tiles

Please refer to Chapter 3.6.3 of the *2022 Single-family Residential Compliance Manual*.

Raised Heel, Extension Truss, or Energy Truss

Please refer to Chapter 3.6.4 of the *2022 Single-family Residential Compliance Manual*.

Nail Base Insulation Panel

Please refer to Chapter 3.6.5 of the *2022 Single-family Residential Compliance Manual*.

Advanced Wall Systems and Advanced Framing

Please refer to Chapter 3.6.6 of the *2022 Single-family Residential Compliance Manual*.

Metal Framing

Please refer to Chapter 3.6.7 of the *2022 Single-family Residential Compliance Manual*.

Structural Foam Wall Systems

Please refer to Chapter 3.6.8 of the *2022 Single-family Residential Compliance Manual*.

Raised Floor Insulation Requirements

Please refer to Chapter 3.6.9 of the *2022 Single-family Residential Compliance Manual*.

ECC-Verified Reduced Building Air Leakage RA3.8

An energy credit is allowed for single-family buildings through the performance approach when the rate of envelope air leakage of the building is less than the air leakage rate assumed for the standard design building of 5 ACH50.

Note for ECC-Raters: A third-party ECC-Rater shall verify the air leakage rate shown on compliance documentation through diagnostic testing of the air leakage of the building.

Figure 3-23: Blower Door Testing

Source: California Energy Commission

Blower Door Testing. The blower door air leakage testing involves closing all the windows and doors; pressurizing the house with a special fan, usually positioned in a doorway Figure 3-23:

Blower Door Testing); and measuring the leakage rate, measured in cubic feet per minute at a 50 Pa pressure difference (CFM50).

The measurement procedure is described in Reference Appendices, Residential Appendix RA3.8 and was derived from the Residential Energy Services Network's (RESNET) Mortgage Industry National Home Energy Rating Standards, Standard 800, which is based on ASTM E779 air-tightness measurement protocols. This procedure requires the use of software consistent with ASTM E779. This test method is intended to produce a measure of the airtightness of a building envelope for determining the energy credit allowance for reduced building air leakage.

Note for Contractors/ Installers: Tips for Implementing the Reduced Building Air Leakage Compliance Credit

This procedure shall be used only to verify the building air leakage rate before the building construction permit is finalized when an energy credit for reduced air leakage is being claimed on compliance documentation.

The ECC-Rater shall measure the building air leakage rate to ensure measured air leakage is less than or equal to the building air leakage rate stated on the certificate of compliance and all other required compliance documentation. ECC-Verified building air leakage shall be documented on compliance forms.

This is a whole-building credit; therefore, no credit is allowed for the installation of envelope requirements that may help reduce the air leakage rate of the building, such as for an exterior air retarding wrap or for an air barrier material or assembly meeting the requirements described in Quality Insulation Installation (QII) RA 3.5.

Alternative Construction Assemblies

Log Homes

Please refer to Chapter 3.7.1 of the *2022 Single-family Residential Compliance Manual*.

Straw Bale

Please refer to Chapter 3.7.2 of the *2022 Single-family Residential Compliance Manual*.

Structural Insulated Panels (SIPs)

Please refer to Chapter 3.7.3 of the *2022 Single-family Residential Compliance Manual*.

Insulating Concrete Forms (ICF)

Please refer to Chapter 3.7.4 of the *2022 Single-family Residential Compliance Manual*.