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STAFF REPORT

(Draft) 2022 Single-Family Residential Alternative Calculation Method Reference Manual

For the 2022 Building Energy Efficiency Standards

Title 24, Part 6, and Associated Administrative Regulations in
Part 1.

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California Energy Commission

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ACKNOWLEDGMENTS

The California Energy Commission (CEC) adopted and put into effect the first *Building Energy Efficiency Standards* in 1978 and have updated these standards periodically in the intervening years. The *Building Energy Efficiency Standards* are a unique California asset that has placed the state on the forefront of energy efficiency, sustainability, energy independence, and climate change issues, and have provided a template for national standards within the United States as well as for other countries around the globe. They have benefitted from the conscientious involvement and enduring commitment to the public good of many persons and organizations along the way. The *2022 Building Energy Efficiency Standards* for residential and nonresidential buildings development and adoption process continued the long-standing practice of maintaining the standards with technical rigor, challenging but achievable design and construction practices, public engagement, and full consideration of the views of stakeholders.

The revisions in the *2022 Building Energy Efficiency Standards* for residential and nonresidential buildings were conceptualized, evaluated, and justified through the excellent work of CEC staff and consultants working under contract to the CEC, supported by the utility-organized Codes and Standards Enhancement Initiative and shaped by the participation of more than 150 stakeholders and the contribution of formal public comments.

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ABSTRACT

The California Energy Commission's (CEC) *2022 Building Energy Efficiency Standards* for residential and nonresidential buildings allows compliance by either a prescriptive or a performance method. Performance compliance uses computer-modeling software to tradeoff efficiency measures. Performance compliance is the most popular compliance method because of the flexibility it provides in the building design.

Compliance software must be certified by the following rules established for modeling software. This document establishes the rules for creating a building model, describes how the proposed design (energy use) is defined, explains how the standard design (energy budget) is established, and reports on the Performance Compliance Certificate. This document does not specify the minimum capabilities of vendor-supplied software. The CEC reserves the right to approve vendor software for limited implementations of what is documented in this manual.

This *Single-Family Residential Alternative Calculation Method Reference Manual* explains how the proposed and standard designs are determined. The explanation for multifamily residential building proposed and standard designs are described in the *Nonresidential and Multifamily Alternative Calculation Method Reference Manual*.

The 2022 compliance manager is the simulation and compliance rule implementation software specified by the CEC. The compliance manager, called California Building Energy Code Compliance (CBECC), models all of the regulated energy performance features affecting the energy compliance of a building.

Keywords: ACM, Alternative Calculation Method, *Building Energy Efficiency Standards*, California Energy Commission, California Building Energy Code Compliance, CBECC, certificate of compliance, CF1R, compliance manager, compliance software, computer compliance, energy budget, energy code, energy use, performance compliance, design, proposed design, standard design

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1 Introduction

1.1 Purpose

This manual documents the rules used for modeling residential buildings for performance-based compliance under California's *2022 Building Energy Efficiency Standards* (Energy Code) for residential and nonresidential buildings. This document explains how the proposed design, standard design, and reference design are established for a building and what is reported on the certificate of compliance (CF1R).

The 2022 compliance manager is the simulation and compliance rule implementation software specified by the California Energy Commission (CEC).

Documentation of detailed calculation algorithms is contained in the companion volume *Appendix G, 2022 Residential Alternative Calculation Method Algorithms*.

This reference manual documents the compliance analysis modeling rules for all aspects of the CEC's Alternative Calculation Method (ACM) Reference Manual for single-family buildings. For modeling rules for multifamily buildings please refer to the Nonresidential and Multifamily Alternative Calculation Method Reference Manual. This document **does not** specify the minimum capabilities of vendor-supplied software. The CEC reserves the right to approve vendor software for limited implementations of what is documented in this manual.

1.2 Other Documents

The basis of this document is the 2022 Energy Code. Documents also relied upon include the *Reference Appendices for the 2022 Building Energy Efficiency Standards* (reference appendices) (CEC---) and the *2022 Single-Family Compliance Manual* (CEC---).

Detailed modeling information for the software user can be found in the California Building Energy Code Compliance Residential (CBECC-Res) User Manual.

1.3 Compliance for Newly Constructed Buildings

Compliance for newly constructed buildings requires calculating the proposed design energy use and the standard design energy use, and the reference design energy use. There may also be additional internal calculations to establish the standard design PV requirement and the proposed design PV scaling when target energy design ratings (EDR) are specified. There are two EDRs that are considered in the energy budget which are described in more detail in in this chapter and [Chapter 1.5 Energy Design Rating](#).

The proposed building shall separately comply with the Source Energy Design Rating (EDR1), Efficiency Energy Design Rating (Efficiency EDR2), and Total Energy Design Rating (Total EDR2).

1.3.1 Energy Design Rating 1 (EDR1)

EDR1 is a dimensionless metric based on hourly source energy. The EDR1 standard design target is established by the ratio of standard design total EDR1 and reference design total EDR1. The proposed design EDR1 must be equal to or less than the standard design EDR1.

EDR1 accounts for the source energy of all end-uses, including space heating, space cooling, ventilation, and water heating, interior lighting, appliances, exterior lighting, PV generation and flexibility measures, as well as renewable portfolio standards and similar obligations.

1.3.2 Energy Design Rating 2 (EDR2)

EDR2 is a dimensionless metric based on the Time Dependent Valuation (TDV) energy consumption of the design. EDR2 is made up of two components, (1) the efficiency EDR2 and (2) the total EDR2.

The TDV energy use of the standard, proposed, and reference designs are used to evaluate three EDR2s — one for efficiency, one for PV/flexibility, and one for total energy. Compliance with EDR2 requires meeting two criteria:

1. Proposed design efficiency EDR2 must be equal to or less than standard design efficiency EDR2. The EDR2 standard efficiency design target is established by the ratio of the sum of “standard design space heating, space cooling, IAQ ventilation and water heating” EDR2, and reference design EDR2 of the same end uses.
2. Total EDR2 (efficiency EDR2, plus PV/flexibility EDR2) of the proposed design must be less than or equal to the total EDR2 of the standard design. The total EDR2 standard design target is established by the ratio of total EDR2 of the standard design and the total EDR2 of the reference design.

To calculate EDR2, energy use is expressed in units of kTDV energy per square foot of conditioned building area (kTDV/ft²). The efficiency EDR2 includes space heating, space cooling, ventilation, water heating, and self-utilization/flexibility credit. Efficiency EDR2 can include a portion of the battery storage energy savings when the self-utilization credit is specified. Total energy calculations include the efficiency end uses plus interior lighting, appliances, cooking, plug loads, and exterior lighting. The total EDR2 may include PV generation and flexibility measures, if specified.

1.4 Compliance for Additions and Alterations

Compliance for additions and alterations requires calculating the proposed design energy use and the standard design energy budget.

When the energy use of the proposed design is less than or equal to the standard design, the addition or alteration or both comply with the standards. The compliance margin is the

difference between the standard design energy use (TDV) and the proposed design energy use (TDV). When the compliance margin is zero or greater, the project complies.

The energy use is expressed in units of kTDV per square foot of conditioned floor area (kTDV/ft²) and accounts for regulated energy end uses, including space heating, space cooling, ventilation, and water heating. Unregulated energy end uses are not included, such as interior lighting, appliances, cooking, plug loads, and exterior lighting. Photovoltaics (PV) generation and flexibility measures, such as battery storage, have no effect on additions and alterations.

1.5 Energy Design Rating

There are two independent EDR metrics based on source energy and TDV. The EDR metric based on source energy is referred to as EDR1 and the EDR metric based on TDV is referred to as EDR2. No tradeoffs are allowed between EDR1 and EDR2.

1.5.1 Energy Design Rating 1 (EDR1)

EDR1 accounts for the source energy of all end-uses, including space heating, space cooling, ventilation, and water heating, interior lighting, appliances, exterior lighting, PV generation and flexibility measures, as well as renewable portfolio standards and similar obligations. In addition to efficiency, projects receive EDR1 benefits from generating renewable energy and shifting energy demand to times when the utility generates low-carbon electricity. The EDR1 is a way to express the energy performance of a building using a scoring system where 100 represents the energy performance of a reference design building meeting the efficiency requirements of the *2006 International Energy Conservation Code (IECC)*. A lower EDR1 score represents less source energy use. The proposed building must have an EDR1 score that is equal to or less than the EDR1 score of the standard design.

The physical bounds for source energy are about 10,500 Btu/kWh upper bound (proxy low-efficiency powerplant) and 0 Btu/kWh lower bound (renewable generation). Delivery losses are the same as the delivery losses used for TDV.

Avoided source energy from incremental renewable generation vary based on renewables portfolio standard (RPS) goals. This is represented as an RPS percentage value which increases annually. The avoided source energy can further vary based on the specific resource used, such as wind, solar or energy storage.

Natural gas long-run source energy is based on the percentage of renewable gas used by utilities. Increased use of renewable gas will decrease the source energy impact of retail natural gas consumption.

Propane long-run source energy does not vary on annual basis. This is because there are no renewable gas offsets that can be used to support propane. The long-run marginal source

energy of propane is constant and considered to be the source energy of propane gas. This is calculated as a direct conversion factor of 100 kBtu/therm.

The hourly source energy determined by the CEC is used to determine compliance.

1.5.2 Energy Design Rating 2 (EDR2)

EDR2 is a dimensionless metric based on the TDV energy use of a proposed or standard design divided by the TDV energy use of the reference design.

The EDR2 is a way to express the energy performance of a building using a scoring system where 100 represents the energy performance of a reference design building meeting the efficiency requirements of the *2006 IECC*. The EDR2 is similar to the energy rating index in the *2014 Residential Energy Services Network (RESNET)* standard. A score of zero represents a building that has zero-net-energy consumption based on the TDV energy consumption. By combining high levels of energy efficiency with renewable energy generating or demand flexibility measures, a score of zero or less could be achieved.

Buildings complying with the current California Building Energy Efficiency Standards are more efficient than the 2006 IECC, so most newly constructed buildings will have EDR2 scores below 100. Buildings with renewable generation (PV) can achieve a negative score. If an EDR2 is calculated for an older, inefficient home, the score would be more than 100.

The Total EDR2 is composed of two components, Efficiency EDR2 and PV/flexibility EDR2.

The efficiency EDR2 is based on the energy efficiency features of the building. PV/flexibility EDR2 includes the effects of the PV system, battery storage system, precooling, and other demand-responsive measures. Total EDR2 combines the efficiency EDR2 and PV/flexibility EDR2 into one final score.

The efficiency EDR2 does not include solar electric generation but can include a self-utilization credit for batteries. The total EDR2 includes the effects of solar generation and any battery storage beyond the self-utilization credit.

1.6 Self-Utilization Credit

When a PV system is coupled with a battery storage system, the software allows a portion of the PV/flexibility EDR2 to be traded against the efficiency EDR2. This modest credit can be used for tradeoffs against building envelope and efficiencies of the equipment installed in the building. More detail is provided in Section [2.1.5.6 Self-Utilization Credit](#).

1.7 Demand Response

Appropriate demand response controls allow building operators to reduce TDV energy by automating the response of a building to changes in utility costs. Demand response is an increasingly important function as distributed energy resources become more common, as

customers have access to time-of-use (TOU) electricity rates, and incentive programs are designed to encourage customers to reduce energy use during peak demand. Demand response occurs on a range of timescales from seconds to seasons and represents any demand change in response to grid or economic needs.

1.7.1 Precooling

Precooling takes advantage of TOU rate schedules, which are the default rates for many utility companies. The software simulates the house being precooled in the hours preceding the onset of the highest peak rates (typically between 4 p.m. and 7 p.m.) and shutting off the cooling system for most, or all, of the highest peak period hours. For participating customers, the thermostat receives a signal from the local utility that contains the information for start and stop of the precooling period, which is determined by the forecasted temperatures for that day.

The thermostat and demand response requirements are from the Standards §110.12(a) and Reference Appendices, Joint Appendix JA5.

2 Proposed, Standard, and Reference Design

2.1 Overview

This chapter describes how the EDRs are calculated, how the proposed design is modeled, and how the standard design is established.

2.1.1 Energy Design Rating

EDR1 is a score from zero to 100, where a lower score represents lower source energy use and accounts for utility renewable portfolio standards and similar obligations. The EDR1 score is a metric of the proposed design source energy divided by the reference design source energy budget. An EDR1 score is calculated for the proposed design and a second EDR1 score is calculated for the standard design. The proposed design EDR1 must be equal or less than the standard design EDR1.

EDR2 is a score from zero to 100, where zero represents a building that has zero-net-energy performance based on the TDV energy consumption, and 100 represents a building that is minimally compliant with the 2006 International Energy Conservation Code. The EDR2 score is a ratio of proposed design TDV budget to reference design TDV budget. The Total EDR2 is composed of two components:

1. Efficiency EDR2.
2. PV/flexibility EDR2.
3. Total EDR2 is calculated by subtracting the PV/flexibility EDR2 from the efficiency EDR2.

An Efficiency EDR2 and Total EDR2 score are calculated for the proposed design and a second Efficiency EDR2 and Total EDR2 score are calculated for the standard design. The proposed design Efficiency EDR2 must be equal or less than the standard design Efficiency EDR2. Additionally, the proposed design Total EDR2 must be equal or less than the standard design Total EDR2.

For a building to comply:

1. Proposed design EDR1 must be equal to or less than the standard design EDR1
2. The Efficiency EDR2 score of proposed efficiency must be equal or less than the Efficiency EDR2 score of the standard efficiency.
3. Proposed Total EDR2 score must be equal or less than the standard design Total EDR2 score.

2.1.2 Proposed Design

The single-family residential building configuration is defined by the user through entries that include floor areas, wall areas, roof areas, ceiling areas, window areas, skylight areas, and door areas. The user also specifies performance characteristics such as R-values, solar heat gain coefficient (SHGC), solar reflectance, and thermal emittance are required inputs. Information about the orientation and tilt is also required for roofs, and exterior walls. Details about the HVAC and water heating systems, as well as any solar generation systems and battery storage, are also defined by the user. The user entries for all building elements should be consistent with the actual building design. If the compliance software models the specific geometry of the building by using a coordinate system or graphic entry technique, the data generated should be consistent with the actual building design.

2.1.3 Standard Design

The standard design building, from which the energy budget is established, is in the same location and has the same geometry as the proposed design, except the wall and window areas are distributed equally among the four cardinal directions (north, east, south, and west). For additions and alterations, the standard design shall have the same wall and fenestration areas and orientations as the proposed building. The details are described below.

The *energy budget* for the residential standard design is the energy that would be used by a building similar to the proposed design if the proposed building met the requirements of the prescriptive standards. The compliance software generates the standard design automatically, based on fixed and restricted inputs and assumptions. Custom energy budget generation shall not be accessible to program users for modification when the program is used for compliance or when the program generates compliance forms.

The basis of the standard design is prescriptive requirements from §150.1(c) of the Energy Code, Table 150.1-A. Prescriptive requirements vary by climate zone. Reference Appendices, Joint Appendix JA2, Table 2-1, contains the 16 California climate zones and representative cities. The climate zone is based on the zip code for the proposed building, as documented in JA2.1.1.

The following sections present the details of how the proposed design and standard design are determined. For many modeling assumptions, the standard design is the same as the proposed design. When a building has special features, for which the CEC has established alternate modeling assumptions, the standard design features will differ from the proposed design, so the building receives appropriate credit for its efficiency. When measures require verification by a Home Energy Rating System (HERS) rater or are designated as a *special feature*, the specific requirement is listed on the CF1R.

2.1.4 Reference Design

The reference design is calculated using the same inputs, assumptions, and algorithms as the standard design except for the following requirements:

- a. Air handler power. The air handler power is 0.8 watts per cubic feet of airflow per minute (W/CFM).
- b. Air infiltration rate. The air infiltration rate is 7.2 air changes per hour at 50 pascals of pressurization (ACH50).
- c. Cooling airflow. The air handler airflow is 300 cubic feet of airflow per minute per ton of cooling capacity (CFM/ton).
- d. Duct R-value. The duct R-value is R-8.
- e. Duct leakage rate. The duct leakage rate is modeled as a Heating, Ventilation, and Air Conditioning (HVAC) distribution efficiency of 80 percent.
- f. Quality insulation installation (QII). QII is modeled as "Yes."
- g. Wall construction. Climate Zones 2–15 have 2x4 R-13 walls. Climate Zones 1 and 16 have 2x6 R-19 walls.
- h. Roof/ceiling construction. Climate Zones 2–15 have R-30 ceiling. Climate Zones 1 and 16 have R-38 ceiling. No climate zones include radiant barriers or cool roofs.
- i. Raised floor construction. Climate Zones 2–15 have 2x10 R-19 floors. Climate Zones 1 and 16 have 2x10 R-30 floors.
- j. Slab edge insulation. Climate Zones 1 and 16 include R-10 insulation 24 inches deep.
- k. Window U-factors. Climate Zones 2–15 have 0.65 U-factor. Climate Zones 1 and 16 have 0.35 U-factor.
- l. Window SHGC. All windows have 0.4 SHGC.
- m. Window area. When the window area is below 18 percent of the floor area, the reference design has the same area as the proposed design. Above 18 percent, the reference design has 18 percent.
- n. HVAC equipment efficiencies. HVAC equipment meets National Appliance Energy Conservation Act (NAECA) requirements in effect in 2006 such as 78 percent AFUE for gas central furnace, and 13 SEER for central air conditioning.
- o. Water-heating efficiency. Water heating modeled as a 40-gallon storage water with a 0.594 energy factor (EF) if gas or a 0.9172 EF if electric.
- p. Appliance and plug-load energy use and internal gains. Energy use and internal gains for appliance and miscellaneous plug loads are modeled as specified the ANSI/RESNET/ICC 301-2014 Standard.

2.1.5 Photovoltaics Requirements

The PV requirements are applicable to newly constructed low-rise residential buildings. PV system details are from PVWatts, which is a web application developed by the National Renewable Energy Laboratory. See Appendix F. for more information.

STANDARD DESIGN

The standard design PV system (based on California flexible installation [CFI] assumptions) is sized to generate enough electricity to offset the entire annual electricity consumption for a mixed fuel building that meets all the 2022 prescriptive requirements.

This standard design PV system is shown on the energy use details screen where the standard design site (kilowatt-hours [kWh]) total is zero after the PV is subtracted (Figure 1).

For PV sizing calculations, the software assumes the CFI orientation (150-270 degrees), standard efficiency for modules and inverters, fixed tracking, standard (excluding horizon) shading, and roof tilt of 22.61 degrees (5:12 pitch).

PROPOSED DESIGN

The proposed PV system is sized to offset the entire annual electricity consumption of the proposed design.

For PV sizing calculations, the software includes user-defined values for:

1. Array orientation, including CFI1 (installation of 150–270 degrees, CFI2 (installation of 105-300), or the actual orientation.
2. Module type, including standard (for example, poly- or monocrystalline silicon modules), premium (for example, high-efficiency monocrystalline silicon modules with anti-reflective coatings), or thin film (in other words, low efficiency such as 11 percent).
3. Inverter efficiency.
4. Array tilt in degrees or roof pitch, or CFI1 or CFI2 (installation up to 7:12).
5. Array tracking type including fixed, single-axis tracking, and two-axis tracking.
6. Annual solar access percentage, excluding horizon shading, of the modules.

The PV size is reported in kWdc.

Figure 1: Energy Use Details

Compliance Summary CO2 Emissions Energy Design Rating Energy Use Details CO2 Details							
End Use	Standard Design Site (kWh)	Standard Design Site (therms)	Standard Design (kTDV/ft ² -yr)	Proposed Design Site (kWh)	Proposed Design Site (therms)	Proposed Design (kTDV/ft ² -yr)	Compliance Margin (kTDV/ft ² -yr)
Space Heating	157	231.6	20.34	157	231.6	20.34	0.00
Space Cooling	1,560		38.39	1,560		38.39	0.00
IAQ Ventilation	247		2.53	247		2.53	0.00
Water Heating	88	121.2	9.91	88	121.2	9.91	0.00
Self Utilization Credit						0.00	0.00
Compliance Total			71.17			71.17	0.00
Photovoltaics	-6,268		-54.30	-6,268 *		-54.30	- %
Battery Flexibility						0.00	
Inside Lighting	616		6.96	616		6.96	
Appl. & Cooking	1,078	47.9	15.08	1,078	47.9	15.08	
Plug Loads	2,371		25.00	2,371		25.00	
Exterior	152		1.60	152		1.60	
TOTAL	0	400.8	65.51	0	400.8	65.51	
Generation Coincident Peak Demand (kW): Standard Design: 2.85 Proposed Design: 2.85 Reduction: 0.00							
* PV System resized to 3.94 kWdc (a factor of 3.937) to achieve 'Standard Design PV' PV scaling							

Source: California Energy Commission

2.1.5.1 Community Solar

For projects that use an approved Neighborhood Solar Shares (NSS) program to provide the required PV, click the "Use Community Solar" checkbox on the EDR/PV tab and select the NSS program from the drop-down list. The software will automatically use the PV characteristics of the NSS program site to size the required PV system for the building.

Figure 2: Community Solar

Project	Analysis	EDR / PV	Battery	Notes	Building	Appliances / DHW	ADU	IAQ
<input checked="" type="checkbox"/> Use Community Solar Project: - select CS project -								

2.1.5.2 Exceptions to the PV Requirements

1. No PV system is required if the solar access roof area (SARA) is less than 80 contiguous square feet. SARA of the building is described in §150.1(c)14 of the Energy Code.
2. No PV system is required when the minimum PV system size specified by §150.1(c)15 of the Energy Code is less than 1.8 kW_{dc}.

3. Buildings with enforcement-authority-approved roof designs, where the enforcement authority determines it is not possible for the PV system, including panels, modules and components and supports and attachments to the roof structure, to meet the requirements of the American Society of Civil Engineers (ASCE), Standard 7-16, Chapter 7, Snow Loads.
4. For buildings that are approved by the local planning department prior to January 1, 2020, with mandatory conditions for approval, shading from roof designs and configurations for steep-sloped roofs, which are required by the mandatory conditions for approval, shall be considered for the annual solar access calculations and roof areas that are not allowed by the mandatory conditions for approval to have PVs shall not be considered in determining the SARA.
5. PV system sizes determined using Equation 150.1-C may be reduced by 25 percent if installed in conjunction with a battery storage system. The battery storage system shall meet the qualification requirements specified in Joint Appendix JA12 and have a minimum usable capacity of 7.5 kWh.

When the solar electric generation system meets one of the prescriptive exceptions, the standard design is modeled with an appropriately sized PV system. The proposed design is modeled with a system size that does not exceed the PV size required by the standard design.

2.1.5.3 Specifying Target Energy Design Rating

The software provides the option of specifying a PV size based on a user-specified target EDR. When this option is selected, the software calculates the required PV size based on the following parameters:

- a. The user-defined target EDR2
- b. The size of the battery storage system and the battery control strategy
- c. The proposed annual kWh budget of the building

2.1.5.4 Battery Storage

Detailed calculations for PV and battery storage are included in Appendices C and D.

The software provides credit for a battery storage system coupled with a PV array. If specified, the battery storage size must be 5 kWh or larger. For Part 6 compliance, PV has no impact on energy efficiency requirements or the efficiency EDR2 unless a battery storage system is included, and the self-utilization credit is modeled.

Including a battery storage system allows downsizing the PV system to reach a specific EDR2 target.

Software includes a checkbox option to allow excess PV generation credit for above-code programs. This option, combined with a battery storage system, allows any PV size with full EDR2 credit.

2.1.5.5 Battery Controls

The three control options available are:

1. **Basic (Default Control).** A simple control strategy that provides a modest credit. The software assumes that the batteries are charged anytime PV generation (generation) is greater than the house load (load); conversely, the batteries are discharged when load exceeds generation. This control strategy does not allow the batteries to discharge into the grid.
2. **Time of Use.** To qualify for the TOU control, the battery storage system shall be installed in the default operation mode to allow charging from an on-site PV system or from the utility grid if a standalone battery storage system. The battery storage system shall begin discharging during the highest-priced TOU hours of the day, which varies by time of the year and the local utility. At a minimum, the system shall be capable of programming three seasonal TOU schedules, such as spring, summer, and winter. This option allows discharging directly into the grid.
3. **Advanced Demand Flexibility Control.** To qualify for the advanced demand flexibility control, the battery storage system shall be programmed by default as basic control or TOU control, as described above. The battery storage control shall meet the demand-responsive control requirements specified in Section 110.12(a). The battery storage system shall have the capability to change the charging and discharging periods in response to signals from the local utility or a third-party aggregator. Upon receiving a demand response signal from a grid operator, this option allows discharging directly into the grid.

VERIFICATION AND REPORTING

PV required size and battery system storage details are reported as special features on the CF1R.

2.1.5.6 Self-Utilization Credit

The 2022 Energy Code does not allow a tradeoff between the efficiency EDR2 and the effect of PV on the total EDR2 unless battery storage is provided. When the PV system is coupled with at least a 5 kWh battery storage system, the software allows a portion of the PV/flexibility EDR2 to be traded against the efficiency EDR2. A modest self-utilization credit can be used for tradeoffs against building envelope and efficiencies of the equipment installed in the building (Table 1). A checkbox is provided in the software to enable this credit.

The magnitude of the credit is equal to the 90 percent of the difference between the 2022 and 2016 Standards envelope requirements, including:

1. Below-deck batt roof insulation value of R-19 for the 2022 Standards, and R-13 for the 2016 Standard.

2. Wall U-factor of 0.048 for the 2022 Standards, and U-factor of 0.051 for the 2016 Standards.
3. Window U-factor of 0.30 for the 2022 Standards, and window U-factor of 0.32 for the 2016 Standards.
4. In cooling climate zones, window SHGC of 0.23 for the 2022 Standards, and 0.25 for the 2016 Standards.
5. QII requirement in the 2022 standards, and no QII requirements in the 2016 Standards.

Table 1 shows the self-utilization credits by climate zone.

Table 1: Self Utilization Credits

Climate Zone	Single-Family
01	13%
02	11%
03	11%
04	11%
05	13%
06	8%
07	6%
08	16%
09	13%
10	13%
11	13%
12	14%
13	12%
14	12%
15	11%
16	12%

Source: California Energy Commission

2.1.5.7 CO₂ Emissions

For every hour of the year, the software calculates all energy end uses in the house, including HVAC, water heating, indoor air quality (IAQ), plug loads, appliances, inside and exterior lighting, and PV generation. Based on these hourly calculations, the software calculates photovoltaic electricity generation that serves the house loads (which reduces the

electricity purchased from the grid) and the hourly exports back to the grid. Next, the software applies source energy factors that represent the CO₂ generation characteristics of the grid to the hourly kWh balances to calculate the CO₂ generation for each hour of the year. Finally, the software totals the hourly results to yield the annual CO₂ emissions in metric tons per year.

The software reports CO₂ generation for:

1. Total CO₂ generation.
2. CO₂ generation excluding exports to the grid (self-use only).

2.2 The Building

PROPOSED DESIGN

The building is defined through entries for zones, surfaces, and equipment. Zone types include attic, conditioned space, crawl space, basements, and garages. The roof is defined as either part of the attic or part of a cathedral ceiling (also called a *rafter roof*). The software models surfaces separating conditioned space from exterior or unconditioned spaces (such as a garage or storage) as interior surfaces adjacent to the unconditioned zone. Exterior surfaces of an attached garage or storage space are modeled as part of the unconditioned zone.

The input file will include entries for floor areas, wall, door, roof and ceiling areas, and fenestration and skylight areas, as well as the water-heating, space-conditioning, ventilation, and distribution systems.

Each surface area is entered along with performance characteristics, including building materials, U-factor, and SHGC. The orientation and tilt (Figure 3) are required for envelope elements.

Building elements are to be consistent with the actual building design and configuration.

STANDARD DESIGN

To determine the standard design for single-family residential buildings, the software creates a building with the same general characteristics (number of stories, attached garage, climate zone) and with wall and window areas distributed equally among the four cardinal directions. Envelope and HVAC performance inputs are set to the prescriptive requirements in §150.1(c) and Table 150.1-A for single-family residential buildings. For additions and alterations, the standard design for existing features in the existing building shall have the same wall and fenestration areas and orientations as the proposed building. The details are below.

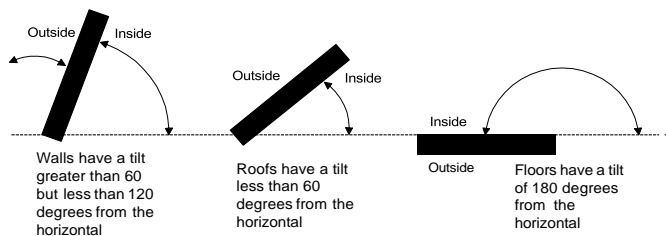
VERIFICATION AND REPORTING

All inputs that are used to establish compliance requirements are reported on the CF1R for verification.

REFERENCE DESIGN

To determine the reference design for low-rise buildings, a building with the same general inputs, assumptions, and algorithms as the standard design building is modeled except for the following requirements:

- a. Duct R-value. The duct R-value is R-8.
- b. Wall construction. Climate Zones 2–15 have 2x4 R-13 walls. Climate Zones 1 and 16 have 2x6 R-19 walls.
- c. Roof/ceiling construction. Climate Zones 2–15 have R-30 ceiling. Climate Zones 1 and 16 have R-38 ceiling. No climate zones include radiant barriers or cool roofs.
- d. Floor construction. Climate Zones 2–15 have 2x10 R-19 floors. Climate Zones 1 and 16 have 2x10 R-30 floors.
- e. Slab edge insulation. Climate Zones 1 and 16 include R-10 insulation 24 inches deep.
- f. Window U-factors. Climate Zones 2–15 have a U-factor of 0.65. Climate Zones 1 and 16 have a U-factor of 0.35.
- g. Window SHGC. All windows have 0.40 SHGC.
- h. Window area. When the window area is below 18 percent of the floor area, the reference design has the same area as the proposed design. Above 18 percent, the reference design has 18 percent.
- i. HVAC equipment efficiencies. HVAC equipment meets NAECA requirements in effect in 2006 such as 78 percent AFUE for gas central furnace, and 13 SEER for central AC.
- j. Water-heating efficiency. Water heating modeled as a 40-gallon storage water with a 0.594 Energy Factor (EF) if gas, or a 0.9172 EF if electric.

Figure 3: Surface Definitions

Source: California Energy Commission

2.2.1 Climate and Weather

PROPOSED DESIGN

The user specifies the climate zone based on the zip code of the proposed building. Compliance requirements, weather, design temperatures, and TDV of energy factors are a function of the climate zone. Compliance software assumes that the ground surrounding residential buildings has a reflectivity of 20 percent in summer and winter.

STANDARD DESIGN

The standard design climate zone is the same as the proposed design.

VERIFICATION AND REPORTING

The zip code and climate zone of the proposed design are reported on the CF1R for verification.

2.2.2 Standards Version

This input determines the appropriate federal appliance efficiency requirements for the standard design to compare with the proposed design.

PROPOSED DESIGN

The user inputs Compliance 2023.

STANDARD DESIGN

The standard design cooling equipment efficiency is based on the federal requirements. A minimum SEER/SEER2 and EER/EER2 (if applicable) that meet the current standard for the type of equipment are modeled.

VERIFICATION AND REPORTING

Compliance version is reported on the CF1R.

2.2.3 Existing Condition Verified

These inputs are used for additions and alterations. The standard design for existing conditions varies based on whether the existing conditions are verified by a Home Energy Rating (HERS) Rater before construction. See Section [2.10.5 Existing + Addition + Alteration Approach](#) for more information.

PROPOSED DESIGN

The user inputs either yes or no. "Yes" indicates that the existing building conditions has been, or will be, verified by a HERS Rater. The default assumption is "no."

STANDARD DESIGN

The standard design assumption is based on §150.2(b), Table 150.2-D. If the user input is “no,” the standard design for the existing component is based on the value in the second column (Standard Design Without Third Party Verification of Existing Conditions Shall be Based On). If the proposed design response is “yes,” the standard design value for the existing components is the value in the third column (Standard Design With Third Party Verification of Existing Conditions Shall be Based On).

VERIFICATION AND REPORTING

Verification of existing conditions is a special feature and is reported in the HERS-required verification listings on the CF1R.

2.2.4 Air Leakage and Infiltration

Air leakage is a building-level characteristic. The compliance software distributes the leakage over the envelope surfaces in accordance with the building configuration and constructs a pressure flow network to simulate the airflows between the conditioned zones, unconditioned zones, and outside.

2.2.4.1 Building Air Leakage and Infiltration (ACH50)

The airflow through a blower door at 50 pascals (Pa) of pressure measured in cubic feet per minute is called CFM50. CFM50 multiplied by 60 minutes, divided by the volume of conditioned space, is the air changes per hour at 50 Pa, called ACH50.

Specific data on ACH50 may be entered if the single-family home or townhouse will have verified building air leakage testing.

PROPOSED DESIGN

ACH50 defaults to 5 for newly constructed buildings in single-family houses and townhomes and 7 for all other buildings that have heating and cooling system ducts, or both, outside conditioned space, and for buildings with no cooling system. In single-family homes and townhomes with no ducts in unconditioned space, the default ACH50 is 4.4 and 6.2 for all other buildings.

Specific data on ACH50 may be entered if the single-family home or townhouse will have verified building air leakage testing. User input of an ACH50 that is less than the default value becomes a special feature requiring HERS verification.

STANDARD DESIGN

The standard design shall have 5 ACH50 for single-family home and 7 for other buildings (ducted space-conditioning).

VERIFICATION AND REPORTING

When the user chooses verified building air leakage testing (any value less than the standard design), diagnostic testing for reduced infiltration, with details and target values modeled in the proposed design, is reported in the HERS-required verification listing on the CF1R.

2.2.4.2 Defining Air Net Leakage

The compliance software creates an air leakage network for the proposed and standard design using the building description. Air leakage is distributed across the envelope surfaces according to the factors in Table 2. The air network is insensitive to wind direction. For buildings modeled with multiple conditioned zones, either a 20-square-foot open door or 30-square-foot open stairwell (in a multistory building) is assumed between any two conditioned zones.

**Table 2: Air Leakage Distribution
(Percentage of Total Leakage by Surface)**

Building Configuration	Ceilings	Floors	Exterior Walls	House to Garage
Slab on Grade	50	0		
Raised Floor	40	10		
No Garage			50	0
Attached Garage			40	10

Source: California Energy Commission

The only difference between the air network for the proposed and standard designs is the ACH50 if the user specifies a value lower than the default.

2.2.5 Quality Insulation Installation

The compliance software user may specify quality insulation installation (QII) for the proposed design as “yes” or “no”. The effective R-value of cavity insulation is reduced, as shown in Table 3 in buildings with no QII. When set to “no,” framed walls, ceilings, and floors are modeled with added winter heat flow between the conditioned zone and attic to represent construction cavities open to the attic. QII does not affect the performance of continuous sheathing in any construction.

PROPOSED DESIGN

The compliance software user may specify compliance with QII. The default is “no” for QII.

STANDARD DESIGN

The standard design is modeled with “yes” for verified QII for newly constructed single-family residential buildings and additions greater than 700 square feet in all climate zones.

VERIFICATION AND REPORTING

The presence of QII is reported in the HERS required verification listings on the CF1R. Verified QII is certified by the installer and field verified to comply with RA3.5. Credit for verified QII applies to ceilings/attics, knee walls, exterior walls, and exterior floors.

For alterations to existing pre-1978 construction, if the existing wall construction is assumed to have no insulation, no wall degradation is assumed for the existing wall.

Table 3: Modeling Rules for Unverified Insulation Installation Quality

Component	Modification
Walls, Floors, Attic Roofs, Cathedral Ceilings	Multiply the cavity insulation R-value/inch by 0.7.
Ceilings Below Attic	Multiply the blown and batt insulation R-value/inch by $0.96 - 0.00347 * R$.
Ceilings Below Attic	Add a heat flow from the conditioned zone to the attic of 0.015 times the area of the ceiling below attic times (the conditioned zone temperature — attic temperature) whenever the attic is colder than the conditioned space.

Source: California Energy Commission

2.2.6 Number of Bedrooms**PROPOSED DESIGN**

The number of bedrooms in a building is used to establish the IAQ mechanical ventilation requirements and determine if a building qualifies as a compact building for incentive programs. The number of bedrooms has a direct effect on water heating use.

STANDARD DESIGN

The standard design shall have the same number of bedrooms as the proposed design.

VERIFICATION AND REPORTING

The number of bedrooms is reported on the CF1R for use in field verification.

2.2.7 Front Orientation

The input for the building front orientation is the actual azimuth of the front of the building. This azimuth will generally be the side of the building facing the street or where the front door is located. The orientations of the other sides of a building viewed from the outside

looking at the front door are called front, left, right, back, or a value relative to the front, and the compliance software calculates the actual azimuth from this input.

For homes that may be built in any orientation, such as a subdivision, multiple orientation compliance can be selected for newly constructed buildings only. When selected the software will model the building using the four cardinal directions (north, east, south, and west).

PROPOSED DESIGN

The user specifies whether compliance is for multiple orientations or a site-specific orientation. For site-specific orientation, the user inputs the actual azimuth of the front in degrees from true north.

STANDARD DESIGN

The compliance software constructs a standard design building that has 25 percent of the proposed model wall and window areas facing each cardinal orientation regardless of the proposed model distribution of wall and window area.

VERIFICATION AND REPORTING

A typical reported value would be "290 degrees." This value would indicate that the front of the building faces north 70° west in surveyors' terms. When compliance is shown for multiple orientations, "all orientations" or "cardinal" is reported as on the CF1R, and the energy use results are reported for four orientations including north, east, south, and west.

2.2.8 Fuel Type

For newly constructed single-family residential buildings, the standard design fuel type is based on the proposed design fuel type. The user specifies natural gas (if available) or propane (if natural gas is not available). The user also identifies the fuel type for cooking appliances, clothes dryer, heating equipment, and water heating equipment. This specification is to establish the TDV values from Reference Appendices, Joint Appendix JA3 used by the compliance software to determine standard and proposed design energy use.

For projects with a run scope of "addition alone," natural gas is available if a gas service line can be connected to the site without a gas main extension. Natural gas is available for addition and/or alteration projects if a gas service line is connected to the existing building.

PROPOSED DESIGN

The user specifies either natural gas, if it is available at the site, or propane (whether propane is used or not).

Standard Design

The standard design assumptions for space heating are as defined in Section 2.4.1 Heating Subsystems, and those for water heating are defined in Section 2.9 Domestic Hot Water (DHW).

2.2.9 Attached Garage

The user specifies whether there is an attached garage. The garage zone is modeled as an unconditioned zone (Section 2.8 Garage/Storage).

PROPOSED DESIGN

The user specifies whether there is an attached unconditioned space or garage.

STANDARD DESIGN

The standard design has the same assumption as the proposed design.

VERIFICATION AND REPORTING

Features of an attached unconditioned space that affect compliance are reported on the CF1R.

2.2.10 Lighting

The details of the calculation assumptions for lighting loads included in Appendix E are based on the Codes and Standards Enhancement (CASE) report on plug loads and lighting (Rubin 2016, see Appendix F).

PROPOSED DESIGN

Fraction of portable lighting, power adjustment multiplier, and the exterior lighting power adjustment multiplier (watts/ft² — watts per square foot) are fixed assumptions.

STANDARD DESIGN

The standard design lighting is set equal to the proposed design lighting.

VERIFICATION AND REPORTING

No lighting information is reported on the CF1R for compliance with Title 24, Part 6.

2.2.11 Appliances

The details of the calculation assumptions for appliances and plug loads contained in Appendix E are based on the Codes and Standards Enhancement (CASE) report on plug loads and lighting (Rubin 2016, see Appendix F).

PROPOSED DESIGN

All buildings with kitchens are assumed to have a refrigerator, dishwasher, and cooking appliance. Optionally, buildings can have a clothes washer and clothes dryer in the conditioned space. The user can select fuel type as gas or electric for the clothes dryer and cooking appliance.

STANDARD DESIGN

The standard design appliances are set equal to the proposed appliances.

VERIFICATION AND REPORTING

No information for the appliance types listed above is reported on the CF1R for compliance with Title 24, Part 6.

2.3 Building Materials and Construction

2.3.1 Materials

Only materials approved by the CEC may be used in defining constructions. Additional materials may be added to the compliance manager through an exceptional method application, as outlined in §10-109(e) and §10-110.

Table 4 shows a partial list of the materials available for construction assemblies.

MATERIAL NAME

The material name is used to select the material for a construction.

THICKNESS

Some materials, such as three-coat stucco, are defined with a specific thickness (not editable by the compliance user). The thickness of other materials, such as softwood used for framing, is selected by the compliance user based on the construction of the building.

CONDUCTIVITY

The conductivity of the material is the steady-state heat flow per square foot, per foot of thickness, or per degree Fahrenheit temperature difference. It is used in simulating the heat flow in the construction.

Table 4: Materials List

Material Name	Thickness (in.)	Conductivity (Btu/h-°F-ft)	Coefficient for Temperature Adjustment of	Specific Heat (Btu/lb-°F)	Density (lb/ft ³)	R-Value per Inch (°F-ft ² -h/Btu-in)

			Conductivity (°F (-1))			
Gypsum Board	0.5	0.09167	0.00122	0.27	40	0.9091
Wood Layer	Varies	0.06127	0.0012	0.45	41	1.36
Synthetic Stucco	0.375	0.2		0.2	58	0.2
3 Coat Stucco	0.875	0.4167		0.2	116	0.2
All other siding						0.21
Carpet	0.5	0.02		0.34	12.3	4.1667
Light Roof	0.2	1		0.2	120	0.0833
5 PSF Roof	0.5	1		0.2	120	0.0833
10 PSF Roof	1	1		0.2	120	0.0833
15 PSF Roof	1.5	1		0.2	120	0.0833
25 PSF Roof	2.5	1		0.2	120	0.0833
TileGap	0.75	0.07353		0.24	0.075	1.1333
SlabOnGrade	3.5	1		0.2	144	0.0833
Earth		1		0.2	115	0.0833
SoftWood		0.08167	0.0012	0.39	35	1.0204
Concrete		1		0.2	144	0.0833
Foam Sheathing	varies	varies	0.00175	0.35	1.5	Varies
Ceiling Insulation	varies	varies	0.00418	0.2	1.5	Varies
Cavity Insulation	varies	varies	0.00325	0.2	1.5	Varies
Vertical Wall Cavity	3.5	0.314	0.00397	0.24	0.075	
GHR Tile	1.21	0.026	0.00175	0.2	38	
ENSOPRO	0.66	0.03	0.00175	0.35	2	
ENSOPRO Plus	1.36	0.025	0.00175	0.35	2	
Door						5

Source: California Energy Commission

COEFFICIENT FOR TEMPERATURE ADJUSTMENT OF CONDUCTIVITY

The conductivity of some materials varies with temperature according to the coefficient listed. Materials that have a coefficient of zero (0) do not vary with temperature.

SPECIFIC HEAT

The specific heat is the amount of heat in British thermal units (Btu) it takes to raise the temperature of 1 pound of the material 1 degree Fahrenheit (Btu/lb-°F).

DENSITY

The density of the material is the weight of the material in pounds per cubic foot (lb/ft³).

R-VALUE PER INCH

The R-value per inch is the resistance to heat flow for a 1-inch thick material.

2.3.2 Construction Assemblies

“Constructions” are defined by the compliance software user to characterize the building’s envelope performance. The user assembles a construction from one or more layers of materials, as shown in Figure 4. For framed constructions, there is a framing layer that has parallel paths for the framing and the cavity between the framing members. The layers that are allowed depend on the surface type. The compliance manager calculates a winter design U-factor that is compared to a construction that meets the prescriptive standard. The U-factor is displayed as an aid to the user. The calculations used in the energy simulation are based on each layer and framing rather than the U-factor.

Figure 4: Example Construction Data Screen

Construction Data

Currently Active Construction: **R19 R5 Stucco Wall**

Construction Name: **R19 R5 Stucco Wall**

Can Assign To: **Exterior Walls**

Construction Type: **Wood Framed Wall**

Construction Layers (inside to outside)

	Cavity Path	Frame Path
Inside Finish:	Gypsum Board	Gypsum Board
Sheathing / Insulation:	- no sheathing/insul.	- no sheathing/insul.
Cavity / Frame:	R 19 in 5-1/2 in. cavity (R-18)	2x6 @ 16 in. O.C.
Sheathing / Insulation:	R5 Sheathing	R5 Sheathing
Exterior Finish:	Synthetic Stucco	Synthetic Stucco

Non-Standard Spray Foam in Cavity

Winter Design U-value: **0.051** Btu/h-ft²-F (meets max code 0.051 U-value (0.051))

Source: California Energy Commission

ASSEMBLY TYPES

The types of assemblies are:

- Exterior wall.
- Interior wall.
- Underground wall.
- Attic roof.
- Cathedral roof.
- Ceiling below attic.
- Interior ceiling.
- Interior floor.
- Exterior floor (over unconditioned space or exterior).

- Floor over crawl space.

CONSTRUCTION TYPE

1. Ceiling below attic (the roof structure is not defined here, but is part of the attic), wood-framed. In a residence with a truss roof, the ceiling is where the insulation is located, while the structure above the ceiling is encompassed by the term "attic" or "roof." The attic or roof consists of (from inside to outside) the radiant barrier, below-deck insulation, framing, above-deck insulation, and the roofing product, such as asphalt or tile roofing. See more in Section [2.6.2 Ceiling Below Attic](#).
2. Cathedral ceiling (with the roof defined as part of the assembly), wood-framed. Since there is no attic, the roof structure is connected to the insulated assembly at this point.
3. Roof, structurally insulated panels (SIP).
4. Walls (interior, exterior, underground), wood- or metal-framed, or SIP.
5. Floors (over exterior, over crawl space, or interior).
6. Party surfaces separate conditioned space included in the analysis from conditioned space not included in the analysis. Party surfaces for spaces not included in the analysis include spaces joining an addition alone to the existing dwelling. Interior walls, ceilings, or floors can be party surfaces.

CONSTRUCTION LAYERS

All assemblies have a cavity path and a frame path.

As assemblies are completed, the screen displays whether the construction meets the prescriptive requirement for that component.

PROPOSED DESIGN

The user defines a construction for each surface type included in the proposed design. Any variation in insulation R-value, framing size or spacing, interior or exterior sheathing, or interior or exterior finish requires the user to define a different construction. Insulation R-values are based on manufacturer-rated properties rounded to the nearest whole R-value. Layers such as sheetrock, wood sheathing, stucco, and carpet whose properties are not compliance variables are included as generic layers with standard thickness and properties.

Walls separating the house from an attached unconditioned attic or garage are modeled as interior walls with unconditioned space as the adjacent zone, which the compliance manager recognizes as a "demising wall." Floors over a garage are modeled as an interior or demising

floor. The exterior walls, floor, and ceiling/roof of the garage are modeled as part of the unconditioned garage zone.

STANDARD DESIGN

The compliance software assembles a construction that meets the prescriptive standards for each user-defined construction or assembly.

VERIFICATION AND REPORTING

All proposed constructions, including insulation, frame type, frame size, and exterior finish or exterior condition, are listed on the CF1R. Nonstandard framing (for example, 24" on center wall framing, advanced wall framing) is reported as a special feature.

2.3.3 Spray-Foam Insulation

The R-values for spray-applied polyurethane foam (SPF) insulation differ depending on whether the product is open cell or closed cell. Spray-foam insulation R-values are calculated based on the nominal thickness of the insulation multiplied by the default thermal resistivity per inch, or the total R-value may be calculated based on the thickness of the insulation multiplied by the tested R-value per inch as certified by the Department of Consumer Affairs, Bureau of Household Goods and Services. (See details Section 2.3.3 Spray-Foam Insulation and Reference Appendices, Residential Appendix RA3.5.) Additional documentation and verification requirements for a value other than the default values shown in Table 5 are required. (See RA3.5.6.)

Table 5: Required Thickness Spray-Foam Insulation (in inches)

Required R-values for SPF insulation	R-11	R-13	R-15	R-19	R-21	R-22	R-25	R-30	R-38
Required thickness closed cell @ R5.8/inch	2.00	2.25	2.75	3.50	3.75	4.00	4.50	5.25	6.75
Required thickness open cell @ R3.6/inch	3.0	3.5	4.2	5.3	5.8	6.1	6.9	8.3	10.6

Source: California Energy Commission

2.3.3.1 Medium-Density Closed-Cell SPF Insulation

The default R-value for spray-foam insulation with a closed cellular structure is R-5.8 per inch, based on the installed nominal thickness of insulation. Closed-cell insulation has an installed nominal density of 1.5 to 2.5 pounds per cubic foot (pcf).

2.3.3.2 Low-Density Open-Cell SPF Insulation

The default R-value for spray-foam insulation with an open cellular structure is calculated as R-3.6 per inch, based on the nominal required thickness of insulation. Open-cell insulation has an installed nominal density of 0.4 to 1.5 pounds per cubic foot (pcf).

PROPOSED DESIGN

The user will select either typical values for open-cell or closed-cell spray-foam insulation or higher-than-typical values and enter the total R-value (rounded to the nearest whole value).

STANDARD DESIGN

The compliance software assembles a construction that meets the prescriptive standards for each assembly type (ceiling/roof, wall, and floor).

VERIFICATION AND REPORTING

When the user elects to use higher-than-typical R-values for open-cell or closed-cell spray-foam insulation, a special features note is included on the CF1R requiring documentation requirements specified in Reference Appendices, Joint Appendix JA4.1.7. Furthermore, a HERS verification requirement for the installation of spray-foam insulation using higher-than-default values is included on the CF1R.

2.4 Building Mechanical Systems

A space-conditioning system (also referred to as HVAC system) is made up of the heating subsystem (also referred to as "heating unit," "heating equipment," or "heating system"); cooling subsystem (also referred to as "cooling unit," "cooling equipment," or "cooling system"); the distribution subsystem details (if any); and fan subsystem (if any). Ventilation cooling systems and indoor air-quality-ventilation systems are defined at the building level for single-family residential buildings. (See also Sections 2.4.9 Indoor Air Quality Ventilation and Section 2.4.10 Ventilation Cooling System.)

2.4.1 Heating Subsystems

The heating subsystem describes the equipment that supplies heat to a space-conditioning system. Heating subsystems are categorized according to the types shown in Table 8.

PROPOSED DESIGN

The user selects the type and supplies required inputs for the heating subsystem, including the appropriately rated heating efficiency. Except for heat pumps, the rated heating capacity is not used as a compliance variable by the compliance software.

When the proposed space-conditioning system is a heat pump, the user specifies the rated heating capacity at 47°F and 17°F for the heat-pump compressor. The capacity is used to

determine the effect of backup electric resistance heat in the simulation. The specified capacities are listed on the CF1R for verification by a HERS Rater.

STANDARD DESIGN

The standard design heating subsystem is a heat pump if the proposed water heating system is gas-fired in climate zones 3, 4, 13, and 14. Otherwise, the heating system is a gas heating system.

When the standard design is a heat pump, the equipment used in the standard design building is an electric split-system heat pump with default ducts in the attic and a heating seasonal performance factor (HSPF) meeting the current *Appliance Efficiency Regulations* minimum efficiency for heat pumps. The standard design heat-pump compressor size is determined by the software as the larger of the compressor size calculated for air-conditioning load, or the compressor with a 47°F rating that is 75 percent of the heating load (at the heating design temperature).

When the standard design is a gas heating system, the equipment used in the standard design building is a gas furnace (or propane if natural gas is not available) with default ducts in the attic and an annual fuel utilization efficiency (AFUE) meeting the *Appliance Efficiency Regulations* minimum efficiency for central systems.

See Table 6 for complete details on heating systems noted above.

Table 6: Standard Design Heating System

Proposed Design	Standard Design
Climate Zones 1-2, 5-12, and 15-16	80 percent AFUE central furnace, default duct
Climate Zones 3-4, and 13-14 (if the water heating system is not a gas-fired system)	80 percent AFUE central furnace, default duct
Climate Zones 3-4, and 13-14 (if the water heating system is a gas-fired system)	8.2 HSPF or 7.5 HSPF2 central heat pump, auto size capacity, default duct

Source: California Energy Commission

VERIFICATION AND REPORTING

The proposed heating system type and rated efficiency are reported in the compliance documentation on the CF1R. For heat pumps, which are supplemented by electric resistance backup heating, the HERS-verified rated heating capacity of each proposed heat pump is reported on the CF1R. Installed capacities must be equal to or larger than the capacities reported for modeled at 47° and 17° (RA 3.4.4.2).

Table 7: HVAC Heating Equipment Types

Name	Heating Equipment Description
CntrlFurnace	Gas- or oil-fired central furnaces, propane furnaces, or heating equipment considered equivalent to a gas-fired central furnace, such as wood stoves that qualify for the wood heat exceptional method. Gas fan-type central furnaces have a minimum AFUE=80%. Distribution can be gravity flow or use any of the ducted systems.
PkgGasFurnace	The furnace side of a packaged air-conditioning system. Packaged gas or propane furnaces have a minimum AFUE=81%. Distribution can be any of the ducted systems.
WallFurnace Gravity	Noncentral gas- or oil-fired wall furnace, gravity flow. Equipment has varying efficiency requirements by capacity. Distribution is ductless.
WallFurnace Fan	Noncentral gas- or oil-fired wall furnace, fan-forced. Equipment has varying efficiency requirements by capacity. Distribution is ductless.
FloorFurnace	Noncentral gas- or oil-fired floor furnace. Equipment has varying efficiency requirements by capacity. Distribution is ductless.
RoomHeater	Noncentral gas- or oil-fired room heaters. Noncentral gas- or oil-fired wall furnace, gravity flow. Equipment has varying efficiency requirements by capacity. Distribution is ductless.
WoodHeat	Wood-fired stove. In areas with no natural gas available, a wood-heating system with any backup heating system is allowed to be installed if exceptional method criteria described in the <i>Residential Compliance Manual</i> are met.
Boiler	Gas or oil boilers. Distribution systems can be radiant, baseboard, or any of the ducted systems. Boiler may be specified for dedicated hydronic systems. Systems in which the boiler provides space heating and fires an indirect gas water heater (IndGas) may be listed as Boiler/CombHydro Boiler and is listed under "Equipment Type" in the HVAC Systems listing.
Electric	All electric heating systems other than space-conditioning heat pumps. Included are electric resistance heaters, electric boilers, and storage water heat pumps (air-water) (StoHP). Distribution system can be radiant, baseboard, or any of the ducted systems.
CombHydro	Water-heating system can be any gas water heater. Distribution systems can be radiant, baseboard, or any of the ducted systems and can be used with any of the terminal units (FanCoil, RadiantFlr, Baseboard, and FanConv).
Single zone dual fuel heat pump	Single-zone system with constant volume fan, direct expansion heat pump cooling and heating, and gas supplemental heating.

Source: California Energy Commission

Table 8: Heat Pump Equipment Types

Name	Heat Pump Equipment Description
SplitHeatPump	Central split heat pump system. Distribution system is one of the ducted systems.
SDHV SplitHeat Pump	Small-duct, high-velocity, central split-system that produces at least 1.2 inches of external static pressure when operated at the certified air volume rate of 220–350 CFM per rated ton of cooling and uses high-velocity room outlets generally greater than 1,000 fpm that have less than 6.0 square inches of free area.
Ductless MiniSplit HeatPump	A heat pump system that has an outdoor section and one or more ductless indoor sections. The indoor section(s) cycle on and off in unison in response to an indoor thermostat.
Ductless MultiSplit HeatPump	A heat pump system that has an outdoor section and two or more ductless indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.
DuctlessVRF HeatPump	A variable-refrigerant-flow (VRF) heat pump system that has one or more outdoor sections and two or more ductless indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.
PkgHeatPump	Central packaged heat pump systems. Central packaged heat pumps are heat pumps in which the blower, coils, and compressor are contained in a single package, powered by single-phase electric current, air-cooled, and rated below 65,000 Btu/h. The distribution system is one of the ducted systems.
RoomHeatPump	Noncentral room air-conditioning systems. These include packaged terminal (commonly called “through-the-wall”) units and any other ductless heat pump systems.
SglPkgVertHeatPump	Single-package vertical heat pump. This is a package air conditioner that uses reverse cycle refrigeration as the prime heat source and may include secondary supplemental heating by means of electrical resistance.
PkgTermHeatPump	Packaged terminal heat pump. This is a package terminal air conditioner that uses reverse cycle refrigeration as the prime heat source; has a supplementary heating source available, with the choice of electric resistant heat; and is industrial equipment.
DuctedMiniSplitHeat Pump	Ducted minisplit heat pump is a system that has an outdoor section and one or more ducted indoor sections. The indoor section(s) cycle on and off in unison in response to an indoor thermostat.

DuctedMultiSplitHeat Pump	Ducted multisplit heat pump is a system that has a single outdoor section, and two or more ducted indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.
Ducted+DuctlessMulti SplitHeatPump	Multisplit heat pump system with a combination of ducted and ductless indoor units.
AirToWater HeatPump	An indoor conditioning coil, a compressor, and a refrigerant-to-water heat exchanger that provides heating and cooling functions. May also have the ability to heat domestic hot water.
Ground Source HeatPump	An indoor conditioning coil with air-moving means, a compressor, and a refrigerant-to-ground heat exchanger that provides heating, cooling, or heating and cooling functions. May also have the ability to heat domestic hot water.
Variable Capacity Heat Pump	VCHP — Meets all the requirements of the VCHP Compliance Option.
Single zone dual fuel heat pump	Single-zone system with constant volume fan, direct expansion heat pump cooling and heating, and gas supplemental heating.

Source: California Energy Commission

2.4.2 Combined Hydronic Space/Water Heating

Combined hydronic space/water heating is a system whereby a water heater is used to provide space heating and water heating. Dedicated hydronic space-heating systems are also a modeling capability. Space-heating terminals may include fan coils, baseboards, and radiant floors.

For combined hydronic systems, the water-heating portion is modeled normally. For space heating, an effective AFUE is calculated for gas water heaters. For electric water heaters, an effective HSPF/HSPF2 is calculated. The procedures for calculating the effective AFUE or HSPF/HSPF2 are described below.

Combined hydronic space-conditioning cannot be combined with heat pump water heating or with zonal control credit.

PROPOSED DESIGN

When a fan coil is used to distribute heat, the fan energy and the heat contribution of the fan motor must be considered. The algorithms for fans used in combined hydronic systems are the same as those used for gas furnaces and are described in Appendix G.

If a large fan coil is used and air-distribution ducts are in the attic, crawl space, or other unconditioned space, the efficiency of the air-distribution system must be determined using methods consistent with those described in Section 2.4.6 Distribution Systems. Duct efficiency is accounted for when the distribution type is ducted.

2.4.2.1 Commercial or Consumer Storage Gas Water Heater

When storage gas water heaters are used in combined hydronic applications, the effective AFUE is given by the following equation:

$$AFUE_{eff} = RE - \left[\frac{PL}{RI} \right] \quad \text{Equation 1}$$

Where:

$AFUE_{eff}$ = The effective AFUE of the gas water heater in satisfying the space heating load.

RE = The recovery efficiency (or thermal efficiency) of the gas storage water heater. A default value of 0.70 may be assumed if the recovery efficiency is unknown. This value is generally available from the CEC appliance directory.

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of piping between the water heater storage tank and the fan coil or other heating elements are in unconditioned space.

RI = The rated input of the gas water heater (kBtu/h) available from the CEC appliance directory.

2.4.2.2 Instantaneous Gas Water Heater

When instantaneous gas water heaters are used in combined hydronic applications, the effective AFUE is given by the following equation:

$$AFUE_{eff} = UEF \quad \text{Equation 2}$$

Where:

$AFUE_{eff}$ = The effective AFUE of the gas water heater in satisfying the space heating load.

UEF = The rated uniform energy factor of the instantaneous gas water heater.

2.4.2.3 Storage Electric Water Heater

The HSPF of storage water heaters used for space heating in a combined hydronic system is given by the following equations.

$$HSPF_{eff} = 3.413 \left[1 - \frac{PL}{3.413kW_i} \right] \quad \text{Equation 3}$$

Where:

$HSPF_{eff}$ = The effective HSPF of the electric water heater in satisfying the space-heating load.

- PL = Pipe losses (kBtu/h). Assumed zero when less than 10 feet of piping between the water heater storage tank and the fan coil or other heating elements are in unconditioned space.
- kW_i = The kilowatts of input to the water heater available from the CEC's appliance directory.

STANDARD DESIGN

When a hydronic system used for heating is proposed to use electricity, the heating equipment for the standard design is an electric split-system heat pump with an HSPF meeting the *Appliance Efficiency Regulations* requirements for split-systems. The standard design heat pump compressor size is determined by the software based on the compressor size calculated for the air-conditioning system.

When electricity is not used for heating, the equipment used in the standard design building is a gas furnace (or propane if natural gas is not available) with default ducts in the attic and an AFUE meeting the *Appliance Efficiency Regulations* minimum efficiency for central systems. When a proposed design uses electric and non-electric heat, the standard design is a gas furnace.

2.4.3 Special Systems — Hydronic Distribution Systems and Terminals

Hydronic distribution systems in unconditioned spaces are included in the building model to account for heat loss to these unconditioned spaces. Heat loss is affected by the length of piping in unconditioned spaces, pipe size, pipe insulation thickness, and pipe insulation R-value.

PROPOSED DESIGN

This listing is completed for hydronic systems that have more than 10 feet of piping (plan view) in unconditioned space. As many rows as necessary may be used to describe the piping system.

STANDARD DESIGN

The standard design is established for a hydronic system in the same way as for a central system, as described in Section 2.4.1 Heating Subsystems.

VERIFICATION AND REPORTING

A hydronic or combined hydronic system is reported on the CF1R.

Other information reported includes:

- *Piping Run Length (ft)*. The length (plan view) of distribution pipe in unconditioned space, in feet, between the primary heating/cooling source and the point of distribution.
- *Nominal Pipe Size (in.)*. The nominal (as opposed to true) pipe diameter in inches.

- *Insulation Thickness (in.)*. The thickness of the insulation in inches. Enter "none" if the pipe is uninsulated.
- *Insulation R-value (hr-ft²-°F/Btu)*. The installed R-value of the pipe insulation. Minimum pipe insulation for hydronic systems is as specified in §150.0(j).

2.4.4 Ground-Source Heat Pump

A ground-source heat pump system, which uses the earth as a source of energy for heating and as a heat sink for energy when cooling, is simulated as a minimum efficiency split-system equivalent to the standard design with default duct conditions in place of the proposed system. The mandatory efficiencies for ground-source heat pumps are a minimum coefficient of performance (COP) for heating and EER/EER2 for cooling.

2.4.5 Air-to-Water Heat Pumps

Air-to-water heat pumps (AWHPs) must be listed in the Title 20 MAEDbS database. For the proposed design, fixed compressor speed AWHPs would be modeled equivalent to the prescriptive air source heat pump in heating and cooling operation. Variable compressor speed AWHPs would be treated with a 2 percent reduction in hourly heating energy use and an 8 percent reduction in hourly cooling energy use, relative to the prescriptive air source heat pump.

2.4.6 Cooling Subsystems

The cooling subsystem describes the equipment that supplies cooling to a space-conditioning system.

PROPOSED DESIGN

Cooling subsystems are categorized according to the types shown in Table 9. The user selects the type of cooling equipment and enters basic information to model the energy use of the equipment. Enter the cooling equipment type and additional information based on the equipment type and zoning, such as the SEER/SEER2 and EER/EER2. For some types of equipment, the user may also specify if the equipment has a multispeed compressor and if the system is zoned or not via checkboxes. For ducted cooling systems, the cooling airflow from the conditioned zone through the cooling coil is input as CFM per ton. The rated cooling capacity is not a compliance variable.

Until there is an approved compliance option for ductless heat pumps (ducted and ductless minisplit, multisplit, and variable-refrigerant flow [VRF] systems), these systems are simulated as a minimum efficiency split-system equivalent to the standard design with default duct conditions.

See sections below for the details of specific inputs.

STANDARD DESIGN

The cooling system for the standard design building is a nonzonal control system, split-system ducted cooling system meeting the minimum requirements of the *Appliance Efficiency Regulations*. The standard design system shall assume verified refrigerant charge in Climate Zones 2 and 8–15 for all systems. Mandatory fan efficacy is assumed in all climate zones.

Table 9: HVAC Cooling Equipment Types (Other Than Heat Pumps)

Name	Cooling Equipment Description
NoCooling	Entered when the proposed building is not cooled or when cooling is optional (to be installed at some future date). Both the standard design equivalent building and the proposed design use the same default system (refer to Section 2.4.8.3 No Cooling).
SplitAirCond	Split air-conditioning systems. Distribution system is one of the ducted systems. (Efficiency metric: SEER/SEER2 and EER/EER2)
PkgAirCond	Central packaged air-conditioning systems less than 65,000 Btu/h cooling capacity. Distribution system is one of the ducted systems. (Efficiency metric: SEER/SEER2 and EER/EER2)
LrgPkgAirCond	Large packaged air-conditioning systems rated at or above 65,000 Btu/h cooling capacity. Distribution system is one of the ducted systems.
SDHVSplitAirCond	Small-duct, high-velocity, split A/C system.
DuctlessMiniSplitAirCond	Ductless minisplit A/C system having an outdoor section and one or more indoor sections. The indoor sections cycle on and off in unison in response to an indoor thermostat.
DuctlessMultiSplitAirCond	Ductless multisplit A/C system having an outdoor section and two or more indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.
DuctlessVRFAirCond	Ductless variable refrigerant flow (VRF) A/C system.

SglPkgVertAirCond	Single-packaged vertical A/C is a self-contained cooling system that is factory-assembled, is arranged vertically, can be mounted on the exterior or interior of a space, and can be installed through the wall. These units can be ducted or ductless. They are rated using ANSI/AHRI 390(I-P)-2003.
PkgTermAirCond	Packaged terminal A/C (PTAC) is a self-contained cooling system that is installed through the wall. These systems do not use ducts. They are rated using AHRI 310/380-2017.
DuctedMiniSplitAirCond	Ducted minisplit A/C system having an outdoor section and one or more indoor sections. The indoor sections cycle on and off in unison in response to an indoor thermostat.
DuctedMultiSplitAirCond	Ducted multisplit A/C system having an outdoor section and two or more indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.
Ducted+DuctlessMultiSplitAirCond	Combination of ducted and ductless multisplit A/C system have an outdoor section and two or more indoor sections. The indoor sections operate independently and can be used to condition multiple zones in response to multiple indoor thermostats.
RoomAirCond	Room air conditioner is a self-contained cooling system that is installed through the wall. These systems do not use ducts. They are rated using ANSI/ASHRAE Standard 16-2016. Same as DuctlessSplitAirCond except that cooling is not supplied to each habitable space in the dwelling unit.
EvapCondenser	Evaporatively cooled condensers. A split mechanical system, with a water-cooled condenser coil.

Source: California Energy Commission

VERIFICATION AND REPORTING

Information shown on the CF1R includes cooling equipment type and cooling efficiency (SEER/SEER2 or EER/EER2 or both). Measures requiring verification (Table 10) are listed in the HERS verification section of the CF1R.

2.4.6.1 Verified Refrigerant Charge or Fault Indicator Display

Proper refrigerant charge is necessary for electrically driven compressor air-conditioning systems to operate at full capacity and efficiency. Software calculations set the compressor

efficiency multiplier to 0.90 to account for the effect of improper refrigerant charge or 0.96 for proper charge.

PROPOSED DESIGN

The software allows the user to indicate if systems will have diagnostically tested refrigerant charge or a field-verified fault indicator display (FID). This allowance applies only to ducted split-systems and packaged air-conditioners and heat pumps. Refrigerant charge verification is required by §150.1(c) and Table 150.1-A for the proposed cooling system type

STANDARD DESIGN

The standard design building is modeled with either diagnostically tested refrigerant charge or a field-verified FID if the building is in Climate Zone 2 or 8–15.

VERIFICATION AND REPORTING

Refrigerant charge or FID require field verification or diagnostic testing and is reported in the HERS required verification listings on the CF1R. Details on refrigerant charge measurement are discussed in *Reference Residential Appendix RA3.2*. Information on the requirements for FIDs is in *Reference Joint Appendix JA6.1*.

Table 10: Summary of Space Conditioning Measures Requiring Verification

Measure	Description	Procedures
Verified Refrigerant Charge	Air-cooled air-conditioners and air-source heat pumps must be tested diagnostically to verify that the system has the correct refrigerant charge. The system must also meet the system airflow requirement.	RA1.2, RA3.2
Verified Fault Indicator Display	A fault indicator display can be installed as an alternative to refrigerant charge testing.	RA3.4.2
Verified System Airflow	When compliance requires verified system airflow greater than or equal to a specified criterion.	RA3.3
Verified Air-Handling Unit Fan Efficacy	To verify that fan efficacy (watt/CFM) is less than or equal to a specified criterion.	RA3.3
Verified HSPF/HSPF2, SEER/SEER2 or EER/EER2	Credit for increased efficiency by installation of specific air-conditioner or heat pump models.	RA3.4.4.1
Verified Heat Pump Capacity	Optional verification of heat-pump system capacity.	RA3.4.4.2

Evaporatively Cooled Condensers	Must be combined with duct leakage testing, refrigerant charge, and verified EER/EER2.	RA3.1.4.3, RA3.2, RA3.4.3, RA3.4.4.1
Whole-House Fan	When verification of the whole-house fan is selected or required, airflow, watt draw, and capacity are verified.	RA3.9
Central Fan Ventilation Cooling System	When compliance includes this type of ventilation cooling, airflow and fan efficacy are verified.	RA3.3.4

Source: California Energy Commission

2.4.6.2 Verified System Airflow

Adequate airflow to the conditioned space is required to allow ducted air-conditioning systems to operate at full efficiency and capacity. Efficiency is achieved by the air-distribution system design by improving the efficiency of motors or by designing and installing air distribution systems that have less resistance to airflow. Software calculations account for the effect of airflow on sensible heat ratio and compressor efficiency.

For systems other than small-duct, high-velocity types, a value less than 350 CFM/ton (minimum 150 CFM/ton) is a valid input only if zonally controlled equipment is selected and multispeed compressor is not selected. Inputs less than 350 CFM/ton for zonally controlled systems require verification using procedures in *Reference Appendices, Residential Appendix RA3.3*.

Section 150.0(m)13 requires verification that the central air-handling unit airflow rate is greater than or equal to 350 CFM/ton for systems other than small-duct, high-velocity types or 250 CFM/ton for small-duct, high-velocity systems. Values greater than the required CFM/ton may be input for compliance credit, require diagnostic testing using procedures in *Reference Appendices, Residential Appendix RA3.3*.

For single-zone systems:

- As an alternative to verification of 350 CFM/ton for systems other than small-duct, high-velocity types or 250 CFM/ton for small-duct, high-velocity systems, HERS verification of a return duct design that conforms to the specification given in Table 150.0-B or C may be used to demonstrate compliance.
- The return duct design alternative is not an input to the compliance software but must be documented on the certificate of installation.
- If a value greater than 350 CFM/ton for systems other than small-duct, high-velocity types or greater than 250 CFM/ton for small-duct, high-velocity systems is modeled for compliance credit, the alternative return duct design method using Table 150.0-B or C is not allowed for demonstrating compliance.

- Variable-capacity systems including multispeed and variable-speed compressor systems must verify airflow rate (CFM/ton) for system operation at the maximum compressor speed and the maximum air handler fan speed.

For zonally controlled systems:

- The Table 150.0-B or C return duct design alternative is not allowed for zonally controlled systems.
- Variable-capacity systems including multispeed, variable-speed, and single-speed compressor systems must all verify airflow rate (CFM/ton) by operating the system at maximum compressor capacity and maximum system fan speed in every zonal control mode with all zones calling for conditioning.
- Single-speed compressor systems must also verify airflow rate (CFM/ton) in every zonal control mode.
- For systems that input less than 350 CFM/ton, HERS verification compliance cannot use group sampling.

PROPOSED DESIGN

The default cooling airflow is 150 CFM/ton for a system with “zonally controlled” selected and “multispeed compressor” not selected (single-speed). Users may model airflow for these systems greater than or equal to 150 CFM/ton, which must be verified using the procedures in *Reference Appendices, Residential Appendix RA3.3*. Inputs less than the rates required by §150.0(m)13 will be penalized in the compliance calculation.

The default cooling airflow is 350 CFM/ton for systems other than small-duct, high-velocity types or 250 CFM/ton for small-duct, high-velocity systems. Users may model a higher-than-default airflow for these systems and receive credit in the compliance calculation if greater-than-default system airflow is diagnostically tested using the procedures of *Reference Appendices, Residential Appendix RA3.3*.

STANDARD DESIGN

The standard design shall assume a system that complies with mandatory (§150.0) and prescriptive (§150.1) requirements for the applicable climate zone.

VERIFICATION AND REPORTING

The airflow rate verification compliance target (CFM or CFM/ton) is reported in the HERS required verification listings of the CF1R. When there is no cooling system, it is reported on the CF1R as a special feature.

2.4.6.3 Verified Air-Handling Unit Fan Efficacy

The mandatory requirement in §150.0(m)13 is for an air-handling unit fan efficacy less than or equal to 0.45 watts/CFM for gas furnace air-handling units, 0.58 watts/CFM for air-handling units that are not gas furnaces, and 0.62 W/CFM for small-duct, high-velocity

systems as verified by a HERS Rater. Users may model a lower fan efficacy (W/CFM) and receive credit in the compliance calculation if the proposed fan efficacy value is diagnostically tested using the procedures in *Reference Appendices, Residential Appendix RA3.3*.

For single-zone systems:

- Installers may elect to use an alternative to HERS verification of the watts/CFM required by §150.0(m)13: HERS verification of a return duct design that conforms to the specification given in Table 150.0-B or C.
- The return duct design alternative is not an input to the compliance software but must be documented on the certificate of installation.
- If a value less than the watts/CFM required by §150.0(m)13 is modeled by the software user for compliance credit, the alternative return duct design method using Table 150.0-B or C is not allowed for use in demonstrating compliance.
- Multispeed or variable-speed compressor systems must verify fan efficacy (watt/CFM) for system operation at the maximum compressor speed and the maximum air handler fan speed.

For zonally controlled systems:

- The Table 150.0-B or C return duct design alternative is not allowed for zonally controlled systems.
- Multispeed, variable-speed, and single-speed compressor systems must all verify fan efficacy (watt/CFM) by operating the system at maximum compressor capacity and maximum system fan speed with all zones calling for conditioning.
- Single-speed compressor systems must verify fan efficacy in every zonal control mode.

PROPOSED DESIGN

The software shall allow the user to enter the fan efficacy. The default mandatory value is 0.45, 0.58, or 0.62 W/CFM, depending on the applicable system type. However, users may specify a lower value and receive credit in the compliance calculation if verified and diagnostically tested using the procedures of *Reference Appendices, Residential Appendix RA3.3*.

If no cooling system is installed, a default value of 0.45 W/CFM is assumed.

STANDARD DESIGN

The standard design shall assume a verified fan efficacy less than or equal to the following:

- 0.45 W/CFM for gas furnace air-handling units, as well as air-handling unit that are not gas furnaces and have a **cooling** capacity less than 54,000 BTU/h

Commented [AG1]: Assuming the 54kBTU/h is based on cooling capacity.

- 0.58 W/CFM for air-handling units that are not gas furnaces and have a [cooling](#) capacity greater than or equal to 54,000 BTU/h
- 0.62 W/CFM for small duct high velocity forced air systems

VERIFICATION AND REPORTING

For user inputs lower than the default mandatory requirement, fan efficacy is reported in the HERS-required verification listings of the CF1R.

For default mandatory 0.45, 0.58, or 0.62 watts/cfm, the choice of either fan efficacy or alternative return duct design according to Table 150.0-B or C is reported in the HERS-required verification listings of the CF1R.

No cooling system is reported as a special feature on the CF1R.

2.4.6.4 Verified Energy Efficiency Ratio (EER/EER2)**PROPOSED DESIGN**

Software shall allow the user the option to enter an EER/EER2 rating for central cooling equipment. For equipment that is rated only with an EER/EER2 (room air conditioners), the user will enter the EER/EER2. The *Appliance Efficiency Regulations* require a minimum SEER/SEER2 and EER/EER2 for central cooling equipment. Only if a value higher than a default minimum EER/EER2 is used is it reported as a HERS-verified measure.

STANDARD DESIGN

The standard design is based on the default minimum efficiency EER/EER2 for the type of cooling equipment modeled in the proposed design, based on the applicable *Appliance Efficiency Regulations*. The standard design for central air-conditioning equipment is 11.7 EER/11.2 EER2.

VERIFICATION AND REPORTING

If an EER/EER2 higher than the default minimum efficiency is modeled in software, the EER/EER2 requires field verification. The EER/EER2 rating is verified using rating data from the [AHRI Directory of Certified Product Performance](#) website or another directory of certified product performance ratings approved by the CEC for determining compliance. Verified EER is reported in the HERS-required verification listings on the CF1R.

2.4.6.5 Verified Seasonal Energy Efficiency Ratio (SEER/SEER2)**PROPOSED DESIGN**

The software allows the user to specify the SEER/SEER2 value.

STANDARD DESIGN

The standard design is based on the default minimum efficiency SEER/SEER2 for the type of cooling equipment modeled in the proposed design, based on the applicable *Appliance Efficiency Regulations*. For central-cooling equipment, the minimum efficiency is 14 SEER/13.8 SEER2.

VERIFICATION AND REPORTING

If a SEER/SEER2 higher than the default minimum efficiency is modeled in software, the SEER/SEER2 requires field verification. The higher-than-minimum SEER/SEER2 rating is verified using rating data from [AHRI Directory of Certified Product Performance](#) website or another directory of certified product performance ratings approved by the CEC for determining compliance. Verified SEER/SEER2 is reported in the HERS-required verification listings on the CF1R.

2.4.6.6 Verified Evaporatively Cooled Condensers

PROPOSED DESIGN

Software shall allow users to specify an evaporatively cooled condensing unit. The installation must comply with the requirements of *Reference Appendices, Residential Appendix RA4.3.2* to ensure the predicted energy savings are achieved. This credit must be combined with verified refrigerant charge testing, EER/EER2, and duct leakage testing.

STANDARD DESIGN

The standard design is based on a split-system air-conditioner meeting the requirements of §150.1(c) and Table 150.1-A.

VERIFICATION AND REPORTING

An evaporatively cooled condensing unit, verified EER/EER2, and duct leakage testing are reported in the HERS required verification listings on the CF1R.

2.4.6.7 Evaporative Cooling

Evaporative cooling technology is best suited for dry climates where direct, indirect, or indirect-direct cooling of the supply air stream can occur without compromising indoor comfort. Direct evaporative coolers are the most common system type available but provide less comfort and deliver more moisture to the indoor space. They are assumed equivalent to a minimum split-system air-conditioner. The evaporative cooling modeling method addresses two performance issues. The first performance issue is the increase in indoor relative humidity levels during periods with extended cooler operation. Since modeling of indoor air moisture levels is beyond the capability of simulation models, a simplified algorithm is used to prohibit evaporative cooler operation during load hours when operation is expected to contribute to uncomfortable indoor conditions. The algorithm disallows cooler

operation when outdoor wet bulb temperatures are 70°F or above. The second performance issue relates to evaporative cooler capacity limitations. Since evaporative coolers are 100 percent outdoor air systems, the related capacity is limited by the outdoor wet bulb temperature. Each hour with calculated cooling load, the algorithm will verify that the cooling capacity is greater than the calculated cooling load.

PROPOSED DESIGN

Software shall allow users to specify one of three types of evaporative cooling: (1) direct evaporative cooler, the most commonly available system type; (2) indirect; or (3) indirect-direct. Product specifications and other modeling details are found in the CEC appliance directory for evaporative cooling. Direct system types are assigned an efficiency of 14 SEER (or minimum appliance efficiency standard for split-system cooling). The default system type is evaporative direct. For indirect or indirect-direct, select the appropriate type from the CEC appliance directory and input a 13 EER as well as the airflow and media saturation effectiveness or cooling effectiveness from the CEC appliance directory.

STANDARD DESIGN

The standard design is based on a split-system air-conditioner meeting the requirements of §150.1(c) and Table 150.1-A.

VERIFICATION AND REPORTING

When a direct evaporative cooling system is modeled, the system type and minimum efficiency are shown in the appropriate section of the CF1R. When indirect or indirect-direct evaporative cooling is modeled, the EER/EER2 verification is shown in the HERS verification section of the CF1R, along with the system type, airflow, and system effectiveness.

2.4.7 Distribution Subsystems

If multiple HVAC distribution systems serve a building, each system, and the conditioned space it serves may be modeled in detail separately or the systems may be aggregated and modeled as one large system. If the systems are aggregated, they must be the same type, and all meet the same minimum specifications.

For duct efficiency calculations, the supply duct begins at the exit from the furnace or air-handler cabinet.

2.4.7.1 Distribution Type

Fan-powered, ducted distribution systems can be used with most heating or cooling systems. When ducted systems are used with furnaces, boilers, or combined hydronic/water heating systems, the electricity used by the fan is calculated. R-value and duct location are specified when a ducted system is specified.

PROPOSED DESIGN

The compliance software shall allow the user to select from the basic types of HVAC distribution systems and locations listed in Table 11. For ducted systems, the default location of the HVAC ducts and the air handler are in the attic.

Table 11: HVAC Distribution Type and Location Descriptors

Name	HVAC Distribution Type and Location Description
Ducts located in attic (ventilated and unventilated)	Ducts located overhead in the attic space.
Ducts located in a crawl space	Ducts located under floor in the crawl space.
Ducts located in a garage	Ducts located in an unconditioned garage space.
Ducts located within the conditioned space (except < 12 linear ft)	Ducts located within the conditioned floor space except for less than 12 linear feet of duct, furnace cabinet, and plenums — typically an HVAC unit in the garage mounted on return box with all other ducts in conditioned space.
Ducts located entirely in conditioned space	HVAC unit or systems with all HVAC ducts (supply and return) within the conditioned floor space. Location of ducts in conditioned space eliminates conduction losses but does not change losses due to leakage. Leakage either from ducts that are not tested for leakage or from sealed ducts is modeled as leakage to outside the conditioned space.
Distribution system without ducts (none)	Air-distribution systems without ducts such as ductless split-system air-conditioners and heat pumps, window air-conditioners, through-the-wall heat pumps, wall furnaces, floor furnaces, radiant electric panels, combined hydronic heating equipment, electric baseboards, or hydronic baseboard finned-tube natural convection systems, etc.
Ducts located in outdoor locations	Ducts in exposed locations outdoors.
Verified low-leakage ducts located entirely in conditioned space	Duct systems for which air leakage to outside is equal to or less than 25 CFM when measured in accordance with Reference Residential Appendix RA3.1.4.3.8.
Ducts located in multiple places	Ducts with different supply and return duct locations.

Source: California Energy Commission

Table 12: Summary of Verified Distribution Systems

Measure	Description	Procedures
Verified Duct Sealing	Mandatory measures require that space-conditioning ducts be sealed. Field verification and diagnostic testing are required to verify that approved duct system materials are used, and that duct leakage meets the specified criteria.	RA3.1.4.3
Verified Duct Location, Reduced Surface Area and R-value	Compliance credit can be taken for improved supply duct location, reduced surface area, and R-value. Field verification is required to verify that the duct system was installed according to the duct design, including location, size and length of ducts, duct insulation R-value, and installation of buried ducts. ¹ For buried duct measures, verified QII is required, as well as duct sealing.	RA3.1.4.1, 3.1.4.1.1
Low-Leakage Ducts in Conditioned Space	When the standards specify use of the procedures in Reference Appendices, Residential Appendix RA3.1.4.3.8 to determine if the space-conditioning system ducts are entirely in directly conditioned space, the duct system location is verified by diagnostic testing. Compliance credit can be taken for verified duct systems with low air leakage to the outside when measured in accordance with Reference Appendices, Residential Appendix RA3.1.4.3.8. Field verification for ducts in conditioned space is required. Duct sealing is required.	RA3.1.4.3.8
Hydronic Delivery in Conditioned Space	Compliance credit can be taken for hydronic delivery systems with no ducting or piping in unconditioned space. For radiant ceiling panels, the verifications in Reference Appendices, Residential Appendix RA3.4.5 must be completed to qualify.	RA3.4.5
Low-Leakage Air-Handling Units	Compliance credit can be taken for installing a factory-sealed air-handling unit tested by the manufacturer and certified to the CEC to have met the requirements for a low-leakage air-handling unit. Field verification of the air handler model number is required. Duct sealing is required.	RA3.1.4.3.9
Verified Return Duct Design	Verification to confirm that the return duct design conforms to the criteria given in Table 150.0-B or	RA3.1.4.4

	Table 150.0-C. as an alternative to meeting 0.45 or 0.58 W/CFM fan efficacy of §150.0(m)13.	
Verified Bypass Duct Condition	Verification to determine if system is zonally controlled and confirm that bypass ducts condition modeled matches installation.	RA3.1.4.6

1. Compliance credit for increased duct insulation R-value (not buried ducts) may be taken without field verification if the R-value is the same throughout the building, and for supply ducts located in crawl spaces and garages where all supply registers are either in the floor or within 2 feet of the floor. If these conditions are met, HERS Rater verification is not required.

Source: California Energy Commission

The software will allow users to select default assumptions or specify any of the verified or diagnostically tested HVAC distribution system conditions in the proposed design (Table 12), including duct leakage target, R-value, supply and return duct area, diameter, and location.

STANDARD DESIGN

The standard heating and cooling system for central systems is modeled with nondesigned air-distribution ducts located as described in Table 13, with duct leakage as specified in Table 21. The standard design duct insulation is determined by Table 150.1-A (assuming attic Option B) as R-6 in Climate Zones 3 and 5–7, and R-8 in Climate Zones 1, 2, 4, and 8–16. The standard design building is assumed to have the same number of stories as the proposed design for determining the duct efficiency.

Table 13: Summary of Standard Design Duct Location

Configuration of the Proposed Design	Standard Design Duct Location	Detailed Specifications
Attic over the dwelling unit	Ducts and air handler located in the attic	Ducts sealed (mandatory requirement) No credit for verified R-value, location, or duct design
No attic but crawl space or basement	Ducts and air handler located in the crawl space or basement	Ducts sealed (mandatory requirement) No credit for verified R-value, location, or duct design
Buildings with no attic, crawl space or basement	Ducts and air handler located indoors	Ducts sealed (mandatory requirement) No credit for verified R-value, location or duct design

This table is applicable only when the standard design system has air-distribution ducts

Source: California Energy Commission

VERIFICATION AND REPORTING

Distribution type, location, R-value, and the determination of whether tested and sealed will be shown on the CF1R. If there are no ducts, the absence of ducts is shown as a special feature on the CF1R. Any duct location other than attic (for example, crawl space) is shown as a special feature on the CF1R. Ducts in crawl space or the basement shall include a special feature note if supply registers are within 2 feet of the floor. Measures that require HERS verification will be shown in the HERS required verification section of the CF1R.

2.4.7.2 Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses.

PROPOSED DESIGN

If any part of the supply or return duct system is in an unconditioned attic, that entire duct system is modeled with an attic location. If no part of the supply or return duct system is located in the attic, but the duct system is not entirely in conditioned space, it is modeled in the unconditioned zone, which contains the largest fraction of the surface area. If the

supply or return duct system is entirely in conditioned space, the duct system is modeled in conditioned space.

For ducted HVAC systems with some or all ducts in unconditioned space, the user specifies the R-value and surface area of supply and return ducts and the duct location.

Duct location and areas other than the defaults shown in Table 14 may be used following the verification procedures in *Reference Appendices, Residential Appendix RA3.1.4.1*.

STANDARD DESIGN

The standard design duct location is determined from the building conditions (Table 13).

VERIFICATION AND REPORTING

Duct location is reported on the CF1R. Ducts entirely in conditioned space and verified low-leakage ducts entirely in conditioned space are reported in the HERS-required verification listing on the CF1R.

Default duct locations are shown in Table 14. The duct surface area for crawl space and basement applies only to buildings or zones with all ducts installed in the crawl space or basement. If the duct is installed in locations other than crawl space or basement, the default duct location is "Other." For houses with two or more stories, 35 percent of the default duct area may be assumed to be in conditioned space, as shown in Table 14.

The surface area of ducts in conditioned space is ignored in calculating conduction losses.

Table 14: Location of Default Duct Surface Area

Supply Duct Location	One story	Two or more stories
All in crawl space	100% crawl space	65% crawl space, 35% conditioned space
All in basement	100% basement	65% basement, 35% conditioned space
Other	100% attic	65% attic, 35% conditioned space

Source: California Energy Commission

2.4.7.3 Duct Surface Area

The supply-side and return-side duct surface areas are treated separately in distribution efficiency calculations. The duct surface area is determined using the following methods.

2.4.7.4 Default Return Duct Surface Area

Default return duct surface area is calculated using:

$$A_{r,out} = K_r \times A_{floor} \quad \text{Equation 4}$$

Where K_r (return duct surface area coefficient) is 0.05 for one-story buildings and 0.1 for two or more stories.

2.4.7.5 Default Supply Duct Surface Area

STANDARD DESIGN

The standard design and default proposed design supply duct surface area is calculated using Equation 5.

$$A_{s, out} = 0.27 \times A_{floor} \times K_S \quad \text{Equation 5}$$

Where K_s (supply duct surface area coefficient) is 1 for one-story buildings and 0.65 for two or more stories.

2.4.7.6 Supply Duct Surface Area for Less Than 12 feet of Duct in Unconditioned Space

PROPOSED DESIGN

For proposed design HVAC systems with air handlers outside the conditioned space but with less than 12 linear feet of duct outside the conditioned space, including air handler and plenum, the supply duct surface area outside the conditioned space is calculated using Equation 6. The return duct area remains the default for this case.

$$A_{s, out} = 0.027 \times A_{floor} \quad \text{Equation 6}$$

2.4.7.7 Diagnostic Duct Surface Area

Proposed designs may claim credit for reduced surface area using the procedures in *Reference Appendices, Residential Appendix RA3.1.4.1*.

The surface area of each duct system segment shall be calculated based on the associated inside dimensions and length. The total supply surface area in each unconditioned location (attic, attic with radiant barrier, crawl space, basement, other) is the sum of the area of all duct segments in that location. The surface area of ducts completely inside conditioned space need not be input in the compliance software and is not included in the calculation of duct system efficiency. The area of ducts in floor cavities or vertical chases that are surrounded by conditioned space and separated from unconditioned space with draft stops are also not included. The software assumes the user input duct system area is 85 percent of the total duct system area. The other 15 percent is assumed to be air handler, plenum, and connectors. Because of this, the total duct system area used in the building simulation is:

Simulated Duct System Area = 1.1765 multiplied by the total user entered duct system area

2.4.7.8 Bypass Duct

Section 150.1(c)13 prohibits use of bypass ducts unless a bypass duct is otherwise specified on the certificate of compliance. A bypass duct may be needed for some single-speed outdoor condensing unit systems. The software allows users to specify a bypass duct for the system. Selection of a bypass duct does not trigger changes in the ACM modeling defaults, but verification by a HERS Rater is required to use the procedure in Reference Appendices, Residential Appendix RA3.1.4.6.

Specification of a zonally controlled system with a single-speed condensing unit will trigger a default airflow rate value of 150 CFM/ton for the calculations. User input less than 350 CFM/ton reduces the compliance margin as compared to systems that model 350 CFM/ton as described in Section 2.4.6.2 Verified System Airflow.

PROPOSED DESIGN

Software shall allow users to specify whether a bypass duct is used for a zonally controlled forced air system.

STANDARD DESIGN

The standard design is based on a split-system air-conditioner meeting the requirements of §150.1(c) and Table 150.1-A. The system is not a zonally controlled system.

VERIFICATION AND REPORTING

An HVAC system with zonal control, and the determination of whether the system is assumed to have a bypass duct or have no bypass duct, is reported in the HERS-required verification listings on the CF1R.

2.4.7.9 Duct System Insulation

For conduction calculations in the standard and proposed designs, 85 percent of the supply and return duct surface is assumed duct material at the related specified R-value, and 15 percent is assumed air handler, plenum, connectors, and other components at the mandatory minimum R-value.

The area weighted effective R-value is calculated by the compliance software using Equation 7, including each segment of the duct system that has a different R-value.

$$R_{\text{eff}} = \frac{(A_1 + A_2 + \dots + A_N)}{\left[\frac{1}{R_1} + \frac{2}{R_2} + \dots + \frac{N}{R_N} \right]} \quad \text{Equation 7}$$

Where:

R_{eff} = Area weighted effective R-value of duct system for use in calculating duct efficiency, (h-ft²-°F/Btu)

A_N = Area of duct segment n, square feet

R_N = R-value of duct segment n including film resistance (duct insulation rated R + 0.7) (h-ft²-°F/Btu)

PROPOSED DESIGN

The software user inputs the R-value of the proposed duct insulation and details. The default duct thermal resistance is based on Table 150.1-A, attic option B, which is R-6 in Climate Zones 3 and 5–7, R-8 in Zones 1, 2, 4, and 8–16.

Duct location and duct R-value are reported on the CF1R. Credit for systems with mixed insulation levels, nonstandard supply and return duct surface areas, or ducts buried in the attic require the compliance and diagnostic procedures in *Reference Appendices, Residential Appendix RA3.1.4.1*.

If verified duct design is selected, the user must enter the duct design into the software. For each duct segment entered, the user must specify Type (supply/return), Buried (yes/no, per Section 2.4.7.10 Buried Attic Ducts), Diameter (inside/nominal), Length, and Duct Insulation R-value. User-entered duct design must be verified by a HERS Rater according to the procedures in *Reference Appendices, Residential Appendix RA3.1.4.1.1*. User-entered duct design and duct location are reported on the CF1R when nonstandard values are specified.

STANDARD DESIGN

The required duct insulation R-value for attic Option B is from Table 150.1-A for the applicable climate zone used in the standard design.

VERIFICATION AND REPORTING

Duct type (supply/return), nominal diameter, length, R-value, and location, and supply and return areas are reported on the CF1R. Verified duct design is reported in the HERS-required verification listing on the CF1R.

2.4.7.10 Buried Attic Ducts

Ducts partly, fully, or deeply buried in blown attic insulation in dwelling units meeting the requirements for verified QII may take credit for increased effective duct insulation. To qualify for buried duct credit, ducts must meet mandatory insulation levels (R-6) prior to burial, be directly or within 3.5 inches of ceiling gypsum board and be surrounded by at least R-30 attic insulation. Moreover, credit is available only for duct runs where the ceiling is level, there is at least 6 inches of space between the duct outer jacket and the roof

sheathing, and the attic insulation has uniform depth. Existing ducts are exempt from mandatory minimum insulation levels, but to qualify for buried duct credit, they must have greater than R-4.2 insulation before burial.

In addition to the above requirements, deeply buried ducts must be buried by at least 3.5 inches of insulation above the top of the duct insulation jacket and located within a lowered area of the ceiling, a deeply buried containment system, or buried by at least 3.5 inches of uniformly level insulation. Mounding insulation to achieve the 3.5-inch burial level is not allowed.

Deeply buried duct containment systems must be installed such that the walls of the system are at least 7 inches wider than the duct diameter (3.5 inches on each side of duct), the walls extend at least 3.5 inches above the duct outer jacket, and the containment area surrounding the duct must be completely filled with blown insulation.

The duct design shall identify the segments of the duct that meet the requirements for being buried, and these are input into the software separately from nonburied ducts. For each buried duct, the user must enter the duct size, R-value, and length, and determination of whether the duct qualifies as deeply buried. The user must also indicate if a duct uses a deeply buried containment system. The software calculates the weighted average effective duct system R-value based on the user-entered duct information, blown insulation type (cellulose or fiberglass), and R-value.

Duct-effective R-values are broken into three categories: partially, fully, and deeply, with each having different burial levels and requirements. Partially buried ducts have less than 3.5 inches of exposed duct depth, fully buried ducts have insulation depth at least level with the duct jacket, and deeply buried ducts have at least 3.5 inches of insulation above the duct jacket in addition to the above requirements. Effective duct R-values used by the software are listed in Table 15, Table 16, Table 17, Table 18, Table 19, and Table 20.

PROPOSED DESIGN

The software calculates the effective R-value of buried ducts based on user-entered duct size, R-value, and length; attic insulation level and type; and determination of whether the duct meets the requirements of a deeply buried duct by using a lowered ceiling chase or a containment system. This feature must be combined with verified QII, verified duct location, reduced surface area and R-value, and verified minimum airflow. The software will allow any combination of duct runs and the associated buried condition, and the overall duct system effective R-value will be a weighted average of the combination. The default is no buried ducts.

STANDARD DESIGN

The standard design has no buried ducts.

VERIFICATION AND REPORTING

Buried duct credit is reported in the HERS required verification listing on the CF1R.

**Table 15: Buried Duct Effective R-Values:
R-8 Ducts With Blown Fiberglass Attic Insulation**

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
3"	R-18	R-26	R-26	R-26	R-26	R-26
4"	R-13	R-18	R-26	R-26	R-26	R-26
5"	R-13	R-18	R-18	R-26	R-26	R-26
6"	R-13	R-18	R-18	R-18	R-26	R-26
7"	R-13	R-13	R-18	R-18	R-26	R-26
8"	R-8	R-13	R-13	R-18	R-18	R-26
9"	R-8	R-13	R-13	R-13	R-18	R-26
10"	R-8	R-13	R-13	R-13	R-18	R-26
12"	R-8	R-8	R-8	R-13	R-13	R-26
14"	R-8	R-8	R-8	R-8	R-13	R-18
16"	R-8	R-8	R-8	R-8	R-8	R-13
18"	R-8	R-8	R-8	R-8	R-8	R-13
20"	R-8	R-8	R-8	R-8	R-8	R-8
22"	R-8	R-8	R-8	R-8	R-8	R-8
24"	R-8	R-8	R-8	R-8	R-8	R-8

Source: California Energy Commission

**Table 16: Buried Duct Effective R-Values:
R-8 Ducts with Blown Cellulose Attic Insulation**

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
3"	R-14	R-20	R-20	R-20	R-32	R-32
4"	R-14	R-14	R-20	R-20	R-20	R-32
5"	R-8	R-14	R-14	R-20	R-20	R-32
6"	R-8	R-14	R-14	R-14	R-20	R-32

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
7"	R-8	R-14	R-14	R-14	R-20	R-20
8"	R-8	R-8	R-8	R-14	R-14	R-20
9"	R-8	R-8	R-8	R-8	R-14	R-20
10"	R-8	R-8	R-8	R-8	R-14	R-20
12"	R-8	R-8	R-8	R-8	R-8	R-14
14"	R-8	R-8	R-8	R-8	R-8	R-8
16"	R-8	R-8	R-8	R-8	R-8	R-8
18"	R-8	R-8	R-8	R-8	R-8	R-8
20"	R-8	R-8	R-8	R-8	R-8	R-8
22"	R-8	R-8	R-8	R-8	R-8	R-8
24"	R-8	R-8	R-8	R-8	R-8	R-8

Source: California Energy Commission

**Table 17: Buried Duct Effective R-Values:
R-6 Ducts with Blown Fiberglass Attic Insulation**

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
3"	R-15	R-24	R-24	R-24	R-24	R-24
4"	R-15	R-24	R-24	R-24	R-24	R-24
5"	R-11	R-15	R-24	R-24	R-24	R-24
6"	R-11	R-15	R-15	R-24	R-24	R-24
7"	R-11	R-15	R-15	R-15	R-24	R-24
8"	R-11	R-15	R-15	R-15	R-24	R-24
9"	R-6	R-11	R-11	R-15	R-24	R-24
10"	R-6	R-11	R-11	R-15	R-15	R-24
12"	R-6	R-6	R-11	R-11	R-15	R-24
14"	R-6	R-6	R-6	R-6	R-11	R-15
16"	R-6	R-6	R-6	R-6	R-11	R-15
18"	R-6	R-6	R-6	R-6	R-6	R-11
20"	R-6	R-6	R-6	R-6	R-6	R-11

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
22"	R-6	R-6	R-6	R-6	R-6	R-6
24"	R-6	R-6	R-6	R-6	R-6	R-6

Source: California Energy Commission

**Table 18: Buried Duct Effective R-Values:
R-6 Ducts with Blown Cellulose Attic Insulation**

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
3"	R-12	R-18	R-18	R-18	R-31	R-31
4"	R-12	R-18	R-18	R-18	R-31	R-31
5"	R-12	R-12	R-18	R-18	R-18	R-31
6"	R-6	R-12	R-12	R-18	R-18	R-31
7"	R-6	R-12	R-12	R-12	R-18	R-31
8"	R-6	R-12	R-12	R-12	R-18	R-31
9"	R-6	R-6	R-6	R-12	R-12	R-18
10"	R-6	R-6	R-6	R-6	R-12	R-18
12"	R-6	R-6	R-6	R-6	R-6	R-12
14"	R-6	R-6	R-6	R-6	R-6	R-12
16"	R-6	R-6	R-6	R-6	R-6	R-6
18"	R-6	R-6	R-6	R-6	R-6	R-6
20"	R-6	R-6	R-6	R-6	R-6	R-6
22"	R-6	R-6	R-6	R-6	R-6	R-6
24"	R-6	R-6	R-6	R-6	R-6	R-6

Source: California Energy Commission

**Table 19: Buried Duct Effective R-Values:
R-4.2 Ducts With Blown Fiberglass Attic Insulation**

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
3"	R-13	R-22	R-22	R-22	R-22	R-22
4"	R-13	R-22	R-22	R-22	R-22	R-22
5"	R-13	R-22	R-22	R-22	R-22	R-22

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
6"	R-13	R-13	R-22	R-22	R-22	R-22
7"	R-9	R-13	R-13	R-22	R-22	R-22
8"	R-9	R-13	R-13	R-13	R-22	R-22
9"	R-9	R-13	R-13	R-13	R-22	R-22
10"	R-4.2	R-9	R-13	R-13	R-13	R-22
12"	R-4.2	R-9	R-9	R-9	R-9	R-22
14"	R-4.2	R-4.2	R-4.2	R-9	R-9	R-22
16"	R-4.2	R-4.2	R-4.2	R-4.2	R-9	R-13
18"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-9
20"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-9
22"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
24"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2

Source: California Energy Commission

**Table 20: Buried Duct Effective R-Values:
R-4.2 Ducts with Blown Cellulose Attic Insulation**

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
3"	R-15	R-15	R-29	R-29	R-29	R-29
4"	R-9	R-15	R-15	R-15	R-29	R-29
5"	R-9	R-15	R-15	R-15	R-29	R-29
6"	R-9	R-9	R-15	R-15	R-15	R-29
7"	R-4.2	R-9	R-9	R-15	R-15	R-29
8"	R-4.2	R-9	R-9	R-9	R-15	R-29
9"	R-4.2	R-9	R-9	R-9	R-15	R-15
10"	R-4.2	R-4.2	R-9	R-9	R-9	R-15
12"	R-4.2	R-4.2	R-4.2	R-4.2	R-9	R-15
14"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-9
16"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-9
18"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2

Duct Diameter	R-30 Ceiling	R-38 Ceiling	R-40 Ceiling	R-43 Ceiling	R-49 Ceiling	R-60 Ceiling
20"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
22"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
24"	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2

Source: California Energy Commission

2.4.7.11 **Duct/Air Handler Leakage**

The total duct/air handler leakage shown in Table 21 is used in simulating the duct system. The supply duct leakage for each case is the table value multiplied by 0.585. The return leakage is the table value multiplied by 0.415.

PROPOSED DESIGN

For each ducted system, the software user specifies one of the duct/air handler leakage cases shown in Table 21.

STANDARD DESIGN

For ducted systems, the standard design is sealed and tested duct systems in existing dwelling units or new duct systems.

VERIFICATION AND REPORTING

Sealed and tested duct systems are listed in the HERS verification section of the CF1R. Duct leakage is measured in accordance with procedures and values specified in Reference Appendices, Residential Appendix RA3.

2.4.7.12 **Low Leakage Air Handlers**

A low-leakage air handler may be specified as well as a lower duct leakage value. (See Section 2.4.7.11.) Installation requires installing one of the list of approved low-leakage air handling units published by the CEC. The manufacturer certifies that the appliance complies with the requirements of Reference Appendices, Joint Appendices JA9.2.1, 9.2.2, 9.2.3, and 9.2.4.

Table 21: Duct/Air Handler Leakage

Case	Duct Leakage	Air Handler Leakage	Total Duct/Air Handler Leakage
Duct systems in existing single-family houses	15%	Included in duct leakage	15%
Sealed and tested new or altered duct systems in unconditioned or conditioned space in a townhome or single-family home	5%	2%	7%
Verified low-leakage ducts in conditioned space	0%	0%	0%
Low leakage air handlers in combination with sealed and tested new duct systems	5% or as measured	0%	5% or as measured

Source: California Energy Commission

PROPOSED DESIGN

Credit can be taken for installing a factory-sealed air-handling unit tested by the manufacturer and certified to the CEC to meet the requirements for a low-leakage air-handler. Field verification of the air handler model number is required.

STANDARD DESIGN

The standard design has a normal air handler.

VERIFICATION AND REPORTING

A low-leakage air handler is reported on the compliance report and field verified in accordance with the procedures specified in Reference Appendices, Residential Appendix RA3.1.4.3.9.

2.4.7.13 Verified Low-Leakage Ducts in Conditioned Space

PROPOSED DESIGN

For ducted systems, the user may specify that all ducts are entirely in conditioned space, and the software will model the duct system with no leakage and no conduction losses.

STANDARD DESIGN

The standard design has ducts in the default location.

VERIFICATION AND REPORTING

Systems that have all ducts entirely in conditioned space are reported on the compliance documents and verified by measurements showing duct leakage to outside conditions is equal to or less than 25 CFM when measured in accordance with *Reference Appendices, Residential Appendix RA3*.

2.4.8 Space-Conditioning Fan Subsystems

Fan systems move air for air-conditioning, heating, and ventilation systems. The software allows the user to define the fans to be used for space-conditioning, IAQ, and ventilation cooling. IAQ and ventilation cooling are discussed in Sections [2.4.10 Indoor Air Quality Ventilation](#) and [2.4.11 Ventilation Cooling System](#).

PROPOSED DESIGN

For the space-conditioning fan system, the user selects the type of equipment and enters basic information to model the energy use of the equipment. For ducted central air-conditioning and heating systems, the fan efficacy default is the mandatory minimum verified efficacy of 0.45, 0.58, or 0.62 W/CFM, depending on applicable system type (also assumed when there is no cooling system).

STANDARD DESIGN

The standard design shall assume a verified fan efficacy complying with the mandatory requirement of less than or equal to the following:

- 0.45 W/CFM for gas furnace air-handling units, as well as air-handling unit that are not gas furnaces and have a capacity less than 54,000 BTU/h
- 0.58 W/CFM for air-handling units that are not gas furnaces and have a capacity greater than or equal to 54,000 BTU/h
- 0.62 W/CFM for small duct high velocity forced air systems

VERIFICATION AND REPORTING

Minimum verified fan efficacy is mandatory for all ducted cooling systems. Fan efficacy is reported in the HERS required verification listings on the CF1R.

2.4.9 Space-Conditioning Systems

This section describes the general procedures for heating and cooling systems in low-rise residential buildings. The system includes the cooling system, the heating system, distribution system, and mechanical fans.

If multiple systems serve a building, each system, and the conditioned space it serves may be modeled in detail separately or the systems may be aggregated and modeled as one large system. If the systems are aggregated, they must be the same type, and all meet the same minimum specifications.

2.4.9.1 Multiple System Types Within a Building

PROPOSED DESIGN

For proposed designs using more than one heating system type, equipment type, or fuel type, if the types do not serve the same floor area, then the user shall zone the building by system type.

STANDARD DESIGN

The standard design shall have the same zoning and heating system types as the proposed design.

VERIFICATION AND REPORTING

The heating system type of each zone is shown on the CF1R.

2.4.9.2 Multiple Systems Serving Same Area

If a space or a zone is served by more than one heating system, compliance is demonstrated with the most TDV energy-consuming system serving the space or the zone. For spaces or zones that are served by electric resistance heat in addition to other heating systems, the electric resistance heat is deemed the most TDV energy-consuming system unless the supplemental heating meets the exception to §150.1(c)6. See eligibility criteria in *Residential Compliance Manual* Section 4.2.2 for conditions under which the supplemental heat may be ignored.

For floor areas served by more than one cooling system, equipment, or fuel type, the system, equipment, and fuel type that satisfy the cooling load are modeled.

2.4.9.3 No Cooling

PROPOSED DESIGN

When the proposed design has no cooling system, the proposed design is required to model the standard design cooling system defined in §150.1(c) and Table 150.1-A. Since the

proposed design system is identical to the standard design system, there is no penalty or credit.

STANDARD DESIGN

The standard design system is the specified in §150.1(c) and Table 150.1-A for the applicable climate zone.

VERIFICATION AND REPORTING

No cooling is reported as a special feature on the CF1R.

2.4.9.4 Zonally Controlled Forced-Air Cooling Systems

Zonally controlled central forced-air cooling systems must be able to deliver, in every zonal control mode, an airflow to the dwelling of ≥ 350 CFM per ton of nominal cooling capacity and operating at an air-handling unit fan efficacy of ≤ 0.45 or 0.58 W/CFM depending on the applicable system type. This is a HERS-verified measure, complying with Reference Appendices, *Residential Appendix RA3.3*.

An exception allows multispeed or variable-speed compressor systems, or single-speed compressor systems to meet the mandatory airflow (CFM/ton) and fan efficacy (watt/CFM) requirements by operating the system at maximum compressor capacity, and system fan speed with all zones calling for conditioning, rather than in every zonal control mode.

PROPOSED DESIGN

The user selects zonally controlled as a cooling system input.

STANDARD DESIGN

The standard design building does not have a zonally controlled cooling system.

VERIFICATION AND REPORTING

Zonally controlled forced-air cooling systems are required to have the system bypass duct status verified by a HERS Rater according to the procedures in *Reference Appendices, Residential Appendix RA3.1.4.6*, and the fan efficacy and airflow rate are required to be verified according to the procedures in *RA3.3*.

2.4.10 Indoor Air Quality Ventilation

For newly constructed buildings and additions greater than 1,000 ft², the Energy Code requires that all dwelling units meet the requirements of ASHRAE Standard 62.2 with the amendments specified in §150.0(o). Providing acceptable IAQ by mechanical ventilation is one of the requirements of Standard 62.2. For single-family homes, the required mechanical

ventilation rate is equal to the total ventilation required for the dwelling minus the calculated annually averaged infiltration rate.

The total required ventilation rate for the dwelling unit is calculated using Energy Code, Equation 150.0-B.

Equation 8 (Equation 150.0-B)

$$Q_{\text{total}} = 0.03A_{\text{floor}} + 7.5(N_{\text{br}} + 1)$$

Where:

Q_{total} = Total required ventilation rate (CFM)

A_{floor} = Conditioned floor area in square feet (ft²)

N_{br} = Number of bedrooms (not fewer than one)

The effective infiltration rate of the dwelling is calculated using Equation 150.0-C or 150.0-D of the Energy Code.

Equation 9 (Equation 150.0-C & D)

$$Q_{50} = V_{\text{du}} \times \text{ACH}_{50} / 60 \text{ min}$$

Where:

Q_{50} = Leakage rate at 50 Pa

V_{du} = Dwelling unit conditioned volume (ft³)

ACH_{50} = Air changes per hour at 50 Pa (0.2 inch water).

The software uses a default of 2 ACH_{50} unless the user input dwelling unit leakage is less than 2 ACH_{50} , in which case the user input value is used in the above equation.

The effective annual average infiltration rate is calculated using Energy Code, Equation 150.0-E.

Equation 10 (Equation 150.0-E)

$$Q_{\text{inf}} = 0.052 \times Q_{50} \times \text{wsf} \times [H/H_r]^2$$

Where:

Q_{inf} = Effective annual infiltration rate (CFM) (L/s)

Q_{50} = Leakage rate at 50 Pa (from equation 150.0-C or 150.0-D)

wsf = Weather and shielding factor from Table 150.0-D (based on a Climate Zone representative city)

H = Vertical distance between the lowest and highest above-grade points within the pressure boundary (ft)

H_r = Reference height, 8.2 ft

Z = 0.4 for calculating the effective annual average infiltration rate

For single-family and horizontally attached dwelling units, the required mechanical ventilation rate is calculated using Equation 150.0-F of the Energy Code.

Equation 11 (Equation 150.0-F)

$$Q_{fan} = Q_{total} - \phi (Q_{inf} \times A_{ext})$$

Where:

Q_{fan} = Fan flow rate in cubic feet per minute (CFM)

Q_{total} = Total required ventilation rate (CFM)

Q_{inf} = Effective annual average infiltration rate, CFM from Equation 150.0-E

A_{ext} = Reduction factor accounting for leaks from adjacent dwelling units; 1 for single-family detached homes, or the ratio of exterior envelope surface area that is not attached to garages or other dwelling units to the total envelope surface area for attached dwelling units not sharing ceilings or floor with other dwelling units, occupiable spaces, public garages, or commercial spaces.

ϕ = 1 for balanced ventilation systems and Q_{inf}/Q_{total} otherwise

For estimating the energy impact of this requirement in compliance software, the minimum ventilation rate is met by either a standalone IAQ fan system or a central air handler fan system that can introduce outdoor air.

The simplest IAQ fan system is an exhaust fan/bathroom fan that meets the criteria in ASHRAE Standard 62.2 for air delivery and minimal noise. More advanced IAQ fan systems that have a supply or both supply and exhaust fans are possible. To calculate the energy use of standalone IAQ fan systems, the systems are assumed to be on continuously.

To calculate the energy use of central fan integrated ventilation, the systems are assumed to be on for at least 20 minutes each hour as described below. The fan flow rate and fan power ratio may be different from the values used when the system is on to provide for heating or cooling, depending on the design or controls on the IAQ ventilation portion of the system.

PROPOSED DESIGN

The proposed design shall incorporate a mechanical ventilation system meeting the above mandatory measures. The compliance software allows the user to specify the IAQ ventilation type (see Table 23), CFM of outdoor ventilation air equal to or greater than what is required by the Energy Code, and W/CFM. The user must also indicate whether the dwelling unit is attached or detached and the vertical distance between the lowest and highest above-grade points.

The default minimum IAQ fan is a standalone unbalanced exhaust system meeting the above airflow requirements.

Commented [AG2]: Moved up to keep discussion of balanced fans together below.

For balanced systems, the software allows the user to specify the Sensible Recovery Efficiency (SRE) and Adjusted Sensible Recovery Efficiency (ASRE) if the system has energy or heat recovery. If SRE and ASRE are not available at the ventilation CFM that is input for the dwelling unit, the user can enter HVI listed ratings for an airflow less than the ventilation CFM and greater than the ventilation CFM. The software will interpolate the values at the ventilation CFM.

Commented [AG3]: The software has this capability now so suggest including this description.

~~For single-family, the default minimum IAQ fan is a standalone unbalanced exhaust system meeting the above airflow requirements.~~

The W/CFM for balanced fan systems should be calculated based on the fan power for both fans and the outdoor ventilation rate. For example, if a balanced system supplies 100 cfm of outdoor air and each fan operates at 30 Watts, the W/CFM that should be entered is $(30W+30W)/100CFM = 0.60W/CFM$.

Commented [AG4]: The question comes up of what fan power to input for balanced system, suggest including this or a similar description for clarity.

Systems with supply ducts (balanced and supply-only) are simulated with increased fan wattage and reduced SRE and ASRE to account for maintenance and installation factors affecting system efficacy. For these systems, fan wattage is increased by a factor of 1.10 (10 percent increase in wattage) and SRE and ASRE are reduced by a factor of 0.90 (10 percent decrease in recovery efficiencies). For IAQ systems with fault indicator displays (FID) meeting the below specifications, these factors don't apply.

Commented [AG5]: See markup in the Standard Design section below for suggested changes to how this applies in the Standard Design to make it a compliance credit.

Even as a compliance credit there are some concerns about verification of this since it's not referenced in the RA. Ensure the verification details are clearly outlined in the Compliance Manuals.

IAQ SYSTEM FAULT INDICATOR DISPLAY REQUIREMENTS

1. Fault indication responding to the following categories:
 - a. Filter check or maintenance, either based on performance or a predetermined schedule.
 - b. Low supply airflow.
 - c. Low exhaust airflow.
 - d. Sensor failure for sensors that assist in monitoring or controlling for the following operations, where such operations are provided: airflow regulation, frost control, supply air tempering, and economizing.

2. Fault indication using one or more of the following means:

- a. A visual display that is readily accessible to occupants of the dwelling unit and located on or within one foot of the IAQ system control.
- b. An electronic application.
- c. An audible alarm accompanied by a visual display.

3. Instrumentation and reporting of the following:

- a. Airflow.
- b. Fan power.

4. FID certified to CEC by the manufacturer as meeting the above requirements.

To receive compliance credit relative to the standard design, balanced and supply-only systems must have accessible supply air filters, outside air inlets, and heat/energy recovery cores (if applicable) as specified in Table 22. For systems not meeting these requirements, compliance credit will be neutralized (see IAQ system standard design for details).

Table 22: IAQ System Component Accessibility Criteria

Dwelling Unit Ventilation System Component	Location	Accessible Determination
Outdoor Air Intake	All locations	Intakes louvers, grilles, or screens shall be >3/8 inches except where prohibited by local jurisdictions or other code requirements.
Outdoor Air Intake	Exterior wall, soffit, or gable end	A point on the perimeter of the outdoor air intake shall be located within 10 feet of a walking surface or grade or the system shall meet the IAQ System FID requirements in the ACM Reference Manual.
Outdoor Air Intake	Roof	Access shall be provided in accordance with California Mechanical Code Section 304.3.1 requirements for appliances.
Filters and Heat Exchangers	Serviceable from conditioned space, unconditioned basements, or mechanical closets. Heat exchangers may also be serviceable from unconditioned attics if the IAQ system meets the FID requirements in the RACM Reference Manual.	The H/ERV or supply ventilation system access panel shall be located within 10 feet of the walking surface.

Commented [AG6]: We recognize a version of this is in the current ACM; however, similar to the FID requirement we are concerned about the verification aspect of this. There are mandatory accessibility requirements in the Mechanical Code and Section 150.0(o). Are these requirements in addition?

At minimum let's make sure they are sufficiently detailed in the Compliance Manual.

2022 ACM Reference Manual

Building Mechanical Systems

~~Filters and Heat Exchangers~~

~~Roof~~

~~For multifamily only, access shall be provided in accordance with California Mechanical Code Section 304.31 requirements for appliances.~~

Source: California Energy Commission

STANDARD DESIGN

For single-family buildings, the standard design mechanical ventilation system type (balanced, supply, or exhaust) is the same as the proposed. Fan efficacy is 0.35 W/CFM for exhaust or supply systems and 0.70 W/CFM for balanced systems. Airflow rate is equal to the proposed design value or 1.25 times the CFM required by the Energy Code, whichever is smaller. ~~The standard design has no heat recovery.~~

Commented [AG7]: This is in conflict with the last paragraph in this section.

If the proposed IAQ system uses the central air handler fan, the standard design IAQ fan efficacy is less than or equal to the following:

- 0.45 W/CFM for gas furnace air-handling units, as well as air-handling unit that are not gas furnaces and have a capacity less than 54,000 BTU/h
- 0.58 W/CFM for air-handling units that are not gas furnaces and have a capacity greater than or equal to 54,000 BTU/h
- 0.62 W/CFM for small duct high velocity forced air systems

~~If the proposed design is balanced or supply-only, the standard design is simulated with increased fan wattage to account for maintenance and installation factors affecting system efficacy. Fan wattage is increased by a factor of 1.10 (10 percent increase in wattage).~~

Commented [AG8]: Suggested edits to apply no FID degradation to Standard Design. This results in no penalty for the Proposed Design, but a compliance credit if the Proposed Design incorporates an approved FID.

If the proposed design is balanced or supply-only and doesn't meet the accessible requirements listed in Table 22, the standard design W/CFM equals the proposed or the default value whichever is lower and if the proposed system has heat recovery the standard will have heat recovery with SRE and ASRE equal to the proposed system. ~~Otherwise, the standard design does not have heat recovery.~~

VERIFICATION AND REPORTING

The required ventilation rate to comply with the Energy Code and the means to achieve compliance are indicated on the CF1R. The IAQ system characteristics are reported in the HERS required verification listing on the CF1R. The diagnostic testing procedures are in Reference Appendices, Residential Appendix RA3.7.

Special features are reported on the CF1R when the proposed system has heat or energy recovery or when the proposed fan efficacy is less than (i.e., more efficient than) 0.35 W/CFM for single-family buildings.

Table 23: IAQ Fans

Type	Description	Inputs
Standalone IAQ Fan (exhaust, supply, or balanced)	Dedicated fan system that provides IAQ ventilation to meet or exceed the requirements of Energy Code §150.0(o).	CFM, W/CFM, and SRE and ASRE for balanced systems
Central Fan Integrated (CFI) (variable or fixed speed)	Automatic operation of the air handler for IAQ ventilation. Ventilation type uses a special damper to induce outdoor IAQ ventilation air and distribute it through the HVAC duct system. Mixing type distributes and mixes IAQ ventilation air supplied by a separate standalone IAQ fan system.	CFM, W/CFM

Source: California Energy Commission

2.4.11 Ventilation Cooling System

Ventilation cooling systems operate at the dwelling-unit level using fans to bring in outside air to cool the house when the air can reduce cooling loads and save cooling energy. System operation is limited to single-family dwellings and operate according to the schedule and setpoints shown in *Table 25*. Whole-house fans require either window operation and attic venting or ducting to exhaust hot air. Central fan ventilation cooling systems (fixed and variable-speed) use the HVAC duct system to distribute outside air and require attic venting. Whole-house fans, which exhaust air through the attic, require at least 1 ft² of free attic ventilation area per 750 CFM of rated capacity for relief or, if greater, the manufacturer specifications (see §150.1(c)12 of the Energy Code).

PROPOSED DESIGN

Software allows the user to specify whether a ventilation cooling system (*Table 24* for system types) is included in conditioned and living zones. The user can specify the airflow and W/CFM (HERS verification required) or a default prescriptive whole-house fan with a capacity of 1.5 CFM/ft² of conditioned floor area. When the default capacity is selected, the user can select HERS verification of the airflow and watts to receive full credit for the system capacity. When HERS verification is not selected, the fan capacity is reduced by a factor of 0.67 (33 percent reduction). Ventilation cooling airflow is limited to 3.5 CFM/ft² of conditioned area.

STANDARD DESIGN

The standard design building for a newly constructed single-family building or for an addition greater than 1,000 ft² to a single-family building has a whole-house fan in Climate Zones 8-14, and no ventilation cooling in other climate zones. (See §150.1(c) and Table 150.1-A.) The whole-house fan has 1.5 CFM/ft² of conditioned floor area, 0.14 watts/CFM, with 1 ft² of attic vent free area for each 750 CFM of rated whole-house fan airflow CFM.

VERIFICATION AND REPORTING

A ventilation cooling system is either a special feature or a HERS verification requirement, the size and type of which are reported on the CF1R (*Table 24*).

Table 24: Ventilation Cooling Fans

Measure	Description	HERS Verification
Whole-House Fan	Traditional whole-house fan mounted in the ceiling to exhaust air from the house to the attic, inducing outside air in through open windows. Whole-house fans are assumed to	Optional RA3.9

	operate between dawn and 11 p.m. only at 33 percent of rated CFM to reflect manual operation of fan and windows by occupant. Fans must be listed in the CEC's Whole House Fan directory. If multiple fans are used, enter the total CFM.	
Central Fan Ventilation Cooling Variable or fixed-speed	Central fan ventilation cooling system. Ventilation type uses a special damper to induce outdoor air and distribute it through the HVAC duct system.	Required RA3.3.4

Source: California Energy Commission

2.5 Conditioned Zones

The software requires the user to enter the characteristics of one or more conditioned zones. Subdividing single-family dwelling units into conditioned zones for input convenience or increased accuracy is optional.

2.5.1 Zone Type

Proposed Design

The zone is defined as conditioned, living, or sleeping. Other zone types include garage, attic, and crawl space.

Standard Design

The standard design is conditioned.

VERIFICATION AND REPORTING

When the zone type is living or sleeping, this is reported as a special feature on the CF1R.

2.5.1.1 Heating Zonal Control Credit

With the heating zonal control credit, the sleeping and living areas are modeled separately for heating, each with its own separate thermostat schedule and internal gain assumptions. Zonal control cannot be modeled with heat pump heating. The total nonclosable opening area between zones cannot exceed 40 ft². Other eligibility criteria for this measure are presented in the *Residential Compliance Manual, Chapter 4*.

PROPOSED DESIGN

The user selects zonal control as a building level input with separate living and sleeping zones.

STANDARD DESIGN

The standard design building is not zoned for living and sleeping separately.

VERIFICATION AND REPORTING

Zonal control is reported as a special feature on the CF1R.

2.5.2 Conditioned Floor Area

The total conditioned floor area (CFA) is the raised floor as well as the slab-on-grade floor area of the conditioned spaces measured from the exterior surface of exterior walls. Stairs are included in conditioned floor area as the area beneath the stairs and the tread of the stairs.

PROPOSED DESIGN

The compliance software requires the user to enter the total conditioned floor area of each conditioned zone.

STANDARD DESIGN

The standard design building has the same conditioned floor area and same conditioned zones as the proposed design.

VERIFICATION AND REPORTING

The conditioned floor area of each conditioned zone is reported on the CF1R.

2.5.3 Number of Stories**2.5.3.1 Number of Stories of the Zone****PROPOSED DESIGN**

The number of stories of the zone.

STANDARD DESIGN

The standard design is the same as the proposed design.

2.5.3.2 Ceiling Height**PROPOSED DESIGN**

The average ceiling height of the proposed design is used to calculate the conditioned volume of the building envelope. The volume (in cubic feet) is determined from the total conditioned floor area and the average ceiling height.

STANDARD DESIGN

The volume of the standard design building is the same as the proposed design.

VERIFICATION AND REPORTING

The conditioned volume of each zone is reported on the CF1R.

2.5.3.3 Free Ventilation Area

Free ventilation area is the window area adjusted to account for bug screens, window framing and dividers, and other factors.

PROPOSED DESIGN

Free ventilation area for the proposed design is calculated as 5 percent of the fenestration area (rough opening), assuming all windows are operable.

STANDARD DESIGN

The standard design value for free ventilation area is the same as the proposed design.

VERIFICATION AND REPORTING

Free ventilation is not reported on the CF1R.

2.5.3.4 Ventilation Height Difference

Ventilation height difference is not a user input.

PROPOSED DESIGN

The default assumption for the proposed design is 2 feet for one-story buildings or one-story dwelling units and 8 feet for two or more stories (as derived from number of stories and other zone details).

STANDARD DESIGN

The standard design is the same as the proposed design.

2.5.3.5 Zone Elevations

The elevation of the top and bottom of each zone is required to set up the airflow network.

PROPOSED DESIGN

The user enters the height of the top surface the lowest floor of the zone relative to the ground outside as the "bottom" of the zone. The user also enters the ceiling height (the floor-to-floor height [ceiling height plus the thickness of the intermediate floor structure] is calculated by the software).

Underground zones are indicated with the number of feet below grade (e.g., -8).

STANDARD DESIGN

The standard design has the same vertical zone dimensions as the proposed design.

2.5.3.6 Mechanical Systems

PROPOSED DESIGN

The software requires the user to specify a previously defined HVAC system to provide heating and cooling for the zone and an IAQ ventilation system. The user may also specify a ventilation cooling system that applies to this and other conditioned zones.

STANDARD DESIGN

The software assigns standard design HVAC, IAQ ventilation, and ventilation cooling systems based on §150.1(c) and Table 150.1-A for the applicable climate zone.

2.5.3.7 Natural Ventilation

Natural ventilation (from windows) is available during cooling mode when needed and available, as shown in *Table 25*. The amount of natural ventilation used by computer software for natural cooling is the lesser of the maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint. When natural cooling is not needed or is unavailable, no natural ventilation is used.

Computer software shall assume that natural cooling is needed when the building is in "cooling mode," when the outside temperature is below the estimated zone temperature, and when the estimated zone temperature is above the natural cooling setpoint temperature. Only the amount of ventilation required to reduce the zone temperature to the natural ventilation setpoint temperature is used, and the natural ventilation setpoint temperature is constrained by the compliance software to be greater than the heating setpoint temperature.

Table 25: Hourly Thermostat Set Points

Hou r	Cooling	Ventini g	Heat Pump Heating	Standard Gas Heating Single- Zone	Zonal Control Gas Heating Living	Zonal Control Gas Heating Sleeping
1	78	Off	68	65	65	65
2	78	Off	68	65	65	65
3	78	Off	68	65	65	65
4	78	Off	68	65	65	65
5	78	Off	68	65	65	65
6	78	68*	68	65	65	65
7	78	68	68	65	65	65
8	83	68	68	68	68	68
9	83	68	68	68	68	68
10	83	68	68	68	68	65
11	83	68	68	68	68	65
12	83	68	68	68	68	65
13	83	68	68	68	68	65
14	82	68	68	68	68	65
15	81	68	68	68	68	65
16	80	68	68	68	68	65
17	79	68	68	68	68	68
18	78	68	68	68	68	68
19	78	68	68	68	68	68
20	78	68	68	68	68	68
21	78	68	68	68	68	68
22	78	68	68	68	68	68
23	78	68	68	68	68	68
24	78	Off	68	65	65	65

**Venting starts in the hour the sun comes up.*

Source: California Energy Commission

2.5.4 Conditioned Zone Assumptions

2.5.4.1 Internal Thermal Mass

Internal mass objects are completely inside a zone so that they do not participate directly in heat flows to other zones or outside. They are connected to the zone radiantly and convectively and participate in the zone energy balance by passively storing and releasing heat as conditions change.

Table 26 shows the standard interior conditioned zone thermal mass objects and the calculation of the simulation inputs that represent them.

Table 26: Conditioned Zone Thermal Mass Objects

Item	Description	Simulation Object
Interior walls	The area of one side of the walls completely inside the conditioned zone is calculated as the conditioned floor area of the zone minus ½ of the area of interior walls adjacent to other conditioned zones. The interior wall is modeled as a construction with 25 percent 2x4 wood framing and sheetrock on both sides.	Wall exposed to the zone on both sides
Interior floors	The area of floors completely inside the conditioned zone is calculated as the difference between the CFA of the zone and the sum of the areas of zone exterior floors and interior floors over other zones. Interior floors are modeled as a surface inside the zone with a construction of carpet, wood decking, 2x12 framing at 16 in. on-center with miscellaneous bridging, electrical, and plumbing, and a sheetrock ceiling below.	Floor/ceiling surface exposed to the zone on both sides
Furniture and heavy contents	Contents of the conditioned zone with significant heat storage capacity and delayed thermal response, for example heavy furniture, bottled drinks, canned goods, contents of dressers, enclosed cabinets. These are represented by a 2 in. thick slab of wood twice as large as the conditioned floor area, exposed to the room on both sides.	Horizontal wood slab exposed to the zone on both sides
Light and thin contents	Contents of the conditioned zone that have a large surface area compared to weight, for example, clothing on hangers, curtains, pots,	Air heat capacity (C_{air}) = CFA * 2

	and pans. These are assumed to be 2 Btu per square foot of conditioned floor area.	
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Source: California Energy Commission

PROPOSED DESIGN

The proposed design has standard conditioned zone thermal mass objects (such as gypsum board in walls, cabinets, sinks, and tubs) that are not user-editable and are not a compliance variable. If the proposed design includes specific interior thermal mass elements that are significantly different from what is included in typical wood-frame production housing, such as masonry partition walls, the user may include them. See also 2.5.6.4 Exterior Thermal Mass.

STANDARD DESIGN

The standard design has standard conditioned zone thermal mass objects.

2.5.4.2 Thermostats and Schedules

Thermostat settings are shown in *Table 25*. The values for cooling, venting, and standard heating apply to the standard design run and are the default for the proposed design run. See the explanation later in this section regarding the values for zonal control.

Heat pumps equipped with supplementary electric resistance heating are assumed to meet mandatory control requirements specified in §110.2(b) and (c).

Systems with no setback required by §110.2(c) (gravity gas wall heaters, gravity floor heaters, gravity room heaters, noncentral electric heaters, fireplaces or decorative gas appliances, wood stoves, room air-conditioners, and room air-conditioner heat pumps) are assumed to have a constant heating set point of 68 degrees Fahrenheit. The cooling set point from *Table 25*s assumed in both the proposed design and standard design.

PROPOSED DESIGN

The proposed design assumes a mandatory setback thermostat meeting the requirements of §110.2(c). Systems exempt from the requirement for a setback thermostat are assumed to have no setback capabilities.

STANDARD DESIGN

The standard design has setback thermostat conditions based on the mandatory requirement for a setback thermostat. For equipment exempt from the setback thermostat requirement, the standard design has no setback thermostat capabilities.

2.5.4.3 Determining Heating Mode vs. Cooling Mode

When the building is in the heating mode, the heating setpoints for each hour are set to the “heating” values in Table 25, the cooling setpoint is a constant 78 degrees Fahrenheit (°F), and the ventilation setpoint is set to a constant 77°F. When the building is in the cooling mode, the heating setpoint is a constant 60°F, and the cooling and venting setpoints are set to the values in Table 25.

The mode depends upon the outdoor temperature averaged over hours 1 through 24 of eight days prior to the current day through two days prior to the current day. (For example, if the current day is June 21, the mode is based on the average temperature for June 13 through 20.) When this running average temperature is equal to or less than 60°F, the building is in a heating mode. When the running average is greater than 60°F, the building is in a cooling mode.

2.5.5 Internal Gains

Internal gains assumptions are included in Appendix E and consistent with the CASE report on plug loads and lighting (Rubin 2016, see Appendix F).

Proposed Design

Plug loads and lighting are fixed assumptions that vary based on the time of day, day of the week (e.g., weekday vs. weekend), and season.

Standard Design

The standard design internal gains are the same as the proposed design.

2.5.6 Exterior Surfaces

The user enters exterior surfaces to define the envelope of the proposed design. The areas, construction assemblies, orientations, and tilts modeled are consistent with the actual building design and shall equal the overall roof/ceiling area with conditioned space on the inside and unconditioned space on the other side.

2.5.6.1 Ceilings Below Attics

Ceilings below attics are horizontal surfaces between conditioned zones and attics. The area of the attic floor is determined by the total area of ceilings below attics defined in conditioned zones.

PROPOSED DESIGN

The software allows the user to define ceilings below attic, enter the area, and select a construction assembly for each.

STANDARD DESIGN

The standard design for newly constructed buildings has the same ceiling below attic area as the proposed design. The standard design is a high-performance attic with a ceiling constructed with 2x4 framed trusses and insulated with the R-values specified in §150.1(c) and Table 150.1-A for the applicable climate zone, assuming Option B. The roof surface is a 10 lbs/ft² tile roof with an air space when the proposed roof is steep slope or a lightweight roof when the proposed roof is low slope.

Single-family dwelling units: Below-roof-deck insulation has R-0 in Climate Zones 1-3 and 5-7 and R-19 in Climate Zones 4 and 8-16. Insulation on the ceiling has R-38 in Climate Zones 1, 2, 4, and 8-16 and R-30 insulation in Climate Zones 3 and 5-7. Climate Zones 2, 3, and 5-7 have a radiant barrier, and Climate Zones 1, 4, and 8-16 have no radiant barrier.

VERIFICATION AND REPORTING

Ceiling below attic area and constructions are reported on the CF1R. SIP assemblies are reported as a special feature on the CF1R.

2.5.6.2 Non-Attic (Cathedral) Ceiling and Roof

Non-attic ceilings, also known as cathedral ceilings, are surfaces with roofing on the outside and finished ceiling on the inside but without an attic space.

PROPOSED DESIGN

The software allows the user to define cathedral ceilings, enter the area, and select a construction assembly for each. The user also enters the roof characteristics of the surface.

STANDARD DESIGN

The standard design has the same area as the proposed design cathedral ceiling modeled as ceiling below attic with the features of Option B from §150.1(c) and Table 150.1-A or for the applicable climate zone.

The standard design building has an area of ceiling below attic equal to the non-attic ceiling/roof areas of the proposed design. The standard design roof and ceiling surfaces are modeled with the same construction assembly and characteristics, aged reflectance, and emittance as §150.1(c), Table 150.1-A for the applicable climate zone.

VERIFICATION AND REPORTING

Non-attic ceiling/roof area and constructions are reported on the CF1R. SIP assemblies are reported as a special feature on the CF1R.

2.5.6.3 Exterior Walls

PROPOSED DESIGN

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

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

STANDARD DESIGN

The standard design building has high-performance walls modeled with the same area of framed walls as is in the proposed design separating conditioned space and the exterior, with a U-factor equivalent to that as specified in §150.1(c)1.B and Table 150.1-A for the applicable climate zone.

Single-family dwellings: Above-grade framed walls in Climate Zones 1-5 and 8-16 have 2 x 6 16-in. on center wood framing with R-21 insulation between framing and R-5 continuous insulation (0.048 U-factor). Climate Zones 6-7 above-grade walls have 2 x 4 16-in. on center wood framing with R-15 insulation between framing and R-4 continuous insulation (0.065 U-factor). Walls adjacent to unconditioned space, such as garage walls, are treated the same as exterior walls, except there is no continuous insulation.

Above-grade mass walls are 6-inch concrete with R-13 interior insulation in 3.5-inch wood furring in Climate Zones 1-15 and R-17 in Climate Zone 16. Below-grade mass walls in Climate Zones 1-15 have R-13, and Climate Zone 16 has R-15 interior insulation in 3.5-inch wood furring. When the proposed design is a wall type such as SIP, straw bale, or other construction type not specifically mentioned above, the standard design wall is a wood-framed wall meeting the requirements of §150.1(c) Table 150.1-A.

The total gross exterior wall area in the standard design is equal to the total gross exterior wall area of the proposed design for each wall type. The gross exterior wall area of framed walls in the standard design (excluding demising walls) is equally divided among the four main compass points -- north, east, south, and west. The gross exterior wall area of mass

walls in the standard design (excluding demising walls and below grade walls) is equally divided among these four main compass points. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation.

VERIFICATION AND REPORTING

Exterior wall area and construction details are reported on the CF1R. Metal-framed and SIP assemblies are reported as a special feature on the CF1R.

2.5.6.4 Exterior Thermal Mass

Constructions for standard exterior mass are supported but not implemented beyond the assumptions for typical mass.

The performance approach assumes that both the proposed design and standard design building have a minimum mass as a function of the conditioned area of slab floor and non-slab-floor. (See Section 2.5.4.1 Internal Thermal Mass.)

Mass such as concrete slab floors, masonry walls, double gypsum board, and other special mass elements can be modeled. When the proposed design has more than the typical assumptions for mass in a building, then each element of heavy mass is modeled in the proposed design, otherwise; the proposed design is modeled with the same thermal mass as the standard design.

PROPOSED DESIGN

The proposed design may be modeled with the default 20 percent exposed mass/80 percent covered mass or with actual mass areas modeled as separate covered and exposed mass surfaces. Exposed mass surfaces covered with flooring material that is in direct contact with the slab can be modeled as exposed mass. Examples of such materials are tile, stone, vinyl, linoleum, and hard-wood.

STANDARD DESIGN

The conditioned slab floor in the standard design is assumed to be 20 percent exposed slab and 80 percent slab covered by carpet or casework. Interior mass assumptions as described in Section 2.5.4.1 Internal Thermal Mass are also assumed. No other mass elements are modeled in the standard design. The standard design mass is modeled with the following characteristics:

- The conditioned slab floor area (slab area) shall have a thickness of 3.5 inches, a volumetric heat capacity of $28 \text{ Btu/ft}^3\text{-}^\circ \text{ F}$, and a conductivity of $0.98 \text{ Btu-in/hr-ft}^2\text{-}^\circ \text{ F}$. The exposed portion shall have a surface conductance of $1.3 \text{ Btu/h-ft}^2\text{-}^\circ \text{ F}$ (no thermal resistance on the surface), and the covered portion shall have a surface conductance of $0.50 \text{ Btu/h-ft}^2\text{-}^\circ \text{ F}$, typical of a carpet and pad.

- The “exposed” portion of the conditioned non-slab floor area shall have a thickness of 2.0 inches, a volumetric heat capacity of 28 Btu/ft³-° F, a conductivity of 0.98 Btu-in/hr- ft²-°F; and a surface conductance of 1.3 Btu/h- ft²-° F (no added thermal resistance on the surface). These thermal mass properties apply to the “exposed” portion of non-slab floors for both the proposed design and standard design. The covered portion of non-slab floors is assumed to have no thermal mass.

VERIFICATION AND REPORTING

Exposed mass greater than 20 percent exposed slab on grade, and any other mass modeled by the user is reported as a special feature on the CF1R.

2.5.6.5 Doors

Doors are defined as an opening in a building envelope. If the rough opening of a door includes fenestration equal to 25 percent or more of glass or fenestration, it is fenestration. (See Section 2.5.6.6 Fenestration.) Doors with less than 25 percent fenestration are considered an opaque door.

PROPOSED DESIGN

The compliance software shall allow users to enter doors specifying the U-factor, area, and orientation. Doors to the exterior or to unconditioned zones are modeled as part of the conditioned zone. For doors with less than 25 percent glass area, the U-factor shall come from Reference Appendices, Joint Appendix *JA4, Table 4.5.1* (default U-factor 0.20) or from National Fenestration Rating Council (NFRC) certification data for the entire door. For unrated doors, the glass area of the door, calculated as the sum of all glass surfaces plus 2 inches on all sides of the glass (to account for a frame), is modeled under the rules for fenestrations; the opaque area of the door is considered the total door area minus this calculated glass area. Doors with 25 percent or more glass area are modeled under the rules for fenestrations using the total area of the door.

When modeling a garage zone, large garage doors (metal roll-up or wood) are modeled with a 1.0 U-factor.

STANDARD DESIGN

The standard design has the same door area for each dwelling unit as the proposed design. The standard design door area is distributed equally among the four main compass points--north, east, south, and west. The U-factor for the standard design is taken from §150.1(c) and Table 150.1-A. All swinging opaque doors are assumed to have a U-factor of 0.20. The net opaque wall area is reduced by the door area in the standard design.

VERIFICATION AND REPORTING

Door area and U-factor are reported on the CF1R.

2.5.6.6 Fenestration

Fenestration is modeled with a U-factor and solar heat gain coefficient (SHGC). Acceptable sources of these values are National Fenestration Rating Council (NFRC), default tables from §110.6 of the Energy Code, and *Reference Appendices, Nonresidential Appendix NA6*.

In limited cases for certain site-built fenestration that is field fabricated, the performance factors (U-factor, SHGC) may come from *Reference Appendices, Nonresidential Appendix NA6* as described in Exception 4 to Section 150.1(c)3A.

There is no detailed model of chromogenic fenestration available. As allowed by Exception 3 to Section 150.1(c)3A, the lower-rated labeled U-factor and SHGC may be used only when installed with automatic controls as noted in the exception. Chromogenic fenestration cannot be averaged with nonchromogenic fenestration.

PROPOSED DESIGN

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

Performance datum (U-factors and SHGC) are from NFRC values or from the CEC default tables from §110.6 of the Energy Code. In spaces other than sunspaces, solar gains from windows or skylights use the California Simulation Engine (CSE) default solar gain targeting.

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

STANDARD DESIGN

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

The standard design has no skylights.

The net wall area on each orientation is reduced by the fenestration area and door area on each façade. The U-factor and SHGC performance factors for the standard design are taken from §150.1(c) and Table 150.1-A, which is 0.30 U-factor in all climate zones. SHGC is 0.23 in Climate Zones 2, 4, and 6-15. Where there is no prescriptive requirement (Climate Zones 1, 3, 5, and 16), the SHGC is set to 0.35.

VERIFICATION AND REPORTING

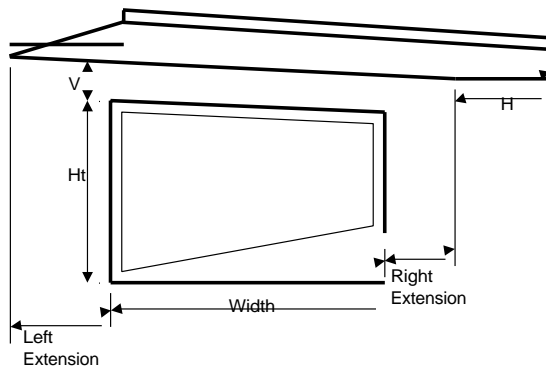
Fenestration area, U-factor, SHGC, orientation, and tilt are reported on the CF1R.

2.5.6.7 Overhangs and Sidesfins

PROPOSED DESIGN

Software users enter a set of basic parameters for a description of an overhang and sidesfin for each individual fenestration or window area entry. The basic parameters include fenestration height, overhang/sidesfin length, and overhang/sidesfin height. Compliance software user entries for overhangs may also include fenestration width, overhang left extension, and overhang right extension. Compliance software user entries for sidesfins may also include fin left extension and fin right extension for both left and right fins. Walls at right angles to windows may be modeled as sidesfins.

Figure 5: Overhang Dimensions



Source: California Energy Commission

Figure 6: Sidefin Dimensions

Source: California Energy Commission

STANDARD DESIGN

The standard design does not have overhangs or sidefins.

VERIFICATION AND REPORTING

Overhang and fin dimensions are reported on the CF1R.

2.5.6.8 Interior Shading Devices

For both the proposed and standard design, all windows are assumed to have draperies, and skylights are assumed to have no interior shading. Window medium drapes are closed at night and half open in the daytime hours. Interior shading is not a compliance variable and is not user-editable.

2.5.6.9 Exterior Shading

For both the proposed and standard design, all windows are assumed to have bug screens, and skylights are assumed to have no exterior shading. Exterior shading is modeled as an additional glazing system layer using the ASHRAE Window Attachment (ASHWAT) calculation.

PROPOSED DESIGN

The compliance software shall require the user to accept the default exterior shading devices, which are bug screens for windows and none for skylights. Credit for shading devices that are allowable for prescriptive compliance are not allowable in performance compliance.

STANDARD DESIGN

The standard design shall assume bug screens. The standard design does not have skylights.

2.5.6.10 Slab on Grade Floors**PROPOSED DESIGN**

The software allows users to enter areas and exterior perimeter of slabs that are heated or unheated, covered, or exposed, and with or without slab-edge insulation. Perimeter is the length of wall between conditioned space and the exterior, but it does not include edges that cannot be insulated, such as between the house and the garage. The default condition for the proposed design is that 80 percent of each slab area is carpeted or covered by walls and cabinets, and 20 percent is exposed. Inputs other than the default condition require that carpet and exposed slab conditions are documented on the construction plans.

When the proposed heating distribution is radiant floor heating (heated slab), the software user will identify that the slab is heated and model the proposed slab edge insulation. The mandatory minimum requirement is R-5 insulation in Climate Zones 1-15 and R-10 in Climate Zone 16 (§110.8[g], Table 110.8-A).

STANDARD DESIGN

The standard design perimeter lengths and slab on grade areas are the same as the proposed design. 80 percent of standard design slab area is carpeted, and 20 percent is exposed. For the standard design, an unheated slab edge has no insulation with the exception of Climate Zone 16, which assumes R-7 to a depth of 16 inches. The standard design for a heated slab is a heated slab with the mandatory slab edge insulation of R-5 in Climate Zones 1-15 and R-10 in Climate Zone 16.

VERIFICATION AND REPORTING

Slab areas, perimeter lengths, and inputs of other than the default condition are reported on the CF1R.

2.5.6.11 Underground Floors**PROPOSED DESIGN**

The software allows users to enter areas and depth below grade of slab floors occurring below grade. Unlike slab-on-grade floors, there is no perimeter length associated with underground floors.

STANDARD DESIGN

The standard design underground floor areas are the same as the proposed design.

2.5.6.12 Raised Floors

PROPOSED DESIGN

The software allows the user to input floor areas and constructions for raised floors over a crawl space, over exterior (garage or unconditioned), and concrete raised floors. The proposed floor area and constructions are consistent with the actual building design.

STANDARD DESIGN

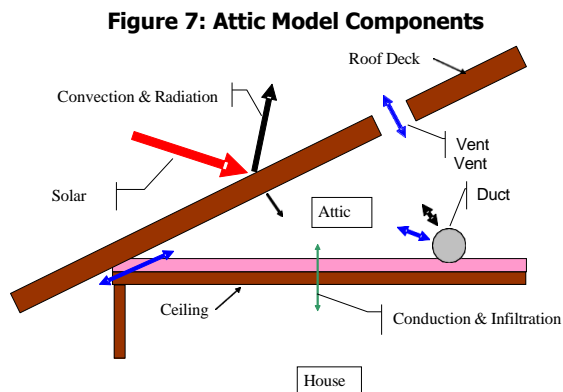
The standard design has the same area and type of construction as the proposed design. The thermal characteristics meet §150.1(c) and Table 150.1-A. For floor areas that are framed construction, the standard design floor has R-19 in 2x6 wood framing, 16-in. on center (0.037 U-factor). For floor areas that are concrete raised floors, the standard design floor is 6 inches of normal weight concrete with R-8 continuous insulation in Climate Zones 1, 2, 11, 13, 14, 16; Climate Zones 12 and 15 have R-4; Climate Zones 3-10 have R-0.

VERIFICATION AND REPORTING

Raised floor areas and constructions are reported on the CF1R.

2.6 Attics

The compliance software models attics as a separate thermal zone and includes the interaction with the air distribution ducts, infiltration exchange between the attic and the house, the solar gains on the roof deck, and other factors. These interactions are illustrated in Figure 7.



Source: California Energy Commission

2.6.1 Attic Components

2.6.1.1 Roof Rise

The roof rise is the ratio of rise to run (or pitch) and refers to the number of feet the roof rises vertically for every 12 feet horizontally. For roofs with multiple pitches, the roof rise that makes up the largest roof area is used.

2.6.1.2 Vent Area

This value is the vent area as a fraction of attic floor area. This value is not a compliance variable and is assumed set equal to attic floor area divided by 300.

2.6.1.3 Fraction High

The fraction of the vent area that is high due to the presence of ridge, roof, or gable end-mounted vents. Soffit vents are considered low ventilation. The default value is zero for attics with standard ventilation. Attics with radiant barriers are required to have a vent high fraction of at least 0.3.

2.6.1.4 Roof Deck/Surface Construction

Typical roof construction types are concrete or clay tile, metal tile, gravel, ballast, or other steep- or low-sloped roofing types.

2.6.1.5 Solar Reflectance

This input is a fraction that specifies the certified aged reflectance of the roofing material or 0.1 default value for uncertified materials. The installed value must be equal to or higher than the value specified on the certificate of compliance. Roof construction with a roof membrane mass of at least 25 lbs/ft², or a roof area that has integrated solar collectors, is assumed to meet the minimum solar reflectance.

2.6.1.6 Thermal Emittance

Thermal emittance is the certified aged thermal emittance (or emissivity) of the roofing material, or a default value. Unless a default value is modeled, the installed value must be equal to or greater than the value modeled. The default value is 0.85 if certified aged thermal emittance value is not available from the [Cool Roof Rating Council \(CRRC\)](http://www.coolroofs.org), www.coolroofs.org. Roof construction with a roof membrane mass of at least 25 lbs/ft² or roof area incorporated integrated solar collectors is assumed to meet the default thermal emittance.

PROPOSED DESIGN

The conditioning is either ventilated or unventilated. Each characteristic of the roof is modeled to reflect the proposed construction. Values for solar reflectance and thermal emittance shall be default or from the CRRC.

Roofs with solar collectors or with thermal mass over the roof membrane with a weight of at least 25 lbs/ft² may model the prescriptive values for solar reflectance and thermal emittance.

STANDARD DESIGN

The standard design depends on the variables of the climate zone and roof slope. Low-sloped roofs (with a roof rise of 2 feet in 12 or less) in Climate Zones 13 and 15 will have a standard design aged solar reflectance of 0.63 and a thermal emittance of 0.85.

Steep-sloped roofs in Climate Zones 10-15 will have a standard design roof with an aged solar reflectance of 0.20 and a minimum thermal emittance of 0.85.

Roofs with solar collectors or with thermal mass over the roof membrane with a weight of at least 25 lbs/ft² are assumed to meet the standard design values for solar reflectance and thermal emittance.

VERIFICATION AND REPORTING

A reflectance of 0.20 or higher is reported as a cool roof. A value higher than the default but less than 0.20 is reported as a non-standard roof reflectance value.

2.6.2 Ceiling Below Attic

PROPOSED DESIGN

For each conditioned zone, the user enters the area and construction of each ceiling surface that is below an attic space. The compliance software shall allow a user to enter multiple ceiling constructions. Surfaces that tilt 60 degrees or more are treated as knee walls and are not included as ceilings. The sum of areas shall equal the overall ceiling area with conditioned space on the inside and unconditioned attic space on the other side.

The compliance software creates an attic zone with a floor area equal to the sum of the areas of all the user input ceilings below an attic in the building. The user specifies the framing and spacing, the materials of the frame path, and the R-value of the insulation path for each ceiling construction.

The user inputs the proposed insulation R-value rounded to the nearest whole R-value. For simulation, all ceiling below attic insulation is assumed to have nominal properties of R-2.6 per inch, a density of 0.5 lb/ft³, and a specific heat of 0.2 Btu/lb.

STANDARD DESIGN

The standard design shall have the same area of ceiling below attic as the proposed design. The ceiling/framing construction is based on the prescriptive requirement and standard framing is assumed to be 2x4 wood trusses at 24 inches on center.

VERIFICATION AND REPORTING

The area, insulation R-value, and layer of each construction are reported on the CF1R.

2.6.3 Attic Roof Surface and Pitch**PROPOSED DESIGN**

The roof pitch is the ratio of rise to run, (for example, 4:12 or 5:12). If the proposed design has more than one roof pitch, the pitch of the largest area is used.

The compliance software creates an attic zone roof. The roof area is calculated as the ceiling below attic area divided by the cosine of the roof slope where the roof slope is an angle in degrees from the horizontal. The roof area is then divided into four equal sections with each section sloping in one of the cardinal directions (north, east, south, and west). Gable walls, dormers, or other exterior vertical surfaces that enclose the attic are ignored.

If the user specifies a roof with a pitch less than 2:12, the compliance software creates an attic with a flat roof that is 30 inches above the ceiling.

STANDARD DESIGN

The standard design shall have the same roof pitch, roof surface area, and orientations as the proposed design.

VERIFICATION AND REPORTING

The roof pitch is reported on the CF1R.

2.6.4 Attic Conditioning

Attics may be ventilated or unventilated. Insulation in a ventilated attic must be installed at the ceiling level. Unventilated attics usually have insulation at the roof deck and sometimes on the ceiling (Section 150.0[a]).

In an unventilated attic, the roof system becomes part of the insulated building enclosure. Local building jurisdictions may impose additional requirements.

PROPOSED DESIGN

A conventional attic is modeled as ventilated. When an attic will not be vented, attic conditioning is modeled as unventilated.

STANDARD DESIGN

Attic ventilation is set to ventilated for the standard design.

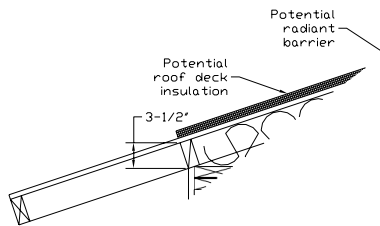
VERIFICATION AND REPORTING

The attic conditioning (ventilated or unventilated) is reported on the CF1R.

2.6.5 Attic Edge

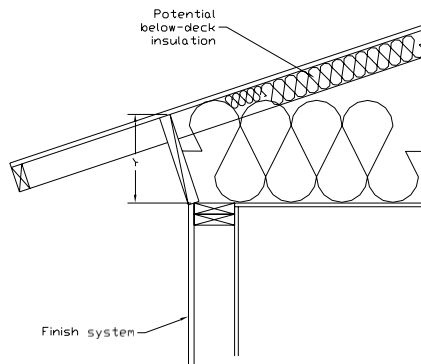
With a standard roof truss (Figure 8), the depth of the ceiling insulation is restricted to the space left between the roof deck and the wall top plate for the insulation path, and the space between the bottom and top chord of the truss in the framing path. If the modeled insulation completely fills this space, there is no attic air space at the edge of the roof. Heat flow through the ceiling in this attic edge area is directly to the outside both horizontally and vertically, instead of to the attic space. Measures that depend on an attic air space, such as radiant barriers or ventilation, do not affect the heat flows in the attic edge area.

Figure 8: Section at Attic Edge with Standard Truss



Source: California Energy Commission

A raised heel truss (Figure 9) provides additional height at the attic edge that, depending on the height Y and the ceiling insulation R , can either reduce or eliminate the attic edge area and its thermal impact.

Figure 9: Section at Attic Edge with a Raised Heel Truss

Source: California Energy Commission

For cases where the depth of insulation (including below-deck insulation depth) is greater than the available height at the attic edge, the compliance software automatically creates cathedral ceiling surfaces to represent the attic edge area and adjusts the dimensions of the attic air space using the algorithms contained in Appendix G. If above-deck insulation is modeled, it is included in the attic edge cathedral ceiling constructions, but radiant barriers below the roof deck are not.

PROPOSED DESIGN

The compliance software shall allow the user to specify that a raised heel truss will be used (as supported by construction drawings), with the default being a standard truss as shown in Figure 8. If the user selects a raised heel truss, the compliance software will require the user to specify the vertical distance between the wall top plate and the bottom of the roof deck (Y in Figure 9).

STANDARD DESIGN

The standard design shall have a standard truss with the default vertical distance of 3.5 inches between wall top plate and roof deck.

VERIFICATION AND REPORTING

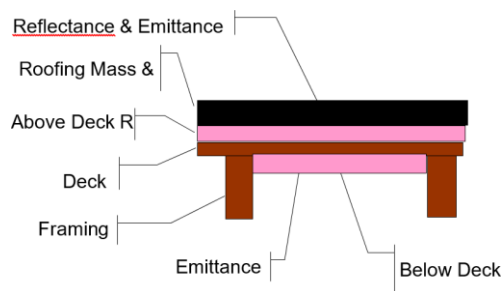
A raised heel truss is a special feature, and the vertical height above the top plate will be included on the CF1R.

2.6.6 The Roof Deck

The roof deck is the construction at the top of the attic and includes the solar optic properties of the exterior surface, the roofing type, the framing, insulation, air gaps, and other features. These are illustrated in

Figure 10, which shows a detailed section through the roof deck.

Figure 10: Components of the Attic Through Roof Deck



Source: California Energy Commission

2.6.6.1 Radiant Barrier

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

PROPOSED DESIGN

The user shall specify whether the proposed design has:

- A radiant Barrier
- No Radiant Barrier

STANDARD DESIGN

The standard design shall have a radiant barrier if required by the prescriptive Energy Code (Section 150.1[c] and Table 150.1-A) for the applicable climate zone with Option B.

VERIFICATION AND REPORTING

Radiant barriers are reported as a special feature on the CF1R.

2.6.6.2 Below Deck Insulation

Below-deck insulation is insulation that will be installed below the roof deck between the roof trusses or rafters.

PROPOSED DESIGN

The compliance software shall allow the user to specify the R-value of insulation that will be installed below the roof deck between the roof trusses or rafters. The default is an uninsulated roof deck.

STANDARD DESIGN

The standard design has below-deck insulation as specified in Section 2.5.6.1 Ceilings Below Attics.

VERIFICATION AND REPORTING

The R-value of any below-deck insulation is reported as a special feature on the CF1R.

2.6.6.3 Roof Deck and Framing

The roof deck is the structural surface that supports the roofing. The compliance software assumes a standard wood deck, and this is not a compliance variable. The size, spacing, and material of the roof deck framing are compliance variables.

PROPOSED DESIGN

The roof deck is wood siding/sheathing/decking. The compliance software shall default the roof deck framing to 2x4 trusses at 24 in. on center. The compliance software shall allow the user to specify alternative framing size, material, and framing spacing.

STANDARD DESIGN

The standard design is 2x4 trusses at 24 in. on center.

VERIFICATION AND REPORTING

Nonstandard roof deck framing or spacing is reported as a special feature on the CF1R.

2.6.6.4 Above Deck Insulation

Above-deck insulation represents the insulation value of the air gap in "concrete or clay tile" or "metal tile or wood shakes." The R-value of any user modeled insulation layers between the roof-deck and the roofing is added to the air gap value.

PROPOSED DESIGN

This input defaults to R-0.85 for "concrete or clay tile" or for "metal tile or wood shakes" to represent the benefit of the air gap but no additional insulation. The compliance software

shall allow the user to specify the R-value of additional above-deck insulation in any roof-deck construction assembly.

STANDARD DESIGN

The standard design accounts for the air gap based on roofing type but has no additional above-deck insulation.

VERIFICATION AND REPORTING

Above-deck insulation R-value is reported as a special feature on the CF1R.

2.6.6.5 Roofing Type and Mass**PROPOSED DESIGN**

The choice of roofing type determines the air gap characteristics between the roofing material and the deck and establishes whether other inputs are needed, as described below. The choices for roof type are shown below.

- **Concrete or clay tile.** Both types have significant thermal mass and an air gap between the deck and the tiles.
- **Metal tile or wood shakes.** These are lightweight with an air gap between the tiles or shakes and the deck. Note that tapered cedar shingles do not qualify and are treated as a conventional roof surface.
- **Other steep-sloped roofing types.** These include asphalt and composite shingles and tapered cedar shingles. These products have no air gap between the shingles and the structural roof deck.
- **Low-sloped membranes.** These are basically flat roofs with a slope of less than 2:12.
- **Above-deck mass.** The above-deck mass depends on the roofing type. The mass is 10 lbs/ft² for concrete and clay tile and 5 lbs/ft² for metal tile, wood shakes, or other steep-slope roofing types. For low-slope roofs, the additional thermal mass is assumed to be gravel or stone, and the user chooses one of the following inputs that is less than or equal to the weight of the material being installed above the roof deck:
 - No mass (asphalt)
 - 5 lbs/ft²
 - 10 lbs/ft²
 - 15 lbs/ft²
 - 25 lbs/ft²

STANDARD DESIGN

The roof slope shall match the proposed design. The roof type for a steep slope roof is 10 lbs/ft² tile. The roof type for low-slope roof is lightweight roof.

VERIFICATION AND REPORTING

The roof type is reported on the CF1R.

2.6.6.6 Solar Reflectance and Thermal Emittance

PROPOSED DESIGN

The compliance software shall allow the user to default the solar reflectance and thermal emittance of the roofing. The solar reflectance product default is 0.10 for all roof types. The thermal emittance default is 0.85.

The compliance software shall allow the user to input aged solar reflectance and thermal emittance of roofing material that are rated by the CRRC. The installed value must be equal to or higher than the value specified in the software. Roof construction with a roof membrane mass of at least 25 lbs/ft² or roof area incorporated integrated solar collectors are assumed to meet the minimal solar reflectance.

STANDARD DESIGN

The solar reflectance and thermal emittance of the standard design roofing are as specified in the prescriptive standards.

VERIFICATION AND REPORTING

Thermal emittance and solar reflectance shall be reported on the CF1R. A reflectance of 0.20 or higher is reported as a cool roof. A value higher than the default but less than 0.20 is reported as a nonstandard roof reflectance value.

2.7 Crawl Spaces

PROPOSED DESIGN

The software user will model the crawl space as a separate unconditioned zone, selecting appropriate vented crawl space (with raised floor insulation), the perimeter of the crawl space (in linear feet) and the height of the crawl space.

STANDARD DESIGN

The standard design has a typical vented crawl space when a crawl space is modeled in the proposed design. Otherwise, the raised floor is assumed to be over exterior or unconditioned space.

VERIFICATION AND REPORTING

The crawl space zone type and characteristics shall be reported on the CF1R.

2.8 Garage/Storage

An attached, unconditioned space is modeled as a separate unconditioned zone. While the features of this space have no effect on compliance directly, it is modeled to accurately represent the building. The modeling of the garage/storage area will shade the walls adjacent to conditioned space and will have a lower air temperature (than the outside) adjacent to those walls. The walls and door that separate the conditioned zone from the garage/storage area are modeled as part of the conditioned zone.

PROPOSED DESIGN

The software user will model the area and type for the floor, exterior walls (ignore windows), large metal roll-up or wood doors (assume a 1.0 U-factor), and roof/ceiling (typically an attic or the same as the conditioned zone).

STANDARD DESIGN

The standard design building has the same features as the proposed design.

VERIFICATION AND REPORTING

The presence of an attached garage or unconditioned space is reported as general information on the CF1R. The general characteristics of the unconditioned zone are reported on the CF1R.

2.9 Domestic Hot Water (DHW)

Water heating energy use is based on the number of bedrooms, fuel type, distribution system, water heater type, and conditioned floor area. Detailed calculation information is included in Appendix B.

PROPOSED DESIGN

The water heating system is defined by the heater type (gas, electric resistance, or heat pump), tank type, dwelling-unit distribution type, efficiency (either UEF or recovery efficiency with the standby loss), tank volume, exterior insulation R-value (only for indirect), rated input, and tank location (for electric resistance and heat pump water heater only).

Heat pump water heaters are defined by energy factor, volume, and tank location or, for Northwest Energy Efficiency Alliance (NEEA) rated heat pumps, by selecting the specific heater brand, model, and tank location.

Water heater and tank types include:

Commented [AT9]: Individual Dwelling Units are missing from this section

- Consumer storage: $\leq 75,000$ Btu/h gas/propane, ≤ 12 kW electric, or ≤ 24 amps heat pump, rated with UEF.
- Consumer instantaneous: $\leq 200,000$ Btu/h gas or propane, or ≤ 12 kW electric. An instantaneous water heater is a water heater with an input rating of $\geq 4,000$ Btu/h/gallon of stored water, rated with a UEF.
- Residential-duty commercial storage: $> 75,000$ Btu/h, $\leq 105,000$ Btu/h gas/propane, ≤ 12 kW electric, ≤ 24 amps heat pump, and rated storage volume < 120 gallons, rated with a UEF.
- Residential-duty commercial instantaneous: $\leq 200,000$ Btu/h gas/propane, ≤ 58.6 kW electric, rated storage volume ≤ 2 gallons, rated with a UEF.
- Commercial storage: $> 75,000$ Btu/h gas/propane, $> 105,000$ Btu/h oil, or > 12 kW electric, rated with thermal efficiency and standby loss.
- Commercial instantaneous: $> 200,000$ Btu/h gas/propane, > 12 kW electric. Instantaneous water heater is a water heater with an input rating of $\geq 4,000$ Btu/h per gallon of stored water, rated with thermal efficiency.
- Heat pump water heater: ≤ 24 amps NEEA rating or rated with UEF.
- Mini-tank (modeled only in conjunction with an instantaneous gas water heater): a small electric storage buffering tank that may be installed downstream of an instantaneous gas water heater to mitigate delivered water temperatures (e.g., cold water sandwich effect). If the standby loss of this aftermarket tank is not listed in the [CEC appliance database](#), a standby loss of 35 W must be assumed.
- Indirect: a tank with no heating element or combustion device used in combination with a boiler or other device serving as the heating element.
- Boiler: a water boiler that supplies hot water, rated with thermal efficiency or AFUE.

Heater element type includes:

- Electric resistance.
- Gas.
- Heat pump.

Dwelling unit distribution system types include:

- Standard (all distribution pipes insulated).
- Point of use.
- Central parallel piping.

- Recirculation with nondemand control (continuous pumping).
- Recirculation with demand control, push button.
- Recirculation with demand control, occupancy/motion sensor.
- HERS-required pipe insulation, all lines.
- HERS-required central parallel piping.
- HERS-required recirculation, demand control, push button.
- HERS-required recirculation with demand control, occupancy/motion sensor.

Some distribution systems have an option to increase the amount of credit received if the option for HERS verification is selected. See Appendix B for the amount of credit and *Reference Appendices, Residential Appendix Table RA2-1* for a summary of inspection requirements.

2.9.1.1 Distribution Compactness

Distribution compactness identifies the proximity between the water heater and use points. The distribution compactness of the water heating system must be specified. The choices include:

- None.
- Compact distribution basic credit.
- Compact distribution expanded credit (HERS).

For both compact distribution basic credit and expanded credit, the plan view distance from the water heater to the master bedroom, the kitchen, and the furthest fixture must be specified. The software will determine if the distances qualify for the credit.

2.9.1.2 Drain Water Heat Recovery

Drain water heat recovery (DWHR) is a system where the waste heat from shower drains is used to preheat the cold inlet water. The preheat water can be routed to the served shower, water heater, or both.

The user specifies the DWHR device for the water heating system. The rated efficiency of the DWHR device, the number of shower(s) served, and the configuration must be specified. The configuration choices include:

- Equal flow to shower and water heater: The potable-side heat exchanger output feeds both the fixture and the water heater inlet. Potable and drain flow rates are equal, assuming no other simultaneous hot water draws.

- Unequal flow to shower: The potable-side heat exchanger output feeds the inlet(s) of the water heater(s) that are part of the parent DHW system. (The inlet temperature is adjusted to reflect recovered heat.)
- Unequal flow to water heater: The potable-side heat exchanger output feeds only the associated fixture.

Multiple DWHR devices can be used for a water heater system.

Drain water heat recovery is a HERS-verified measure.

2.9.2 Domestic Water Heating Systems

The standard design is a single heat pump water heater with a 2.0 UEF, with compact distribution basic credit in Climate Zones 1 and 16, and a drain water heat recovery system in Climate Zone 16. In Climate Zone 16, the standard design DWHR has an exchanger efficiency of 0.65, serving 100 percent of showers, with an equal shower configuration.

If the proposed building has an attached garage, then the standard design HPWH location is the garage. If the proposed building does not have an attached garage, then the standard design HPWH location is in the conditioned space with the air inlet and outlet ducted to the outside.

In Climate Zones 3, 4, 13, and 14, if the proposed design is gas, then the standard design is a single gas or propane consumer instantaneous water heater for each dwelling unit. The single consumer instantaneous water heater is modeled with an input of 200,000 Btu/h, a tank volume of zero gallons, a high draw pattern, and a UEF meeting the minimum federal standards. The current minimum federal standard for a high-draw-pattern instantaneous water heater is 0.81 UEF.

2.9.3 Solar Thermal Water Heating Credit

When a water heating system has a solar thermal system to provide part of the water heating, the user enters information about the Solar Rating and Certification Corporation (SRCC) OG-100 approved collector (manufacturer, brand, model number), including details of the installation (azimuth, tilt),

Alternatively, the user can enter the OG-300 rated solar fraction for their specific climate zone.

2.10 Additions/Alterations

Addition and alteration compliance is based on Energy Code, §150.2. The energy budget for additions and alterations is based on TDV energy. Alterations must model the entire

dwelling unit. Additions may be modeled as addition alone, as “existing+addition+alteration,” or the entire building may be modeled as an entirely new building (whole building, §150.2[c]).

Additions that are 1,000 ft² or less are exempt from dwelling unit ventilation requirements of §150.0(o)1C, §150.0(o)1E, or §150.0(o)1F. When an addition to any building creates a new dwelling unit, this exception does not apply.

The standard design does not include:

- Cool roof when an addition is 300 ft² or less.
- Ventilation cooling for additions that are 1,000 ft² or less.
- Solar generation/PV requirements.

2.10.1 Accessory Dwelling Units

When an accessory dwelling unit (ADU) is detached and newly constructed, it must comply using the whole building approach as described in Section 2.10.2 Whole Building. When an ADU is created by conditioning an existing unconditioned space and is either attached or detached, it may comply using any of the compliance approaches allowed for additions as described in Section 2.10.3 Alteration-Along Approach or Section 2.10.4 Addition-Along Approach.

2.10.2 Whole Building

The entire proposed building, including all additions or alterations or both, is modeled the same as a newly constructed building. The building complies if the proposed design uses equal or less energy than the standard design.

2.10.3 Alteration-Along Approach

The proposed alteration alone floor area is modeled. The alteration requirements of §150.2(b) are applied to any features that do not exist.

2.10.4 Addition-Along Approach

The proposed addition alone is modeled the same as a newly constructed building except that the internal gains are prorated based on the size of the dwelling. None of the exceptions included for prescriptive additions, which are implemented in the existing plus addition plus alteration compliance approach (Section 2.10.5 Existing+ Addition_ Alteration Approach), are given to the addition alone approach. (See Energy Code, §150.2[a]2.B.) The addition complies if the proposed design uses equal or less space heating, space cooling, and water heating TDV energy than the standard design.

The addition-alone approach shall not be used when alterations to the existing building are proposed. Modifications to any surfaces between the existing building and the addition are part of the addition and are not considered alterations.

PROPOSED DESIGN

The user shall indicate that an addition alone is being modeled and enter the conditioned floor area of the addition. Any surfaces that are between the existing building and the addition are not modeled or are treated as adiabatic surfaces. All other features of the addition shall be modeled the same as a newly constructed building.

When an existing HVAC system is extended to serve the addition, the standard design shall assume the same efficiency for the HVAC equipment as the proposed design. (See Sections 2.4.1 Heating Subsystems and 2.4.5 Cooling Subsystems.)

When a dual-glazed greenhouse or garden window is installed in an addition or alteration, the proposed design U-factor can be assumed to be 0.30.

STANDARD DESIGN

The addition alone is modeled the same as a newly constructed building, with the following exceptions:

- A. When roofing requirements are included in Table 150.1-A, they are included in the standard design if the added conditioned floor area is greater than 300 ft².
- B. When ventilation cooling (whole-house fan) is required by Table 150.1-A, it is included in the standard design when the added conditioned floor area is greater than 1,000 ft². The capacity shall be based on 1.5 CFM/ft² of conditioned floor area for the entire dwelling unit conditioned floor area.
- C. When compliance with IAQ requirements of §150.0(o) apply to an addition with greater than 1,000 ft² added, the conditioned floor area of the entire dwelling unit shall be used to determine the required ventilation airflow. For additions with 1,000 ft² or less of added conditioned floor area, no IAQ requirements apply.
- D. PV requirements are not included.
- E. The standard design HVAC system is a natural gas furnace (or propane if natural gas is not available) if the proposed design has a gas heating system. The standard design HVAC system is a split heat pump if the proposed design has an electric heating system. See Section 2.4.1 Heating Subsystems for equipment efficiencies and operating details for each type of system. The cooling system for the standard design building is a nonzonal control system, split-system ducted cooling system, meeting the minimum requirements of the *Appliance Efficiency Regulations*. See Section 2.4.56 Cooling Subsystems for equipment efficiencies and operating details for each type of system.

Commented [AG10]: Correction to section #

- F. For dwelling units with water heaters serving individual dwelling units, the standard design DHW system is a heat pump water heater with a 2.0 UEF. In climate zone 3, 4, 13 and 14, if the proposed design is gas, the standard design DHW system is a natural gas tankless (or propane if natural gas is not available) water heating system. See Section 2.9.2 Individual Dwelling Units for equipment efficiencies and operating details for each type of water heater.

Commented [AG11]: Section 150.2(a)1D specifies that when a new water heater is installed to serve an addition it may either be a HPWH, gas tankless, or for additions less than 500ft² an electric point of use. Shouldn't these allowances supersede the 150.1 requirements that are described here? Perhaps we've missed another nuance of the code, otherwise suggest updating to the following language:

For dwelling units with water heaters serving individual dwelling units, the standard design DHW system is a natural gas tankless (or propane if natural gas is not available) if the proposed design has a gas water heating system. The standard design HVAC system is a heat pump water heater if the proposed design has an electric water heating system.

2.10.5 Existing + Addition + Alteration Approach

Energy Code §150.2(a)2 contains the provisions for additions and §150.2(b)2 for alterations when the existing building is included in the calculations. These provisions are the "Existing + Addition + Alteration" (or "E+A+A") performance approach.

PROPOSED DESIGN

The proposed design is modeled by identifying each energy feature as part of the existing building (as existing, altered, or new), or as part of the addition. The compliance software uses this information to create an E+A+A standard design using the rules in the standards that take into account whether altered components meet or exceed the threshold at which they receive a compliance credit and whether any related measures are triggered by altering a given component.

For building surfaces and systems designated below, all compliance software must provide an input field with labels for the proposed design, which define how the standard design requirements are established based on the option selected by the software user:

- **Existing:** The surface or system remains unchanged within the proposed design. (Both standard design and proposed design have the same features and characteristics.)
- **Altered:** the surface or system is altered in the proposed design. No verification of existing conditions is assumed with this designation.
- **Verified Altered:** the surface or system is altered in the proposed design, and the original condition is verified by a HERS Rater (an optional selection).
- **New:** a new surface or system is added in the proposed design (may be in the existing building or the addition).

Deleted features are not included in the proposed design.

§150.2, Table 150.2-D specifies the details of the standard design for altered components based on whether verification of existing conditions is selected or not:

- **Altered** with no third-party verification of existing conditions (the default selection). This compliance path does not require an on-site inspection of existing conditions prior to the start of construction. The attributes of the existing condition are undefined, with the standard design for altered components based on §150.2, Table

150.2-D, and the climate zone. Energy compliance credit or penalty is a function of the difference between the value for that specific feature allowed in Table 150.2-D and the modeled/installed efficiency of the feature.

- **Verified Altered** existing conditions. This compliance path requires that a HERS Rater perform an on-site inspection of pre-alteration conditions prior to construction. If an altered component or system meets or exceeds the prescriptive alteration requirements, the compliance software uses the user-defined and verified existing condition as the standard design value. Energy compliance credit is then based on the difference between the verified existing condition for that altered feature and the modeled/installed efficiency of the proposed design.

2.10.5.1 **QII**

STANDARD DESIGN

The standard design includes QII for additions greater than 700 ft² in any low-rise single-family building in Climate Zones 1-16 (§150.2[a]1Bv).

The provisions of §150.2(a)1Aiv, as applied to converting an existing unconditioned space to conditioned space, are accommodations made by the HERS Rater in the field. No adjustments to the energy budget are made.

2.10.5.2 **PV**

STANDARD DESIGN

The standard design does not include PV for additions and alterations.

2.10.5.3 **Roof/Ceilings**

STANDARD DESIGN

The standard design roof/ceiling construction assembly is based on the proposed design assembly type as shown in Table 27. For additions less than or equal to 700 ft², radiant barrier requirements follow Option C (§150.1[c]9B). The standard design for unaltered ceilings and roofs is the existing condition.

Table 27: Standard Design for Roofs/Ceilings

Proposed Design Roof/Ceiling Types	Addition ≤ 300 ft ²	Addition > 300 ft ² and ≤ 700 ft ²	Addition > 700 ft ²	Altered	Verified Altered
Roof Deck Insulation (below-deck, where	NR	NR	CZ 4, 8-16 = R-19 (single-family)	NR	Existing

Commented [AG12]: Remove since this ACM is for SF only.

required) at vented attic					
Ceilings Below Attic	CZ 1, 2, 4, 8-16 = R-38 CZ 3, 5-7 = R-30	CZ 1, 2, 4, 8-16 = R-38 CZ 3, 5-7 = R-30	CZ 1, 2, 4, 8-16 = R-38 CZ 3, 5-7 = R-30	CZ 5, 7 = R-19 CZ 1-4, 6, 8-16 = R-49	Existing
Non-Attic (Cathedral) Ceilings and Roofs	R-22/U-0.043	R-22/U-0.043	Same as above	R-19/U-0.054	Existing
Radiant Barrier	CZ 2-15 REQ CZ 1, 16 NR	CZ 2-15 REQ CZ 1, 16 NR	CZ 2, 3, 5-7 REQ CZ 1, 4, 8-16 NR	NR	Existing
Roofing Surface (Cool Roof) Steep-Sloped	NR	CZ 10-15 =0.20 Reflectance, =0.75 Emittance	CZ 10-15 =0.20 Reflectance, =0.75 Emittance	CZ 4, 8-15 =0.20 Reflectance =0.75 Emittance	Existing
Roofing Surface (Cool Roof) Low-Sloped	NR	CZ 13, 15 = 0.63 Reflectance, =0.75 Emittance	CZ 13, 15 = 0.63 Reflectance, =0.75 Emittance	CZ 4, 6-15 =0.63 Reflectance =0.75 Emittance	Existing
Above Deck Insulation, Low-Sloped	NR	NR	NR	CZ 1, 2, 4, 8-16 R-14 continuous	Existing

Source: California Energy Commission

2.10.5.4 Exterior Walls and Doors

PROPOSED DESIGN

Existing structures with insulated wood-framed walls that are being converted to conditioned space using an E+A+A approach are allowed to show compliance using the existing wall framing, without having to upgrade to current prescriptive continuous insulation requirements. The walls are modeled as an assembly with the existing framing and either R-15 (in 2x4 framing) or R-21 (in 2x6 framing) insulation (Exception to §150.0[c]1 and §150.2[a]1).

STANDARD DESIGN

The areas, orientation, and tilt of existing, new, and altered net exterior wall areas (with windows and doors subtracted) are the same in the existing and addition portions of standard design as in the proposed design.

If the proposed wall area is framed, the gross exterior wall area (excluding knee walls) is equally divided among the four building orientations: front, left, back and right. The gross exterior wall area of any unframed walls is also equally divided among the four orientations in the standard design.

The standard design exterior wall construction assembly is based on the proposed design assembly type as shown in Table 28. Framed walls are modeled as 16-in. on center wood framing. The standard design for unaltered walls is the existing condition.

The standard design for exterior opaque or swinging doors is 0.20 U-factor. Fire-rated doors (from the house to garage) use the proposed design door U-factor as the standard design U-factor.

Table 28: Standard Design for Walls and Doors

Proposed Design Exterior Wall Assembly Type or Door	Addition	Altered	Verified Altered
Framed & Non-Mass Exterior Walls	CZ 1-5, 8-16 = R-21+R-5 in 2x6 (U0.048) CZ 6-7 = R-15+R-4 in 2x4 (U-0.065)	R-13 in 2x4 R-20 in 2x6	Existing
Wood framed existing walls where siding is not removed, or an extension of an existing wall	R-15 in 2x4 R-21 in 2x6	R-13 in 2x4 R-20 in 2x6	Existing
Framed Wall Adjacent to Unconditioned (e.g., Demising or Garage Wall)	R-15 in 2x4 R-21 in 2x6	R-13 in 2x4 R-20 in 2x6	Existing
Above Grade Mass Interior Insulated	CZ 1-15 = R-13 (0.077) CZ 16 = R-17 (0.059)	N/R Mandatory requirements have no	Existing

		insulation for mass walls	
Below Grade Mass Interior Insulation	CZ 1-15 = R-13 (0.077) CZ 16 = R-15 (0.067)	N/R Mandatory requirements have no insulation for mass walls	Existing
Swinging Doors	0.20	0.20	Existing

Source: California Energy Commission

2.10.5.5 Fenestration

PROPOSED DESIGN

Fenestration areas are modeled in the addition as new. In an existing building, they may be existing, altered, or new. Altered (replacement) fenestration is defined in §150.2(b)1.B as "existing fenestration area in an existing wall or roof [which is] replaced with a new manufactured fenestration product... Up to the total fenestration area removed in the existing wall or roof...." Altered also includes fenestration installed in the same existing wall, even if in a different location on that wall. Added fenestration area in an existing wall or roof is fenestration that did not previously exist and is modeled as new.

STANDARD DESIGN

Standard design fenestration U-factor and SHGC are based on the scope of the project (addition vs. alteration), and for additions the square footage is taken into consideration as well, as shown in Table 29. Vertical glazing includes all fenestration in exterior walls such as windows, clerestories, and glazed doors. Skylights include all glazed openings in roofs and ceilings.

New fenestration in an alteration is modeled with the same U-factor and SHGC as required for an addition.

West-facing limitations are combined with the maximum fenestration allowed and are not an additional allowance.

The standard design is set for fenestration areas and orientations as shown in Table 29:

- Proposed design \leq allowed percentage of total fenestration area:

In the existing building, the standard design uses the same area and orientation of each existing or altered fenestration area (in the respective existing or altered wall or roof.)

In the addition, new fenestration is divided equally among the four project compass points similar to new gross wall areas in the addition described above.

- Proposed design > allowed percentage of total fenestration area:

The standard design first calculates the allowed total fenestration area as the total existing and altered fenestration area in existing or altered walls and roofs. Added to this is the percent of fenestration allowed in the addition, based on the conditioned floor area of the addition.

Table 29: Standard Design for Fenestration (in Walls and Roofs)

Proposed Design Fenestration Type	Addition \leq 400 ft ²	Addition > 400 and \leq 700 ft ²	Addition > 700 ft ²	Altered	Verified Altered
Vertical Glazing: Area and Orientation	75 ft ² or 30%	120 ft ² or 25%	175 ft ² or 20%	See full description below.	Existing
West Facing Maximum Allowed	CZ 2, 4, 6 - 15=60 ft ²	CZ 2, 4, 6 - 15=60 ft ²	CZ 2, 4, 6 - 15=70 ft ² or 5%	NR	NR
Vertical Glazing: U-Factor	0.30	0.30	0.30	0.40	See below
Vertical Glazing: SHGC	CZ 2, 4, 6-15=0.23 CZ 1,3, 5 & 16=0.35	CZ 2, 4, 6-15=0.23 CZ 1,3, 5 & 16=0.35	CZ 2, 4, 6-15=0.23 CZ 1,3, 5 & 16=0.35	CZ 2, 4, 6-15=0.35 CZ 1,3, 5 & 16=0.35	Existing
Skylight: Area and Orientation	No skylight area in the standard design	No skylight area in the standard design	No skylight area in the standard design	NR	Existing
Skylight: U-Factor	0.30	0.30	0.30	0.55	Existing
Skylight: SHGC	CZ 2, 4, 6 - 15=0.23 CZ 1,3 5 & 16=0.35	CZ 2, 4, 6 - 15=0.23 CZ 1,3 5 & 16=0.35	CZ 2, 4, 6 - 15=0.23 CZ 1,3 5 & 16=0.35	CZ 2, 4, 6 - 15=0.30 CZ 1,3 5 & 16=0.35	Existing

Source: California Energy Commission

2.10.5.6 Overhangs, Sidesfins and Other Exterior Shading

STANDARD DESIGN

The standard design for a proposed building with overhangs, sidefins, and exterior shades is shown in Table 30. Exterior shading (limited to bug screens) is treated differently than fixed overhangs and sidefins, as explained in Section 2.5.6.9 Exterior Shading.

Table 30: Standard Design for Overhangs, Sidefins, and Other Exterior Shading

Proposed Design Shading Type	Addition	Altered	Verified Altered
Overhangs and Sidefins	No overhangs or sidefins	Proposed altered condition	Same as altered
Exterior Shading	Standard (bug screens on fenestration, none on skylights)	Proposed altered condition	Existing exterior shading
Window Film	No window film	Proposed altered condition	Existing exterior shading

Source: California Energy Commission

2.10.5.7 Window Film

PROPOSED DESIGN

A window film must have at least a 15-year warranty and is treated as a window replacement. The values modeled are either the default values from Tables 110.6-A and 110.6-B or the NFRC Window Film Energy Performance Label.

2.10.5.8 Floors

STANDARD DESIGN

Table 150.2-C requires that the standard design be based on the mandatory requirements from §150.0(d). The standard design for floors is shown in Table 31.

Table 31: Standard Designs for Floors

Proposed Design Floor Type	Addition	Altered (mandatory)	Verified Altered
Raised Floor Over Crawl Space or Over Exterior	R-19 in 2x6 16" o.c. wood framing	R-19 in 2x6 16" o.c. wood framing	If proposed $U \leq 0.037$, standard design = existing raised; if proposed $U > 0.037$, standard design = 0.037

Slab-on-Grade: Unheated	CZ1-15: R-0 CZ16: R-7 16" vertical	R-0	Existing unheated slab-on-grade
Slab-on-Grade: Heated	CZ1-15: R-5 16" vertical CZ 16: R-10 16" vertical	CZ1-15: R-5 16" vertical CZ 16: R-10 16" vertical	Existing heated slab-on-grade
Raised Concrete Slab	CZ1,2,11,13,14,16: R-8 CZ3-10: R-0 CZ12,15: R-4	R-0	Existing raised concrete slab

Source: California Energy Commission

2.10.5.9 Thermal Mass

STANDARD DESIGN

The standard design for thermal mass in existing plus addition plus alteration calculations is the same as for all newly constructed buildings as explained in Section 2.5.4.1 Internal Thermal Mass.

2.10.5.10 Air Leakage and Infiltration

STANDARD DESIGN

Standard design air leakage and infiltration is shown in Table 32.

Table 32: Standard Design for Air Leakage and Infiltration

Proposed Air Leakage and Infiltration	Addition	Altered	Verified Altered
Single-Family Buildings	5 ACH50	5 ACH50	Diagnostic testing of existing ACH50 value by HERS Rater

Source: California Energy Commission

2.10.5.11 Space Conditioning System

STANDARD DESIGN

The standard design for space-conditioning systems is shown in Table 33.

When cooling ventilation (whole-house fan) is required by §150.1 and §150.2, the capacity is 1.5 CFM/ft² of conditioned floor area for the entire dwelling unit.

When compliance with IAQ requirements of §150.0(o) apply to an addition with greater than 1,000 ft² added, the conditioned floor area of the entire dwelling unit is used to

determine the required ventilation airflow. For additions with 1,000 ft² or less of added conditioned floor area, no IAQ requirements shall apply.

Table 33: Standard Design for Space Conditioning Systems

Proposed Design Space-Conditioning System Type	Addition	Altered	Verified Altered
Heating System	See Section 2.10.4 Addition-Alone Approach and 2015 Federal Appliance Stds. based on fuel source and equipment type	Same as Addition	Existing heating fuel type and equipment type/efficiency If the existing equipment is electric resistance and none of the exceptions to §150.2(b)1G are met the Standard Design system shall be a heat pump meeting the requirements of Section 2.10.4 Addition-Alone Approach.
Cooling System	See Section 2.10.4 Addition-Alone Approach and 2015 Federal Appliance Standards based on fuel source and equipment type	Same as Addition	Existing cooling equipment type/efficiency
Refrigerant Charge	CZ 2, 8-15: Yes CZ 1, 3-7: No	Same as Addition	Existing
Whole-House Fan (WHF) applies only if addition > 1,000 ft ²	CZ 8-14; 1.5 CFM/ft ²	N/A	Existing condition. To count as Existing the WHF must be ≥ 1.5 CFM/ft ² and be CEC-rated
Indoor Air Quality applies only if addition > 1,000 ft ² or if addition is a dwelling unit	Meet mandatory ventilation for entire dwelling	Same as Addition	Existing

Commented [AG13]: Add space

Source: California Energy Commission

2.10.5.12 **Duct System**

PROPOSED DESIGN

Duct insulation shall be based on the new or replacement R-value input by the user. Duct leakage shall be based on the tested duct leakage rate entered by the user or a default rate of 30 percent.

STANDARD DESIGN

Table 34: Standard Design for Duct Systems

Proposed Design Duct System Type	No Verification of Existing Conditions	Verified Existing Conditions
Altered or Extended Ducts >25 ft	CZ 1-2, 4, 8-16: Duct insulation R-8 and duct leakage of 10% CZ 3, 5-7: Duct insulation R-6 and duct leakage of 10%	Existing duct R-value and duct leakage the lesser of 30% or the existing leakage rate
New Ducts	CZ 1-2, 4, 8-16: Duct insulation R-8 and duct leakage of 5% CZ 3, 5-7: Duct insulation R-6 and duct leakage of 5%	N/A

Based on Table 150.2-A

Note 1: Refer to §150.2(b)1Diia for definition of an "Entirely New or Complete Replacement Duct System."

Source: California Energy Commission

2.10.5.13 **Water Heating System**

STANDARD DESIGN

Table 35: Standard Design for Water Heater Systems

Proposed Design Water Heating System Type	Addition (adding water heater)	Altered	Verified Altered
Single-Family	Prescriptive water heating system per section 2.10.4	Existing fuel type, proposed tank type, mandatory	Existing water heater type(s), efficiency, distribution system.

	Addition-Along Approach	requirements (excluding any solar)	
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Source: California Energy Commission

2.11 Documentation

The software shall be capable of displaying and printing an output of the energy use summary and a text file of the building features. These are the same features as shown on the CF1R when generated using the report manager.

See public domain software user guide or vendor software guide for detailed modeling guidelines.

3 Energy Design Rating Details

The EDR is an alternate way to express the energy performance of a home using a scoring system where 100 represents the energy performance of a reference design building meeting the envelope requirements of the 2006 IECC. The EDR is similar to the energy rating index in the 2015 IECC and the 2014 RESNET standard. Combining high levels of energy efficiency with generating renewable energy, a score of zero or less can be achieved.

Buildings complying with the current Energy Code are more efficient than the 2006 IECC, so most newly constructed buildings will have EDR scores below 100. Buildings with renewable generation like PV can achieve a negative score. If EDRs were calculated for an older inefficient home, the score would likely be well over 100.

There are two EDRs used to evaluate single-family residential buildings. EDR1 is based on source energy and the proposed design EDR1 must be equal or less than the standard design EDR1. EDR2 is based on TDV energy and has two components that must be met for compliance. The EDR2 score of proposed efficiency must be equal or less than the EDR2 score of the standard efficiency, and the total proposed EDR2 score must be equal or less than the total standard design EDR2.

3.1 CALGreen

The software can calculate an EDR1 and EDR2 as required in the CALGreen energy provisions (Title 24, Part 11). The EDR1 and EDR2 implementation applies only to newly constructed single-family residential buildings.