California Energy Commission

STAFF REPORT

2016

RESIDENTIAL ALTERNATIVE CALCULATION METHOD REFERENCE MANUAL

For the *2016 Building Energy Efficiency Standards*

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

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CEC-400-2015-024-SD-REV3

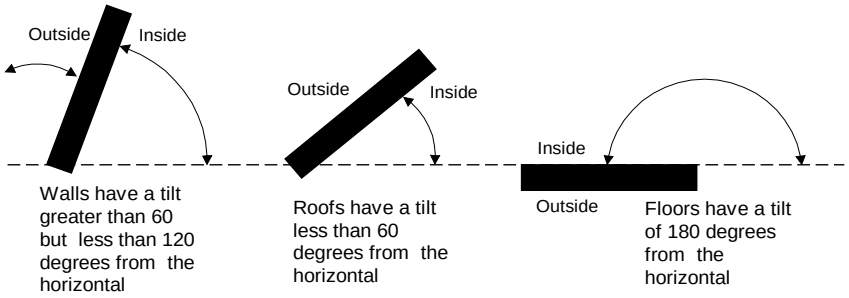
STANDARD DESIGN

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 is reported on the CF1R for verification.

Figure 1: Surface Definitions



2.2.2 Standards Version

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

PROPOSED DESIGN

The user inputs Compliance2017.

STANDARD DESIGN

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

VERIFICATION AND REPORTING

Compliance version is reported on the CF1R.

2.2.3 PV System Credit

The compliance credit available for photovoltaic (PV) systems is available for new construction only and is dependent on the climate zone and dwelling unit size. The credit may be used to tradeoff any efficiency measure, with limits as described below. The PV system must meet the eligibility and verification requirements of Residential Appendix RA4.6.1 and must meet the minimum system size described below.

The PV compliance credit for both single- and multi-family buildings is calculated by the compliance software and is equal to:

Equation 1: $PV_{credit} = TDV_{std} * PV_{maxpct} / 100.0$

Where:

PV_{credit} = PV compliance credit (kTDV/ft²)
TDV_{std} = Standard Design Compliance Total (kTDV/ft²)
PV_{maxpct} = Maximum PV Credit Percentage from Table 1

The minimum PV system size for compliance credit is calculated by the compliance software and is equal to:

Equation 2: $PV_{minsize} = ROUND((PV_{threshold} + PV_{addedsize}) * N_{dwellingunits}, 1)$

For average dwelling units less than or equal to $CFA_{threshold}$:

Equation 3: $PV_{addedsize} = 0$

For average dwelling units larger than $CFA_{threshold}$:

Equation 4: $PV_{addedsize} = PV_{credit} * (CFA_{dwellingunit} - CFA_{threshold}) / PV_{genrate}$

Where:

$PV_{minsize}$ = Minimum PV System Size (kWdc) for compliance credit
$PV_{threshold}$ = Threshold PV System Size per dwelling unit (kWdc) from Table 2
$N_{dwellingunits}$ = Number of dwelling units
$PV_{addedsize}$ = Added PV System Size (kWdc) required
$CFA_{dwellingunit}$ = Average Conditioned floor area per dwelling unit (ft²)
$CFA_{threshold}$ = Average Threshold Conditioned floor per dwelling unit (ft²) from Table 2
$PV_{generate}$ = PV Generation Rate (kTDV/kWdc) from Table 1

~~If the PV size entered by the user is less than PV minimum size then there is no compliance credit.~~

~~Equation 5: $PV_{credit} = 0$ when $PV_{usersize} < PV_{minsize}$~~

~~Where:~~

~~$PV_{minsize}$ = Minimum PV System Size (kWdc) for compliance credit~~
~~$PV_{usersize}$ = PV size entered by user (kWdc)~~

Table 1: PV Credit Calculation Factors

Climate Zone	PV Generation Rate (kTDV/kWdc)	Maximum PV Credit for Single Family	Maximum PV Credit for Multi Family
01	26762	8.0%~~8.4%~~	4.4%~~4.7%~~
02	30021	8.6%~~11.4%~~	5.0%~~5.3%~~
03	31137	6.9%~~7.9%~~	3.1%~~3.4%~~
04	30935	17.7%~~23.2%~~	11.4%~~9.9%~~
05	33490	7.6%~~8.6%~~	2.3%~~2.7%~~
06	30081	0.0%	0.0%
07	30701	0.0%	0.0%
08	29254	28.1%~~31.2%~~	9.1%~~9.0%~~
09	29889	25.9%~~25.2%~~	11.0%~~9.8%~~
10	30200	23.1%~~22.4%~~	10.0%~~9.1%~~
11	29693	17.7%~~17.8%~~	8.7%~~8.1%~~
12	29328	22.0%~~20.7%~~	9.5%~~9.0%~~
13	29553	19.8%~~19.5%~~	9.2%~~8.6%~~
14	31651	16.0%~~16.1%~~	8.2%~~7.7%~~
15	29177	16.3%~~16.2%~~	7.3%~~7.1%~~
16	30930	15.1%~~14.6%~~	8.6%~~7.4%~~

Table 2: PV Threshold Factors

Dwelling Type	PV threshold (kWdc)	CFA threshold (ft^2)
Single Family	2.0	2000
Multi Family	1.0	1000

The maximum PV credits in Table 1 are calculated by using a prototype analysis with the proposed features set equal to the 2016 prescriptive requirements except replacing the 2016 high performance attics (HPA) and high performance walls (HPW) with the 2013 prescriptive requirements. The percentages are calculated by dividing the compliance margin (kTDV/ft^2) by the standard design compliance energy use (kTDV/ft^2) and multiplying by -100. Climate zones 6 and 7 have no 2016 requirement for either HPA or HPW, so there is no PV credit in those climate zones.

Proposed Design

The software allows the user to ~~input the rated power output of the~~specify the use of PV compliance credit and establishes the minimum solar system in kilowatts direct current (DC). ~~If the rated system is greater than or equal to the minimum PV system size, t~~The software calculates the solar credit and subtracts it from the proposed design. ~~If the rated system is less than the minimum PV system size, the software sets the solar credit to zero and displays a message to the user that the minimum PV system size criteria was not met.~~

Table 5: Materials List

Material Name	Thickness (in.)	Conductivity (Btu/h-°F-ft)	Coefficient for Temperature Adjustment of Conductivity (°F(-1))	Specific Heat (Btu/lb-°F)	Density (lb/ft^3)	R-Value per Inch (°F-ft^2-h/ Btu-in)
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
~~R4~~ Synthetic Stucco	~~1~~0.375	~~0.02083~~0.2	~~0.00418~~	~~0.35~~0.2	~~1.5~~58	~~4~~0.2
3 Coat Stucco	0.875	0.4167		0.2	116	0.2
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						

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 14: Buried Duct Effective R-values

	Nominal Round Duct Diameter								
Attic Insulation	4''	5''	6''	7''	8''	10''	12''	14''	16''
	Effective Duct Insulation R-value for Blown Fiberglass Insulation								
R-30	R-13	R-13	R-13	R-9	R-9	R-4.2	R-4.2	R-4.2	R-4.2
R-38	R-25	R-25	R-25	R-13	R-13	R-9	R-9	R-4.2	R-4.2
R-40	R-25	R-25	R-25	R-25	R-13	R-13	R-9	R-9	R-4.2
R-43	R-25	R-25	R-25	R-25	R-25	R-13	R-9	R-9	R-4.2
R-49	R-25	R-25	R-25	R-25	R-25	R-25	R-13	R-13	R-9
R-60	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-13
	Effective Duct Insulation R-value for Blown Cellulose Insulation								
R-30	R-9	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
R-38	R-15	R-15	R-9	R-9	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
R-40	R-15	R-15	R-15	R-9	R-9	R-4.2	R-4.2	R-4.2	R-4.2
R-43	R-15	R-15	R-15	R-15	R-9	R-4.2	R-4.2	R-4.2	R-4.2
R-49	R-31	R-31	R-15	R-15	R-15	R-9	R-9	R-4.2	R-4.2
R-60	R-31	R-31	R-31	R-31	R-31	R-15	R-15	R-9	R-9

2.4.6.11 *Duct/Air Handler Leakage*

The total duct/air handler ~~average~~ leakage ~~factors~~ shown in Table 15 ~~are~~is used in simulating the duct system. The supply duct leakage for each case is the table value times ~~1.17~~0.585. The return leakage is the table value times ~~0.83~~0.415.

Proposed Design

For each ducted system the software user specifies one of the duct/air handler leakage cases shown in Table 15.

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.*

2.4.6.12 *Low Leakage Air Handlers*

A low leakage air handler may be specified as well as a lower duct leakage value (see Section 2.4.6.11). Installation requires installing one of the list of approved low leakage air handling units published by the Energy Commission. The manufacturer certifies that the appliance complies with the requirements of Reference Joint Appendices 9.2.1, 9.2.2, 9.2.3, and 9.2.4.

Table 15: Duct/Air Handler Leakage ~~Factors~~

Case	Duct Leakage	Air Handler Leakage	Total Duct/Air Handler Leakage
~~Untested duct systems in homes built prior to June 1, 2001~~			
~~Untested duct systems in homes built after June 1, 2001~~			
Duct systems in existing single-family dwelling units	15%	Included in duct leakage	15%
Sealed and tested new or altered duct systems in unconditioned or conditioned space in a multi-family dwelling unit	12%	Included in duct leakage	12%
Sealed and tested new or altered duct systems in unconditioned or conditioned space in a townhome or single family dwelling unit	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

~~Case~~	~~Average of Supply and Return~~
~~Untested duct systems in homes built prior to June 1, 2001~~	~~0.86~~
~~Untested duct systems in homes built after June 1, 2001~~	~~0.89~~
~~Sealed and tested duct systems in existing dwelling units~~	~~0.915~~
~~Sealed and tested new duct systems~~	~~0.965~~
~~Verified low leakage ducts in conditioned space~~	~~1.00~~
~~Low leakage air handlers in combination with sealed and tested new duct systems~~	~~0.97 or as measured~~

2.4.7 Space Conditioning Fan Subsystems

PROPOSED DESIGN

The proposed design shall incorporate a mechanical ventilation system fan. This requirement is a mandatory measure. The compliance software allows the user to specify the IAQ ventilation type (see Table 16) and the cfm of outdoor ventilation air which must be equal to or greater than what is required by ASHRAE Standard 62.2. The default is a standalone exhaust system meeting standard 62.2.

STANDARD DESIGN

The mechanical ventilation system in the standard design is the same as the proposed design. The air flow rate is equal to the proposed design. ~~The apparent heat or enthalpy recovery efficiency is the same as the proposed design~~The sensible heat recovery effectiveness is 0. For standalone IAQ fan systems, the fan power ratio is equal to the proposed design value or 1.2 W/cfm, whichever is smaller. For central air handler fans, the fan power ratio is 0.58 W/cfm of central system airflow in ventilation mode.

VERIFICATION AND REPORTING

The required ventilation rate to comply with ASHRAE Standard 62.2 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 RA3.7.

Table 16: IAQ Fans

Type	Description	Inputs
Standalone IAQ Fan (exhaust, supply or balanced)	Dedicated fan system that provides indoor air quality ventilation to meet or exceed the requirements of ASHRAE Standard 62.2.	cfm, Watts/cfm, recovery effectiveness for balanced only
Central Fan Integrated (CFI) (variable or fixed speed)	Automatic operation of the normal furnace fan for IAQ ventilation purposes. 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, Watts/cfm

Table 17: CF1R Report – Indoor Air Quality

IAQ System Name	IAQ System Type	Whole Building IAQ Airflow Rate (cfm)	Standalone IAQ Fan Power Ratio (W/cfm)
SFam IAQVentRpt	Default	28.5	0.25

2.4.10 Ventilation Cooling System

Ventilation cooling systems operate at the dwelling-unit level using fans to bring in outside air to cool the house when this can reduce cooling loads and save cooling energy. Ventilation cooling systems such as whole house fans involve window operation and attic venting. Central fan

ventilation cooling systems use the HVAC duct system to distribute ventilation air. Ventilation cooling systems operate according to the schedule and setpoints shown in Table 19. Ventilation cooling systems that exhaust air through the attic require a minimum of the larger of 1 ft^2 of free attic ventilation area per 750 cfm of rated capacity for relief or the manufacturer specifications (see Section 150.1(c)12 of the standards).

PROPOSED DESIGN

Software allows the user to specify whether a ventilation cooling system is included in conditioned and living zones (see Table 18). The user can specify the actual fan specifications or a default prescriptive whole house fan with a capacity of 1.5 CFM/ft^2 of conditioned floor area when there is a ventilated attic.

STANDARD DESIGN

The standard design building for a newly constructed building or for an addition greater than 1,000 square feet has a whole house fan in climate zones 8 through 14 and no ventilation cooling in other climate zones (see Section 150.1(c) and Table 150.1-A). The whole house fan has 1.5 CFM/ft^2 of conditioned floor area with 1 square foot of attic vent free area for each 750 CFM of rated whole house fan air-flow CFM.

VERIFICATION AND REPORTING

A ventilation cooling system is a special feature and the size and type is reported on the CF1R.

Table 18: Ventilation Cooling Fans

Measure	Description
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 operate between dawn and 11 PM only at ~~25~~33 percent of rated cfm to reflect manual operation of fan and windows by occupant. Fans must be listed in the California Energy Commission'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.

VERIFICATION AND REPORTING

Non-attic ceiling/roof area and constructions are reported on the CF1R. Metal frame or 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 ~~or unconditioned space~~, with a U-factor equivalent to that as specified in Section 150.1(c)1.B. and Table 150.1-A for the applicable climate zone. Walls have 2″x6″ 16-in. on center wood framing with R-19 insulation between framing and R-5 continuous insulation in climate zones 1-5, 8-16 or 2″x4″ 16-in. on center wood framing with R-15 insulation between framing and R-4 continuous insulation in climate zones 6-7. Walls adjacent to unconditioned space, such as garage walls, are treated the same as exterior walls except there is no continuous insulation.

The standard design building is modeled with the same area of above grade mass walls with interior and exterior insulation equivalent to the requirements in Section 150.1(c)1.B. and Table 150.1-A for the applicable climate zone.

The standard design building is modeled with the same area of below grade mass walls with interior insulation equivalent to the requirements in Section 150.1(c)1.B. and Table 150.1-A for the applicable climate zone.

The gross exterior wall area in the standard design is equal to the gross exterior wall area of the proposed design. If the proposed wall area is framed wall, the gross exterior wall area of framed walls in the standard design (excluding knee walls) contains wood framing and is equally divided between the four main compass points, north, east, south, and west.

Wall construction shall match wall construction and thermal characteristics of Section 150.1(c), Table 150.1-A. Window and door areas are subtracted from the gross wall area to determine the net wall

area in each orientation. ~~Walls adjacent to unconditioned space (garage walls) for all climate zones are wood framed, 2"x4", 16-in. on center, R-15 cavity insulation.~~

VERIFICATION AND REPORTING

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

2.5.6.4 *Exterior Thermal Mass*

Constructions for standard exterior mass is 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).

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 materials that is in direct contact with the slab can be considered 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 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 Btu/ft^3-°F; a conductivity of 0.98 Btu-in/hr-ft^2-°F. The exposed portion shall have a surface conductance of 1.3 Btu/h-ft^2-°F (no thermal resistance on the surface) and the covered portion shall have a surface conductance of 0.50 Btu/h-ft^2-°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/ft^3-°F; a conductivity of 0.98 Btu-in/hr- ft^2-ºF; and a surface conductance of 1.3 Btu/h- ft^2-°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.

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 dwelling units, number of bedrooms, fuel type, distribution system, water heater type, and conditioned floor area. Detailed calculation information is included in Appendix B.

Beginning June 12, 2017, EF ratings are replaced with the new federal standard for water heating energy efficiency, Uniform Energy Factor (UEF). The classification of small and large water heater change to consumer and commercial heaters, respectively, and a new class of residential-duty commercial water heater.

For the remainder of the 2016 Building Energy Efficiency Standards cycle, any UEF input is converted to EF by the software using methods described in Appendix B.

PROPOSED DESIGN

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

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

Water heater and tank types include:

- Consumer/s~~S~~mall storage: ≤ 75,000 Btu/h gas/propane, ~~≤105,000 Btu/h oil,~~ ≤ 12 kW electric, or ≤ 24 amps heat pump. Rated with UEF or EF.
- ~~Small tankless: gas or propane with an input of 200,000 Btu/h or less, oil with an input of 210,000 Btu/h or less, or electric with an input of 12 kW or less. Tankless water heater is a~~

~~water heater with an input rating of ≥ 4,000 Btu/h/gallon of stored water. Rated with an energy factor.~~

- Consumer/small instantaneous: ≤ 200,000 Btu/h gas or propane, or ≤ 12 kW electric. Instantaneous water heater is a water heater with an input rating of ≥ 4,000 Btu/h/gallon of stored water. Rated with a UEF or EF.

- Residential-Duty Commercial storage: > 75,000 Btu/h, and ≤ 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 (large) instantaneous: ≤ 200,000 Btu/h gas/propane, ≤ 58.6 kW electric, and rated storage volume ≤ 2 gallons. Rated with a UEF.

- ~~Large storage: > 75,000 Btu/h gas/propane, >105,000 Btu/h oil, or > 12 kW electric. Rated with thermal efficiency and standby loss.~~

- ~~Large tankless: gas or propane with an input of >200,000 Btu/h, oil with an input of >210,000 Btu/h, or electric with an input of >12 kW. Tankless water heater is a water heater with an input rating of ≥ 4,000 Btu/h per gallon of stored water. Rated with thermal efficiency.~~

- Commercial/large storage: > 75,000 Btu/h gas/propane, >105,000 Btu/h oil, or > 12 kW electric. Rated with thermal efficiency and standby loss.

- Commercial/large instantaneous: >200,000 Btu/h gas/propane, > 12 kW electric. Instantaneous water heater is a water heater with an input rating of ≥ 4,000 Btu/h per gallon of stored water. Rated with thermal efficiency.

- Mini-tank (only modeled 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 Energy Commission appliance database, a standby loss of ~~100~~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, or
- Heat pump.

For water heating systems serving a single dwelling unit, a dwelling unit distribution type must be specified. Dwelling unit distribution system types for systems serving individual dwelling units include:

- Standard (~~the full length of the line from the water heater to the kitchen fixtures and all piping of nominal ¾" or larger diameter insulated with 1 inch of insulation~~all distribution pipes insulated)
- ~~Pipe insulation, all lines~~
- Point of use
- Central parallel piping
- Recirculation with non-demand 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
- HERS required compact distribution system

When a multi-family building has central water heating, both a dwelling unit and a central system distribution type must be specified. Dwelling unit distribution types for this case include:

- Standard (~~the full length of the line from the water heater to the kitchen fixtures and all piping of nominal ¾" or larger diameter insulated with 1 inch of insulation~~ all distribution pipes insulated)
- ~~Pipe insulation, all lines~~
- HERS required pipe insulation, all lines

Multi-family central hot water heating central system distribution types include:

- No loops or recirculation system pump
- Recirculation with no control (continuous pumping)
- Recirculation demand control (standard design for new construction)
- Recirculation with temperature modulation control
- Recirculation with temperature modulation and monitoring

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.

STANDARD DESIGN

2.9.1 Individual dwelling units

For systems serving individual dwelling units the standard design is a single gas or propane consumer~~small~~ instantaneous water heater for each dwelling unit. The standard design is natural gas except if the proposed water heater is propane; then the standard is modeled as propane. The consumer~~small~~ instantaneous water heater is modeled with an input of 200,000 Btu/h, a tank volume of zero gallons, high draw pattern, and a~~n energy factor~~ UEF meeting federal standards. The current federal standard for a~~n~~ high draw pattern instantaneous water heater is 0.81 UEF, or the equivalent of ~~(0.82 – (0.0019*vol)) or~~ 0.82 energy factor for the standard system.

2.9.2 Multiple dwelling units

When the proposed design is a central water heating system, the standard design consists of the water heating devices, a recirculation system and solar systems as follows:

Water heating device. The standard design consists of the same number of water heating devices as the proposed design using the efficiencies required in the Appliance Efficiency Standards. The standard design is natural gas except if the proposed water heater is propane, then the standard is modeled as propane. Each water heating device in the proposed system is examined separately. If the proposed water heating device is gas or propane, the standard design is set to the same type and characteristics as the proposed design. If the proposed water heating device is not natural gas or propane, then the standard design is converted to a gas or propane water heater of a similar type and characteristics as the proposed design. The appropriate efficiencies and standby losses for each standard water heating device are then assigned to match the minimum requirements of the definitions and Tables F-2 and F-3 of the 2015 Appliance Efficiency Standards.

Recirculating system. The standard design includes a recirculation system with controls that regulate pump operation based on measurement of hot water demand and hot water return temperature, and capable of turning off the system as described in Appendix B4 Hourly Recirculation Distribution Loss for Central Water Heating Systems. When a building has more than eight dwelling units, the standard design has one recirculation loop. When a building with eight or fewer dwelling units includes a recirculation system, the standard design has one recirculation loop.

Solar. The standard design has a solar water heating system meeting the installation criteria specified in *Reference Residential Appendix RA4* and with a minimum solar savings fraction of 0.20 in climate zones 1 through 9, or 0.35 in climate zones 10 through 16.

VERIFICATION AND REPORTING

All modeled features and the number of devices modeled for the water heating system are reported on the CF1R. Electric resistance and heat pump water heaters indicate the location of the

water heater. NEEA-rated heat pumps are identified by the heater type, which must be verified by the building inspector.

Where distribution systems specify HERS verification, those features are listed in the HERS required verification listings on the CF1R.

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 Solar Fraction (SF) is determined using ~~an F-chart program~~the CEC Solar Water Heating Calculator, OG-100 ~~or OG-300~~ calculation method, or the certified OG-300 rating ~~(see www.gosolarcalifornia.org)~~. (Note: The OG-300 rating can only be used for system serving individual dwelling units and not central systems.) The calculation method requires that the user specify the climate zone and conditioned floor area, in addition to published data for the solar thermal water heating system.

2.10 Additions/Alterations

Addition and alteration compliance is based on standards Section 150.2. Alterations must model the entire dwelling unit. When there is no addition, Section 150.2(b)2 requires at least two components of the residence must be altered. Additions may be modeled as an entirely new building (whole building), addition alone, or as "existing+addition+alteration".

2.10.1 Whole Building

The entire proposed building, including all additions and/or alterations, 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. This is a difficult standard to meet as the existing building usually does not meet current standards and must be upgraded.

2.10.2 Addition Alone 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 compliance approach (see Section 2.10.3) are given to the addition alone approach (see Standards Section 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

fenestration product…Up to the total fenestration area removed in the existing wall or roof…." Added fenestration area in an existing wall or roof is modeled as new.

STANDARD DESIGN

Standard design fenestration U-factor and SHGC are based on the proposed design fenestration as shown in Table 23. 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 maximum fenestration allowed and are not an additional allowance.

The standard design is set for fenestration areas and orientations as shown in Table 23:

- ***Proposed design ≤ allowed % total fenestration area:***

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

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

- ***Proposed design > allowed % 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 + % of the addition conditioned floor area.

2.10.3.4 *Overhangs, Sidefins and Other Exterior Shading*

STANDARD DESIGN

The standard design for a proposed building with overhangs, sidefins and/or ~~other~~ exterior shades are shown in Table 24. Exterior shading (currently limited to bug screens) is ~~T~~treated differently than fixed overhangs and sidefins~~, exterior shading includes such features as exterior woven or louvered sunscreen, or roll-down awnings or slats~~ as explained in Section 2.5.6.9.

Table 30: EDR Adjustments by End Use for Gas Fuel Type

Climate Zone	Single Family Space Heating	Single Family Water Heating	Single Family Appliances	Multi Family Space Heating	Multi Family Water Heating	Multi Family Appliances
1	1.01	0.44	0.59	0.99	0.49	0.57
2	1.02	0.46	0.59	1.01	0.51	0.57
3	1.16	0.46	0.59	1.17	0.50	0.57
4	1.04	0.47	0.59	1.03	0.52	0.57
5	1.05	0.45	0.60	1.04	0.51	0.58
6	1.17	0.50	0.60	1.15	0.56	0.58
7	1.22	0.47	0.59	1.36	0.52	0.57
8	1.20	0.50	0.60	1.21	0.56	0.58
9	1.17	0.50	0.60	1.17	0.58	0.58
10	1.12	0.51	0.60	1.09	0.58	0.58
11	1.00	0.48	0.59	0.98	0.54	0.57
12	1.05	0.47	0.59	1.03	0.53	0.57
13	1.03	0.49	0.59	1.01	0.55	0.57
14	1.01	0.51	0.60	0.99	0.57	0.58
15	1.13	0.59	0.60	1.10	0.65	0.58
16	0.95	0.48	0.60	0.91	0.53	0.58
~~01~~	~~0.84~~	~~0.38~~	~~0.57~~	~~0.83~~	~~0.42~~	~~0.56~~
~~02~~	~~0.91~~	~~0.42~~	~~0.57~~	~~0.90~~	~~0.46~~	~~0.56~~
~~03~~	~~1.00~~	~~0.40~~	~~0.57~~	~~1.02~~	~~0.44~~	~~0.56~~
~~04~~	~~0.92~~	~~0.41~~	~~0.57~~	~~0.91~~	~~0.45~~	~~0.56~~
~~05~~	~~0.90~~	~~0.40~~	~~0.57~~	~~0.91~~	~~0.43~~	~~0.56~~
~~06~~	~~1.00~~	~~0.45~~	~~0.58~~	~~1.00~~	~~0.50~~	~~0.57~~
~~07~~	~~1.07~~	~~0.44~~	~~0.58~~	~~1.22~~	~~0.48~~	~~0.56~~
~~08~~	~~1.05~~	~~0.47~~	~~0.59~~	~~1.07~~	~~0.51~~	~~0.57~~
~~09~~	~~1.02~~	~~0.47~~	~~0.59~~	~~1.02~~	~~0.52~~	~~0.57~~
~~10~~	~~0.97~~	~~0.49~~	~~0.58~~	~~0.96~~	~~0.52~~	~~0.57~~
~~11~~	~~0.89~~	~~0.44~~	~~0.57~~	~~0.88~~	~~0.48~~	~~0.56~~
~~12~~	~~0.93~~	~~0.43~~	~~0.57~~	~~0.92~~	~~0.46~~	~~0.56~~
~~13~~	~~0.91~~	~~0.44~~	~~0.57~~	~~0.89~~	~~0.46~~	~~0.56~~
~~14~~	~~0.87~~	~~0.48~~	~~0.58~~	~~0.85~~	~~0.52~~	~~0.57~~

~~15~~	~~0.97~~	~~0.53~~	~~0.58~~	~~0.95~~	~~0.59~~	~~0.57~~
~~16~~	~~0.68~~	~~0.35~~	~~0.57~~	~~0.65~~	~~0.45~~	~~0.56~~

The ratios were calculated by using a prototype analysis once with gas fuel type for space heating, water heating and appliances, and once with electric fuel types. The ratio is the end use energy for the EDR reference building run with gas (kTDV/ft^2) divided by the run with electric (kTDV/ft^2).

3.2 Reference Design

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

- Air handler power. The air handler power is 0.8 W/cfm.
- Air infiltration rate. The air infiltration rate is 7.2 ACH50.
- Cooling airflow. The air handler airflow is 300 CFM/ton.
- Duct R-value. The duct R-value is R-8.
- Duct leakage rate. The duct leakage rate is modeled as an HVAC distribution efficiency of 80 percent.
- Insulation Installation Quality (QII): QII is modeled as “improved”.
- Wall construction. Climate zones 2-15 have 2x4 R-13 walls. Climate zones 1 and 16 have 2x6 R-19 walls.
- 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.
- Floor construction. Climate zones 2-15 have 2x10 R-19 floors. Climate zones 1 and 16 have 2x10 R-30 floors.
- Slab edge insulation. Climate zones 1 and 16 include R-10 insulation 24 inches deep.
- Window U-factors. Climate zones 2-15 have 0.65 U-factor. Climate zones 1 and 16 have 0.35 U-factor.
- Window SHGC. All windows have 0.4 SHGC.
- 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.
- HVAC equipment efficiencies. HVAC equipment meets NAECA requirements in effect in 2006 such as 78 percent AFUE for gas central furnace, 13 SEER for central AC.
- Water heating efficiency. Water heating modeled as a 40 gallon storage water with a 0.594 EF if gas or a 0.9172 EF if electric.
- 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.

3.3 Energy Design Rating PV System Credit

The PV credit reflected in the Energy Design Rating for both single- and multi-family buildings uses calculations found in PVWatts technical documentation (see Appendix D). The PV system size and module type are required inputs. Users may select simplified or detailed inputs. With detailed inputs, the inverter efficiency must be included. The user can select either detailed installation information for the orientation and angle/tilt of the array or select California flexible installation.

Installation and verification must meet the requirements of *Residential Appendix RA4.6.1*.

3.4 Net Energy Metering

Net Energy Metering (NEM) sets rules for compensation of PV generated electricity. NEM sizing rules limit the PV size to a PV equal to the site annual kWh.

NEM compensation rules set the limits for compensating PV generation. Compensation varies by (1) behind the meter self-utilized kWh, (2) hourly exports, and (3) net annual surplus.

3.5 Battery Storage

The software provides an EDR credit for a battery storage system that is coupled with a PV array. If specified, the battery storage size must be 6 kWh or larger. For Part 6 compliance this credit has no impact on energy efficiency components. Including a battery storage system allows downsizing the PV system to reach a specific EDR target.

Two control options available are:

> Default Control – A simple control strategy that provides a modest EDR credit. With default control, the software assumes that the batteries are charged anytime PV generation (generation) is greater than the house load (load), and conversely, the batteries are discharged when load exceeds generation.
>
> Advanced/Utility or Aggregator-Controlled – A more sophisticated control strategy maximizes the TDV value of stored kWh. With advanced control, the software assumes that the batteries are charged when generation exceeds the load; batteries only discharge during the highest "anticipated" TDV intervals to maximize the value of the stored kWh.

For Part 6 compliance, the proposed design EDR credit is limited to a PV size equal to the site annual kWh. The effect of a larger PV array has a minimal impact on the EDR score. For above code projects, the software allows oversizing the proposed design PV system by a factor of 1.6 for full credit if a battery system of at least 6 kWh is coupled with the PV system.

Software includes an option to allow excess PV generation EDR credit for above code programs. This allows exceeding the 1.6 size limit. When selected, the software allows any size PV with full EDR credit.

APPENDIX A – SPECIAL FEATURES

Measure	*CF1R Documentation Requirement*
GENERAL	
Controlled-Ventilation Crawlspace (CVC)	Not yet implemented
Photovoltaic (PV) system credit	Special feature
Zonal heating controls	Special feature
ENVELOPE	
Above deck insulation	Special feature
Advanced wall framing	Special feature
Below deck insulation	Special feature
Building air leakage / reduced infiltration	HERS verification of reported ACH50 value
Cool roof	Special feature
Dynamic glazing	Not yet implemented
Exterior shading device	Not yet implemented
Exposed slab area greater than 20%	Special feature
High quality insulation installation (QII)	HERS verification
Metal-framed assembly	Special feature
Non-default spray foam insulation R-values	HERS verification
Overhangs and sidefins	Special feature
Raised heel truss (height above top plate)	Special feature
Spray foam insulation, closed cell >R-5.8/inch	HERS verification
Spray foam insulation, open cell >R-3.6/inch	HERS verification
Structurally insulated panel (SIP) assembly	Special feature
MECHANICAL	
Air handling unit fan efficacy	HERS verification
Airflow or System Airflow (cfm)	HERS verification
Central fan ventilation cooling, fixed speed	Special feature

Multi-family: Recirculating demand control	Special feature
Multi-family: No loops or recirc pump	Special feature
Multi-family: Recirculating with no control (continuous pumping)	Special feature
Multi-family: Recirculating with temperature modulation	Special feature
Multi-family: Recirculating with temperature modulation and monitoring	Special feature
Multi-family: Solar water heating credit	Special feature and additional documentation
Central parallel piping	Special feature
Central parallel piping (HERS verified)	HERS verification
Pipe insulation, all lines	Special feature
Pipe insulation, all lines (HERS verified)	HERS verification
Point of use	Special feature
Recirculation with demand control, occupancy/ motion sensor	Special feature
Recirculation with demand control, occupancy/ motion sensor (HERS verified)	HERS verification
Recirculation with demand control, push button	Special feature
Recirculation with demand control, push button (HERS verified)	HERS verification
Recirculation with non-demand control (continuous pumping)	Special feature
Solar water heating credit, single family building	Special feature and additional documentation
Northwest Energy Efficiency Alliance (NEEA) rated heat pump water heater	Special feature
ADDITIONS/ALTERATIONS	
Verified existing conditions	HERS verification

Equation 5 calculates the distribution loss multiplier (DLM) which combines two terms: the standard distribution loss multiplier (SDLM), which depends on the floor area of the dwelling unit and the distribution system multiplier (DSM) listed in Table B-1.

$$DLM_k = 1 + (SDLM_k - 1) \times DSM_k \qquad \textit{Equation 5}$$

where

DLM_k = Distribution loss multiplier (unitless)

$SDLM_k$ = Standard distribution loss multiplier (unitless), see *Equation 6*.

DSM_k = Distribution system multiplier (unitless), see Section 3.2.

Several relationships below depend on CFA_k, the floor area served

Equation 6 calculates the standard distribution loss multiplier (SDLM) based on dwelling unit floor area. Note that in *Equation 6*, that floor area is capped at 2500 ft² -- without that limit, *Equation 6* produces unrealistic $SDLM_k$ values for large floor areas.

$$\begin{aligned} SDLM_k &= 1.0032 \\ &+0.0001864 \times CFA_k \\ &-0.0000000215 \times CFA_k \times CFA_k \end{aligned}$$

$$\begin{aligned} SDLM_k &= 1.004 \\ &\cancel{+ 0.000202 \times \min(2500, CFAU_k)} \\ &- 0.0000000231 \times \min(2500, CFAU_k) \times \min(2500, CFAU_k) \end{aligned} \qquad \textit{Equation 6}$$

where

$SDLM_k$= Standard distribution loss multiplier (unitless).

$CFAU_k$= Dwelling unit conditioned floor area (ft2) served by the kth system, calculated using methods specified in *Equation 7*.

Single dwelling unit,

$$CFAU_k = CFA / NK$$

For multiple dwelling units served by a central system: *Equation 7*

Method WH-CFAU

$$CFAU_k = \frac{\sum_{\text{all units served by system k}} CFA_i}{Nunit_k}$$

Alternatively, if the system-to-unit relationships not known:

$$CFAU_k = \frac{\sum_{\text{all units served by any central system}} CFA_i}{\text{Number of units served by any central system}}$$

Note: "Method" designations are invariant tags that facilitate cross-references from comments in implementation code.

When a water heating system has more than one water heater, the total system load is assumed to be shared equally by each water heater, as shown in *Equation 8*.

$$HARL_j = \frac{HARL_k}{NWH_k} \qquad \textit{Equation 8}$$

where

$HARL_j$ = Hourly adjusted recovery load for the jth water heater of the kth system (Btu).

$HARL_k$ = Hourly adjusted total recovery load for the kth system (Btu)

NWH_k = The number of water heaters in the kth system.

B4.1. Distribution Losses within the Dwelling Unit

The distribution system multiplier (DSM, unitless) is an adjustment for alternative water heating distribution systems within the dwelling unit. A value of 1.00 for "standard" distribution systems, defined as a non-recirculating system with the following mandatory requirements:

The full length of distribution piping is ~~the line from the water heater to the kitchen fixtures shall be insulated in accordance with Standards Section 150.0(j)2. All piping of nominal ¾" or larger diameter~~ insulated in accordance with Section 150.0(j)2.

For all four system types, values for alternative distribution systems are given in Table B-1. Improved DSM values are available for cases where voluntary HERS inspections are completed, as per the eligibility criteria shown in Reference Residential Appendix RA4.4. Detailed descriptions of all of the distribution system measures are found in Residential Appendix RA 4.4.

Table B-1. Distribution System Multipliers within a Dwelling Unit with One or More Water Heaters

Distribution System Types	Assigned Distribution System Multiplier	System Type 1 and 2	System Type 3 and 4
No HERS Inspection Required			
Trunk and Branch -Standard (STD)	1.0	Yes	Yes
~~Pipe Insulation (PIC)~~	~~0.9~~	~~Yes~~	~~Yes~~
Central Parallel Piping (PP)	~~1.05~~1.10	Yes	
Point of Use (POU)	~~0.3~~0.30	Yes	
Recirculation: Non-Demand Control Options (R-ND)	~~9.0~~9.80*	Yes	
Recirculation with Manual Demand Control (R-DRmc)	~~1.6~~1.75*	Yes	
Recirculation with Motion Sensor Demand Control (R-DRsc)	~~2.4~~2.60*	Yes	
Optional Cases: HERS Inspection Required			
Pipe Insulation (PIC-H)	~~0.8~~0.85	Yes	Yes
Central Parallel Piping with 5' maximum length (PP-H)	~~0.95~~1.00	Yes	
Compact Design (CHWDS-H)	~~0.7~~0.70	Yes	
Recirculation with Manual Demand Control (R-DRmc-H)	~~1.45~~1.60*	Yes	
Recirculation with Motion Sensor Demand Control (RDRsc-H)	~~2.2~~2.40*	Yes	
~~Non-Compliant Installation Distribution Multiplier~~	~~1.2~~	~~Yes~~	~~Yes~~
*Recirculation DSMs reflect impact of reduced hot water consumption associated with recirculation systems.			

B4.2. Cold Water Inlet Temperature

The water heater inlet temperature is assumed to vary on a daily basis with the following relationship defined by the data included in the climate zone weather files. For each day of the year, T_{inlet} will be calculated as follows:

$$T_{inlet} = T_{ground} \times 0.65 + T_{avg31} \times 0.35 \qquad \textit{Equation 9}$$

where

T_{avg31} = outdoor dry-bulb temperature averaged over all hours of the previous 31 days (note for January days, weather data from December will be used)

T_{ground} = Ground temperature (°F) for current day of year, calculated using *Equation 10*.

For each day (θ = 1 TO 365)

$$T_{ground}(\theta) = TyrAve - 0.5 \times (TyrMax - TyrMin) \times COS(2 \times \pi \times ((\theta - 1)/PB) - PO - PHI) \times GM \qquad \textit{Equation 10}$$

where

TyrAve = average annual temperature, °F

Table B-4. Pipe Size Schedule

Number of dwelling units served $NUnit_n$ or $NUnit_b$	Loop pipe nominal size Dia_n in	Branch pipe nominal size Dia_b in
< 2	1.5	1
2 ≤ N < 8	1.5	
8 ≤ N < 21	2	
21 ≤ N < 42	2.5	
42 ≤ N < 68	3	
68 ≤ N < 101	3.5	
101 ≤ N < 145	4	
145 ≤ N < 198	5	
N >= 198	6	

B6. High Rise Residential Buildings, Hotels and Motels

Simulations for high rise residential buildings, hotels and motels shall follow all the rules for central or individual water heating with the following exceptions.

For central systems which do not use recirculation but use electric trace heaters the program shall assume equivalency between the recirculation system and the electric trace heaters.

For individual water heater systems which use electric trace heating instead of gas, the program shall assume equivalency.

B7. Energy Use of Individual Water Heaters

Once the hourly adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below and summed.

B7.1. Small/Consumer Gas or Oil Storage Water Heaters

The hourly energy use of storage gas or oil storage water heaters is given by the following equation.

$$WHEU_j = \frac{HARL_j \times HPAF_j}{LDEF_j} \qquad \textit{Equation 32}$$

where

$WHEU_j$ = Hourly energy use of the water heater (Btu for fuel or kWh for electric). The above equation provides a value in unit of Btu. For electric water heaters, the calculation result needs to be converted to the unit of kWh by dividing 3413 Btu/kWh.

$HARL_j$ = Hourly adjusted recovery load (Btu).

$HPAF_j$ = 1 for all non-heat pump water heaters.

$LDEF_j$ = The annual load dependent energy factor (LDEF) is given by *Equation 33*. This equation adjusts the nominal EF rating for storage water heaters for different load conditions.

$$LDEF_j = \min\left[LDEF_{\max}, \max\left(LDEF_{\min}, \ln\left(\frac{AAHARL_j \times 24}{1000}\right)\left(a \times EF_j + b\right) + \left(c \times EF_j + d\right)\right)\right] \quad \textit{Equation 33}$$

where

a,b,c,d = Coefficients from the table below based on the water heater type.

Table B-5. LDEF Coefficients

Coefficient	Storage Gas
a	-0.098311
b	0.240182
c	1.356491
d	-0.872446
$LDEF_{min}$	.1
$LDEF_{max}$	.90

$AAHARL_j$ = Annual average hourly adjusted load (Btu) = $\frac{1}{8760}\sum_{1}^{8760} HARL_j$. Note that calculation of $AAHARL_j$ requires a preliminary annual simulation that sums $HARL_j$ values for each hour.

EF_j = Energy factor of the water heater (unitless). This is based on the DOE test procedure. EF for storage gas water heaters with volume less than 20 gallons must be assumed to be 0.58 unless the manufacturer has voluntarily reported an actual EF to the California Energy Commission.

B7.2. Small/Consumer Gas or Oil Instantaneous Water Heater

The hourly energy use for instantaneous gas or oil water heaters is given by Equation 34, where the nominal rating is multiplied by 0.92 to reflect the impacts of heat exchanger cycling under real world load patterns.

$$WHEU_j = \frac{HARL_j}{EF_j \times 0.92} \quad \textit{Equation 34}$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu).

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers' literature or from the CEC Appliance Database.

0.92 = Efficiency adjustment factor

B7.3. Small/Consumer Electric Instantaneous Water Heater

The hourly energy use for instantaneous electric water heaters is given by the following equation.

$$WHEU_{j,elec} = \frac{HARL_j}{EF_j \cdot 0.92 \cdot 3413} \qquad \textit{Equation 35}$$

where

$WHEU_{j,elec}$ = Hourly electric energy use of the water heater (kWh).

$HARL_j$ = Hourly adjusted recovery load (Btu).

EF_j = Energy factor from DOE test procedure (unitless).

0.92 = Adjustment factor to adjust for overall performance.

3413 = Unit conversion factor (Btu/kWh).

B7.4. Mini-Tank Electric Water Heater

Mini-tank electric heaters are occasionally used with gas tankless water heaters to mitigate hot water delivery problems related to temperature fluctuations that may occur between draws. If mini-tank electric heaters are installed, the installed units must be listed in the CEC Appliance Database and their reported standby loss (in Watts) will be modeled to occur each hour of the year. (If the unit is not listed in the CEC Appliance Database, a standby power consumption of ~~100~~35 W should be assumed.)

$$WHEU_{j,elec} = MTSBL_j / 1000 \qquad \textit{Equation 36}$$

where

$WHEU_{j,elec}$ = Hourly standby electrical energy use of mini-tank electric water heaters (kWh)

$MTSBL_j$ = Mini-tank standby power (W) for tank j (if not listed in CEC Appliance directory, assume ~~100~~35 W)

B7.5. Large/Commercial Gas or Oil Storage Water Heater

Energy use for large storage gas is determined by the following equations. Note: large storage gas water heaters are defined as any gas storage water heater with a minimum input rate of 75,000 Btu/h.

$$WHEU_j = \frac{HARL_j}{EFF_j} + SBL_j \qquad \textit{Equation 37}$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu).

$HARL_j$ = Hourly adjusted recovery load (Btu)

SBL_j = Total Standby Loss (Btu/hr). Obtain from CEC Appliance Database or from AHRI certification database. This value includes tank losses and pilot energy. If standby rating is not available from either of the two databases, it shall be calculated as per Table F-2 of the 2015 Appliance Efficiency Regulations, as follows:

$SBL = Q/800 + 110\ (V)^{1/2}$, where Q is the input rating in Btu/hour, and V is the tank volume in gallons.

EFF_j = Efficiency (fraction, not %). Obtained from CEC Appliance Database or from manufacturer's literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

B7.6. Large/Commercial Instantaneous, Indirect Gas, and Hot Water Supply Boilers

Energy use for these types of water heaters is given by the following equation.

$$WHEU_j = \frac{HARL_j}{EFF_j \times 0.92} + PILOT_j \qquad \textit{Equation 38}$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation.

$HARL_j$ = Hourly adjusted recovery load. For independent hot water storage tank(s) substitute $HARL_j$ from Section B3. .

EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

$PILOT_j$ = Pilot light energy (Btu/h) for large instantaneous. For large instantaneous water heaters, and hot water supply boilers with efficiency less than 89 percent assume the default is 750 Btu/hr if no information is provided in manufacturer's literature or CEC Appliance Database.

0.92 = Adjustment factor used when system is not supplying a storage system.

B7.7. Small/Consumer Storage Electric or Heat Pump Water Heaters

Energy use for small electric water heaters is calculated as described in the HPWHsim Project Report (Ecotope, 2015 and 2016). The HPWH model uses a detailed, physically based, multi-node model that operates on a one-minute time step implemented using a suitable loop at the time-step level within CSE. Tank heat losses and heat pump source temperatures are linked to the CSE zone heat balance as appropriate. Thus, for example, the modeled air temperature of a garage containing a heat pump water heater will reflect the heat extracted.

$SCH_{k,m}$ = Operating schedule of the circulation pump, see ***Table 0-2***. The operating schedule for the proposed design shall be based on user input control method. The standard design operation schedule is demand control.

B7.10. Conversion between Energy Factor and Uniform Energy Factor

For consumer water heaters and residential-duty commercial water heaters, Energy Factor (EF) can be converted into Uniform Energy Factor (UEF) and vice versa. The mathematical conversion factors translate values determined under the energy factor, thermal efficiency, and standby loss test procedures for consumer water heaters and certain commercial waters heaters to those determined under the new UEF test procedure. The mathematical conversion factors are detailed in the DOE final rule under docket EERE-2015-BT-TP-0007.

For the remainder of the 2016 Building Energy Efficiency Standards cycle, UEF input is converted to EF by CBECC using these methods.