



**HVAC**  
**DUCTLESS HVAC, RESIDENTIAL - FUEL**  
**SUBSTITUTION**  
**SWHC044-01**

**C O N T E N T S**

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## MEASURE NAME

Ductless HVAC, Residential, Fuel Substitution

## STATEWIDE MEASURE ID

*SWHC044-01*

## TECHNOLOGY SUMMARY

Wall furnaces and window air conditioners are in-zone HVAC systems designed to heat and cool a space to provide thermal comfort. Natural gas wall furnaces are ductless systems installed directly into the wall. Air from the immediate area is drawn into the heat exchanger and becomes warm. This air is then distributed to the space through (convection) heat transfer.

Electric window air conditioners are packaged systems installed directly in open windows. Window air conditioners use HVAC refrigeration principles to extract heat from air in the immediate space. The main interior side components consist of an evaporator, fan blower, and filter while the main exterior side components consist of a compressor, condenser coil, and propeller fan. The fan blower pulls in warm room air and moves it through a filter, removing unwanted particles. As the blower pushes the warm air across the evaporator, heat is absorbed through the refrigerant and air is cooled. This cooled air is blown out through the front panel and into the space. The heat drawn from the interior is dissipated outside as the fan blows the air over the condenser.

Wall furnace and window air conditioner unit systems can be replaced with more energy efficient mini-split heat pumps. Mini-split heat pumps are all electric ductless heating and cooling systems that control the temperature in individual or multiple rooms. A mini-split system is comprised of two main components: an indoor air-handling unit and an outdoor heat pump. The indoor unit includes a fan and an evaporator coil while the outdoor unit includes a compressor, condensing coil, and fan. The indoor and outdoor units are linked via a conduit, which encases the power cable, refrigerant and suction tubing, and a condensation drain line. Mini-splits pull heat from the inside air and move it outside via the refrigerant to provide cooling. Conversely, they extract heat from the outside and move it inside to heat the space by compressing and expanding the refrigerant. Mini-splits also typically have no ducts, reducing a large amount of energy lost through leaks and cracks in the duct systems.

Efficiency for these technologies is measured based on the Annual Fuel Utilization Efficiency (AFUE) rating, Heating Season Performance Factor (HSPF), Seasonal Energy Efficiency Ratio (SEER), and Energy Efficiency Ratio (EER). AFUE measures the gas furnace's efficiency in converting fuel to energy. It is expressed as a percentage, meaning that that percentage of energy turns into heat. HSPF is the ratio of the amount of heat output transferred during the heating season per on each unit of electricity used. A more efficient heat pump has a higher HSPF rating. SEER and EER measure air conditioning and heat pump cooling efficiency. SEER is calculated by the cooling output for a typical cooling season divided by the total electric energy used during that same time. EER does not account for the varying temperatures during the cooling season; it measures the efficiency at only one peak cooling temperature. A unit with a higher SEER or EER is more efficient.

## MEASURE CASE DESCRIPTION

The measure case for this measure is an efficient, above code, air source mini-split heat pump unit.

The minimum qualifying measure efficiencies for the measure in Tier 1 is based on Energy Star minimum efficiency requirements and exceed the Title 20, Title 24, and Code of Federal Regulations standards (see code requirements). The remaining three tiers are based on efficiency requirements for DEER2020 measures for Residential SEER-rated split HPs (RE-HV-ResHP-16p0S-9p0H, RE-HV-ResHP-17p0S-9p4H, RE-HV-ResHP-18p0S-9p7H). HSPF values shown reflect the average values for each SEER range and applicable sizes from the CEC appliance database. A summary of the minimum efficiency requirements is shown in the table below.

### Measure Case Technology Characterization

Equipment	Tier	SEER	HSPF
Mini-Split Heat Pump	Tier 1	15	8.5
	Tier 2	16	8.8
	Tier 3	17	9.4
	Tier 4	18	9.8

### BASE CASE DESCRIPTION

The base case is defined as a system with both a natural gas gravity wall furnace and an electric window air conditioner unit.

The baseline system sizes for this measure can vary per household. Due to the total capacities found in the Single Family and Mobile Home DEER2020 prototypes it is assumed that those systems include two window ACs and furnaces each. The capacity ranges for the individual HVAC units shown below were used to select the applicable code efficiencies. For each range, the most efficient code efficiency was used for the base case. See the table below for the baseline equipment sizing assumptions obtained from the DEER2020 eQuest prototypes.

### Base Case System Sizing Assumptions

Value	SFm	MFm	Dmo	Total Range
Building Cooling Capacity Range (tons)	2.2-4.0	1.0-1.3	3.5	1.0-4.0
Building Heating Capacity Range (kBtUh)	41.3-75.1	14.9-23.9	55.0	14.9-75.1
Assumed No. of Cooling Units per Building	2	1	2	
Assumed No. of Heating Units per Building	2	1	2	
Cooling Capacity per Unit Range (tons)	1.1-2.0	1.0-1.3	1.8	1.0-2.0
Heating Capacity per Unit Range (kBtUh)	20.7-37.5	14.9-23.9	27.5	14.9-37.5

Baseline energy efficiency requirements can be found in California 2019 Title 20 1605.1(1) and 1605.1(2)<sup>1</sup> as well as Federal Standard 10 CFR § 430.2(i)(2) and 430.2(b)<sup>2</sup> for the wall furnace and window air conditioner, respectively.

<sup>1</sup> California Energy Commission (CEC) Title 20 § 1605.1(1) and 1605.1(2)

<sup>2</sup> US Department of Energy (DOE) 10 CFR § 430.2(i)(2) and 430.2(b)

## Base Case Technology Characterization

Equipment	AFUE	EER
Natural Gas Wall Furnace	67%	N/A
Electric Window Air Conditioner	N/A	10.4

## CODE REQUIREMENTS

This measure is governed by California Appliance Efficiency Standards (Title 20), California Building Energy Efficiency Standards (Title 24), and Federal Regulations.

Code	Technology	Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2019)	Wall Furnace	Section 1605.1 (1)	April 16, 2013
CA Appliance Efficiency Regulations – Title 20 (2019)	Terminal Air Conditioner	Section 1605.1 (2)	October 7, 2010 (non-standard), January 1, 2017 (standard)
CA Appliance Efficiency Regulations – Title 20 (2019)	Split-System Heat Pump	Section 1605.1 (c)(1)	January 1, 2015
CA Building Energy Efficiency Standards – Title 24 (2019)	Wall Furnace	Section 110.1	January 1, 2020
CA Building Energy Efficiency Standards – Title 24 (2019)	Terminal Air Conditioner	Section 110.1	January 1, 2020
CA Building Energy Efficiency Standards – Title 24 (2019)	Split-System Heat Pump	Section 110.1	January 1, 2020
Federal Standards – Code of Federal Regulations	Wall Furnace	Section 110.1 (i)(2)	April 16, 2013
Federal Standards – Code of Federal Regulations	Terminal Air Conditioner	Section 430.2 (b)	June 1, 2014
Federal Standards – Code of Federal Regulations	Split-System Heat Pump	Section 430.2 (c)(1) Section 430.2 (c)(5)	January 1, 2015 January 1, 2023

## Base Case Code Requirements

### Title 20 1605.1(1) California State Minimum AFUE (%) for Residential Gas Wall Furnace

Each residential gas wall furnace must have a minimum AFUE not less than the value shown in Table E-2.

Table E-2  
Standards for Gas Wall Furnaces, Floor Furnaces, and Room Heaters

Appliance	Design Type	Capacity (Btu per hour)	Minimum AFUE (%)
			Effective On or After April 16, 2013
Wall furnace	Fan	≤ 42,000	75
Wall furnace	Fan	> 42,000	76
Wall furnace	Gravity	≤ 27,000	65
Wall furnace	Gravity	> 27,000 and ≤ 46,000	66
Wall furnace	Gravity	> 46,000	67
Floor furnace	All	≤ 37,000	57
Floor furnace	All	> 37,000	58
Room heater	All	≤ 20,000	61
Room heater	All	> 20,000 and ≤ 27,000	66
Room heater	All	> 27,000 and ≤ 46,000	67
Room heater	All	> 46,000	68

**Title 24 Section 110.1 California State Minimum AFUE (%) for Residential Gas Wall Furnace**

Refers to California Appliance Efficiency Regulations Title 20 – Table E-2 in section 1605.1 (1)

**Code of Federal Regulations § 100.2(i)(2) Minimum AFUE (%) for Residential Gas Wall Furnace**

The minimum AFUE for a residential gas wall furnace manufactured on or after April 16, 2013 is equivalent to the values mentioned in California Title 20 and Title 24.

**Title 20 Section 1605.1(2) California State Minimum Efficiency for Residential Terminal Air Conditioner**

The EER of non-standard size packaged terminal air conditioners manufactured on or after October 7, 2010 and of standard size packaged terminal air conditioners manufactured on or after January 1, 2017 shall not be less than the values shown in Table B-4.

Table B-4  
Standards for Standard Size Packaged Terminal Air Conditioners and Standard  
Size Packaged Terminal Heat Pumps Manufactured On or After January 1, 2017

Appliance	Cooling Capacity (Btu/hour)	Minimum Efficiency	
		Minimum EER	Minimum COP
Packaged Terminal Air Conditioners	< 7,000	11.9	—
	≥ 7,000 < 15,000	14.0 – (0.300 x Cap <sup>1</sup> )	—
	≥ 15,000	9.5	—
Packaged Terminal Heat Pumps	< 7,000	11.9	3.3
	≥ 7,000 < 15,000	14.0 – (0.300 x Cap <sup>1</sup> )	3.7 - (0.052 x Cap <sup>1</sup> )
	≥ 15,000	9.5	2.9

<sup>1</sup> Cap means cooling capacity in thousand British thermal units per hour (Btu/h) at 95°F outdoor dry-bulb temperature.

**Title 24 Section 110.1 California State Minimum Efficiency for Residential Terminal Air Conditioner**

Refers to California Appliance Efficiency Regulations Title 20 – Table B-4 in section 1605.1 (2)

**Code of Federal Regulations § 430.2(b) Minimum Efficiency for Residential Terminal Air Conditioner**

The residential terminal air conditioner must have a minimum combined energy efficiency ratio as shown in the table below.

Product class	Energy efficiency ratio, effective from Oct. 1, 2000 to May 31, 2014	Combined energy efficiency ratio, effective as of June 1, 2014
1. Without reverse cycle, with louvered sides, and less than 6,000 Btu/h	9.7	11.0
2. Without reverse cycle, with louvered sides, and 6,000 to 7,999 Btu/h	9.7	11.0
3. Without reverse cycle, with louvered sides, and 8,000 to 13,999 Btu/h	9.8	10.9
4. Without reverse cycle, with louvered sides, and 14,000 to 19,999 Btu/h	9.7	10.7
5a. Without reverse cycle, with louvered sides, and 20,000 to 27,999 Btu/h	8.5	9.4
5b. Without reverse cycle, with louvered sides, and 28,000 Btu/h or more	8.5	9.0
6. Without reverse cycle, without louvered sides, and less than 6,000 Btu/h	9.0	10.0
7. Without reverse cycle, without louvered sides, and 6,000 to 7,999 Btu/h	9.0	10.0
8a. Without reverse cycle, without louvered sides, and 8,000 to 10,999 Btu/h	8.5	9.6
8b. Without reverse cycle, without louvered sides, and 11,000 to 13,999 Btu/h	8.5	9.5
9. Without reverse cycle, without louvered sides, and 14,000 to 19,999 Btu/h	8.5	9.3
10. Without reverse cycle, without louvered sides, and 20,000 Btu/h or more	8.5	9.4
11. With reverse cycle, with louvered sides, and less than 20,000 Btu/h	9.0	9.8
12. With reverse cycle, without louvered sides, and less than 14,000 Btu/h	8.5	9.3
13. With reverse cycle, with louvered sides, and 20,000 Btu/h or more	8.5	9.3
14. With reverse cycle, without louvered sides, and 14,000 Btu/h or more	8.0	8.7
15. Casement-Only	8.7	9.5
16. Casement-Slider	9.5	10.4

### Measure Case Code Requirements

Current code requirements for relevant mini-split heat pump technologies are discussed below to verify that the measure case equipment exceeds applicable code requirements.

#### Title 20 Section 1605.1(c)(1) California State Minimum Efficiency for Residential Split-System Heat Pump

The residential split-system heat pump must have the minimum SEER and HSPF values and not be less than the values shown in Table C-3.

Table C-3  
Standards for Single Phase Air-Cooled Air Conditioners with Cooling Capacity Less than 65,000 Btu per Hour and Single Phase Air-Source Heat Pumps with Cooling Capacity Less than 65,000 Btu per Hour, Not Subject to EPA Act

Product Class	Minimum Efficiency Effective January 1, 2015			
	Minimum SEER	Minimum HSPF	Minimum EER	Average Off-Mode Power Consumption $P_{off}$ (watts)
Split system air conditioners with rated cooling capacity < 45,000 Btu/hour <sup>1</sup>	14.0	—	12.2	30
Split system air conditioners with rated cooling capacity ≥ 45,000 Btu/hour <sup>1</sup>	14.0	—	11.7	30
Split system heat pumps with rated cooling capacity < 45,000 Btu/hour <sup>1</sup>	14.0	8.2	12.2	33
Split system heat pumps with rated cooling capacity ≥ 45,000 Btu/hour <sup>1</sup>			11.7	33
Single package air conditioners <sup>1</sup>	14.0	—	11.0	30
Single package heat pumps	14.0	8.0	—	33
Space constrained air conditioners – split system	12.0	—	—	30
Space constrained heat pumps – split system	12.0	7.4	—	33
Space constrained air conditioners – single package	12.0	—	—	30
Space constrained heat pumps – single package	12.0	7.4	—	33
Small duct, high velocity air conditioner systems	12.0	—	—	30
Small duct, high velocity heat pump systems	12.0	7.2	—	30

<sup>1</sup> See 10 C.F.R. section 430.32(c) for less stringent federal standards applicable to these units that are manufactured on or after January 1, 2015 and installed in states other than Arizona, California, Nevada, or New Mexico.

#### Title 24 Section 110.1 California State Minimum Efficiency for Residential Split-System Heat Pump

The residential split-system heat pump must have the minimum HSPF and SEER values and not be less than the values shown in Tables 4-3 and 4-6, respectively.

Table 4-3: Minimum Heating Efficiency for Heat Pumps

Equipment Type	Reference	Configuration/Size	Minimum Heating Efficiency
Packaged terminal heat pumps (heating mode)	Table 110.2 E	Newly constructed or newly conditioned buildings or additions	$3.7 - (0.052 \times \text{Cap}^1/1000) = \text{COP}$
Packaged terminal heat pumps (heating mode)	Table 110.2 E	Replacements	$2.9 - (0.026 \times \text{Cap}^1/1000) = \text{COP}$
Single-phase air source heat pumps (NAECA)	Table C-3	< 65,000 Btu/hr cooling	Packaged 8.0 HSPF Split 8.2 HSPF
		Space constrained < 65,000 Btu/hr cooling capacity	7.4 HSPF
		Small duct, high velocity < 65,000 Btu/hr cooling capacity	7.2 HSPF
Three-phase air source heat pumps	Table C-4	< 65,000 Btu/hr	7.7 HSPF
		≥ 65,000 and < 135,000	3.3 COP
		≥ 135,000 and < 240,000	3.2 COP
		≥ 240,000 and < 760,000	3.2 COP
Water-source heat pumps	Table C-5	≥ 65,000 and < 135,000 Btu/hr	4.2 COP
		≥ 135,000 Btu/hr, < 240,000 Btu/hr	3.9 COP
Single package vertical heat pumps	Table C-5	< 65,000 single-phase	3.0 COP
		< 65,000 3-Phase	3.0 COP
		≥ 65,000 and < 135,000	3.0 COP
		≥ 135,000 and < 240,000	2.9 COP

1. Cap = Cooling Capacity

Source: California Appliance Efficiency Regulation Title 20 and Energy Efficiency Standards

Table 4-6: Minimum Cooling Efficiencies for Central Air Conditioners and Heat Pumps (Cooling Capacity Less Than 65,000 Btu/hour) (NR = No Requirement)

Appliance	Type	SEER	EER
Central Air Conditioners <sup>1</sup>	Split-System <45,000 Btu/h	14	12.2
	Split-System ≥45,000 Btu/h	14	11.7
	Single-Package	14	11.0
Central Air Source Heat Pumps	Split-System	14	NR
	Single-Package	14	NR
Space-Constrained Air Conditioner	Split-System	12	NR
	Single-Package	12	NR
Space-Constrained Heat Pump	Split-System	12	NR
	Single-Package	12	NR
Small-Duct, High-Velocity Air Conditioner	All	12	NR
Small-Duct, High-Velocity Heat Pump	All	12	NR

Source: California Appliance Efficiency Regulations, Title 20, Table C-3 and Federal Appliance Standards (NAECA)

### Code of Federal Regulations § 430.2(c)(1) and § 430.2(c)(5) Minimum Efficiency for Residential Split-System Heat Pump

(430.2)(c)(1) The minimum HSPF and SEER values of a residential split-system heat pump manufactured on or after January 1, 2015 and before January 1, 2023 is equivalent to the values mentioned in Title 20 and Title 24.

(430.2)(c)(5) For split-system heat pumps manufactured on or after January 1, 2023, the HSPF and SEER values must not be less than the values shown in the table below.



Product class	Seasonal energy efficiency ratio 2 (SEER2)	Heating seasonal performance factor 2 (HSPF2)
(i)(A) Split systems—air conditioners with a certified cooling capacity less than 45,000 Btu/hr	13.4	
(i)(B) Split systems—air conditioners with a certified cooling capacity equal to or greater than 45,000 Btu/hr	13.4	
(ii) Split systems—heat pumps	14.3	7.5
(iii) Single-package units—air conditioners	13.4	
(iv) Single-package units—heat pumps	13.4	6.7
(v) Small-duct, high-velocity systems	12	6.1
(vi)(A) Space-constrained products—air conditioners	11.7	
(vi)(B) Space-constrained products—heat pumps	11.9	6.3

## NORMALIZING UNIT

Capacity (Tons)

## PROGRAM REQUIREMENTS

### *Fuel Substitution Test*

Per CPUC Decision 19-08-009 Rulemaking 13-11-005 “Decision Modifying the Energy Efficiency Three-Prong Test Related to Fuel Substitution”, for all fuel substitution measures, the measure must ‘not increase total source energy consumption when compared with the baseline comparison measure available utilizing the original fuel’.<sup>3</sup> Also, the measure ‘must not adversely impact the environment compared to the baseline measure utilizing the original fuel. Fuel substitution calculations were conducted using CPUC’s “Fuel Substitution Calculator” to confirm the measures in this workpaper pass Parts One and Two of the Fuel Substitution Test<sup>4</sup>.

<sup>3</sup> California Public Utilities Commission (CPUC). 2019. “Decision 19-08-009 Rulemaking 13-11-005 Decision Modifying the Energy Efficiency Three-Prong Test Related to Fuel Substitution”. August 1.

<sup>4</sup> Southern California Edison (SCE). 2019. “SWHC044-01 Fuel Substitution Calculator.xlsx”.

### Measure Implementation Eligibility

All measure application type, delivery type, and sector combinations that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

#### Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Normal replacement	DnDeemed	Res
Normal replacement	DnDeemDI	Res
Normal replacement	UpDeemed	Res
New construction	DnDeemed	Res
New construction	DnDeemDI	Res

Please note that new construction (NC) is not supported nor offered through Upstream delivery channel.

New construction measures are only eligible for downstream application under the following conditions. These are defined as new services in fuel substitution technical guidance<sup>5</sup>.

- measures are installed in new areas of an existing building,
- measures are installed in a major renovation of an existing building, or
- measures are installed in capacity expansions of existing systems to serve existing and/or new load retrofits that require a new energy service.

For upstream delivery method, the participant baselines are unknown, and the spillover effects are unknown. The manufacturer doesn't know whether the purchased measure is replacing a gas or an electric baseline appliance. Claimed savings for these delivery types will be adjusted using the ratio of baseline gas appliance to total baseline appliances. These ratios will be determined from (Residential Appliance Saturation Survey (RASS) <sup>6</sup>. If there are no workpapers available for the electric to electric portion, the savings claimed for that portion on claims side is automatically set to zero.

For Midstream delivery the implementer shall survey 10% of the mid-stream baseline existing conditions and fuel type to determine actual gas/electric baseline proportions, and the program administrator shall adjust claimed savings based upon these survey results.

In addition, for mid-stream delivery method, the implementer should provide the retailer or distribution location where the product was sold, rated capacity, proposed building type where the product will be installed (single family, multi-family or mobile homes), and cooling and heating efficiency.

For downstream deemed and downstream direct-install delivery types, in addition to the standard information such as building type, climate zone, and capacity of the units, the following data must be submitted with each project application by the project developer:

<sup>5</sup> Fuel Substitution Technical Guidance-v1.1

<sup>6</sup> California Energy Commission. 2010. "2009 California Residential Appliance Saturation Study".

- What is the existing fuel type for space heating?
- Did the site require any electric infrastructure upgrades for the proposed electrification measure? If yes, provide the itemized invoices with infrastructure upgrade costs.
- Did the owner install any other electrification measures at this site? If yes, list the measures and provide the itemized invoices with infrastructure upgrade costs (if any).

#### *Eligible Products*

##### **General Eligibility Requirements**

The mini-split heat pump unit must meet or exceed the minimum efficiency requirements set forth in the measure. The existing furnace equipment must be removed and disposed of rather than refurbished and sold. Existing gas line(s) serving removed gas equipment must be capped off and removed refrigerant must be handled and disposed in accordance with all state and local regulations including but not limited to CA Energy Standards, CA Building Code, CA Plumbing Code, and NEC.

#### *Eligible Building Types and Vintages*

This measure is applicable for all residential building types (single family, multifamily, and mobile homes) of existing vintages.

#### *Eligible Climate Zones*

This measure is applicable in all California climate zones.

#### *Incentive Amounts*

Fuel substitution measures face market barriers, including consumer market failures and supplier market failures. Deployment of these measures may require rebates or financial incentives to participants that exceed the measure cost.

### **PROGRAM EXCLUSIONS**

This measure is not eligible when there is no natural gas to electricity fuel substitution for heating and/or when the measures includes a non-regulated fuel. New construction measures are only eligible under certain conditions listed in the above section. Ground up constructions are not eligible

### **DATA COLLECTION REQUIREMENTS**

Baseline equipment type and fuel source must be verified, for downstream and direct install measures.

Per CPUC Decision 19-08-009<sup>7</sup>, building infrastructure costs which include panel upgrades or gas line installations/upgrades required to facilitate these fuel substitution measures shall be collected for 10% of each downstream and direct install measures.

## USE CATEGORY

HVAC

## ELECTRIC SAVINGS (kWh)

The electric unit energy savings (UES) and demand reduction were derived from unit energy consumption (UEC) estimated using eQUEST version 3.65 energy modeling software. The software uses the DOE2.3 energy modeling simulation engine for residential building types.

DEER2020 prototypes from the Database of Energy Efficient Resources (DEER) were utilized for the building energy use simulations. The DEER2020 prototypes were generated using MASControl v3.00.00. The DEER2020 prototypes for existing era building vintages 2003, 2007, 2011, and 2015 for single family and multifamily homes and building vintages 2000 and 2006 for mobile homes were used to develop base and measure case unit energy consumption (UEC) and demand estimates. The estimates also took into account all five DEER residential thermostat schedules.

### DEER Prototype Tech ID by Measure

Measure	DEER Prototype Tech ID
Wall Furnace-Window AC to Mini-Split	SplitHP1SpRes-S14-H8.2

## Prototype Modifications

The baseline prototypes extracted from DEER2020 were modified to simulate a natural gas wall furnace and an electric window air conditioner unit within single family, multifamily, and mobile homes. The baseline models used the 2019 Title 20 standard 67% AFUE heating and 10.4 EER cooling efficiencies.

The DEER2020 prototypes models were modified to simulate the base and measure case, summarized in the table below.

### Summary of Modifications for Measure Case Simulations

Type (DOE2 Keyword Listed)	DEER Prototype Defaulted	Base Case	Measure Case
SYSTEM TYPE (A)	Pkg Vol Var Temp	Pkg Vol Var Temp	Pkg Vol Var Temp
SYSTEM:RETURN-AIR-PATH (B)	Duct	Direct	Direct
SYSTEM:DUCT-AIR-LOSS (B)	0.15	0	0

<sup>7</sup> California Public Utilities Commission (CPUC). 2019. "Decision 19-08-009 Rulemaking 13-11-005 Decision Modifying the Energy Efficiency Three-Prong Test Related to Fuel Substitution". August 1

Type (DOE2 Keyword Listed)	DEER Prototype Defaulted	Base Case	Measure Case
SYSTEM:SUPPLY-KW/FLOW (C)	0.000652	0	0
SYSTEM:MIN-OUTSIDE-AIR	n/a	0	0
SYSTEM:OA-CONTROL (D)	OA Temperature	Fixed Fraction	Fixed Fraction
SYSTEM:COOLING-EIR (E)	0.328	0.245	<b>Tier 1:</b> 0.277 <b>Tier 2:</b> 0.267 <b>Tier 3:</b> 0.257 <b>Tier 4:</b> 0.249
SYSTEM:HEAT-SOURCE	Furnace	Furnace	Heat Pump
SYSTEM:FURNACE-HIR	n/a	1.722 (67% AFUE)	n/a
SYSTEM:HEATING-EIR (F)	n/a	n/a	<b>Tier 1:</b> 0.285 (HSPF=8.5) <b>Tier 2:</b> 0.279 (HSPF=8.8) <b>Tier 3:</b> 0.267 (HSPF=9.4) <b>Tier 4:</b> 0.258 (HSPF=9.8)

Additional notes regarding the prototype adjustments:

- A. System Type of Packaged Volume Variable Temperature (PVVT) was selected for the base and measure case because DEER prototypes are set-up as a single zone and PVVT is the default DOE2 system type in DEER Residential prototypes that closely replicates a single zone unit. The system type was assumed to be operating at significant partial load hours since all spaces will not be occupied at the same time. When comparing the annual space cooling energy consumption for PVVT with the Residential Appliance Saturation Study (RASS)<sup>8</sup> space cooling electric UEC for a room AC, the UEC for PVVT was only 3% higher. When modeling the DEER prototypes as a Packaged Single Zone (PSZ), the UEC for PSZ was 60% higher than the RASS data. PVVT performed better at partial load. Modeling the entire building type as a PSZ significantly overestimated the cooling energy usage. The additional updates below are made in attempt to adjust parameters to model the desired unit types.
- B. Return Air Path is set to Direct and Duct Air Loss is set to zero to simulate the equipment being in zone only.
- C. Fan Power kW/CFM is set to zero because the total per unit efficiency for each system is captured in the unit EIRs and HIR values. Per DOE2 Help Files, "If you include fan electric energy consumption in your value of COOLING-EIR, then you should set SUPPLY-KW/FLOW to zero (and SUPPLY-STATIC should be omitted). Otherwise, the supply fan electrical energy will be double counted." Both base and measure case systems are ductless, thus this also assumes any variation in static pressure between base and measure case equipment is not significant and is considered as part of the EIR/HIR values. Note that static pressure on both Ductless and Window AC systems are generally very low, e.g., less than 0.10 inch of WC.

<sup>8</sup> California Energy Commission. 2010. "2009 California Residential Appliance Saturation Study".

- D. Outside Air Control is set to Fixed Fraction and the Minimum Outside Air Ratio set to zero to simulate that neither the baseline or measure case systems bring in outside air.
- E. SEER calculated in eQuest includes an assumption of fan power. However, per AHRI standard 210/240<sup>9</sup> and DOE CFR 429.16<sup>10</sup>, split system SEERs are always tested with an indoor unit. Therefore, calculations converting SEER/EER to Cooling EIR is calculated without additional fan power assumptions.
- F. HSPF values were selected based on the average HSPF values for mini-split systems between one and four tons extracted from the CEC appliance database for each tiers SEER rating. Similar assumptions to the SEER were made when converting HSPF to Heating EIR.

### Electric Unit Energy Savings

Once the base case and measure case model simulations of energy consumption were completed, the total energy savings were calculated as the difference between the modeled total (whole building) energy consumption of the base case and measure case models, as shown below. The unit electric energy savings (kWh per year per ton) were calculated by dividing the total energy savings by the total building HVAC cooling capacity.

$$ES = EC_{Base} - EC_{Measure}$$

$$UES_{Tons} = \frac{ES}{Cap. Tons}$$

<i>ES =</i>	<i>Total energy savings (kWh)</i>
<i>EC =</i>	<i>Modeled energy consumption of the base case and measure case units (kWh)</i>
<i>UES<sub>Ton</sub> =</i>	<i>Unit energy savings (kWh/Ton)</i>
<i>Cap. Tons =</i>	<i>Total cooling capacity of the model's HVAC system (Tons)</i>

As both Normal Replacement and New Construction measures would assume the same baseline equipment efficiencies, the same savings are mapped to both measure application types.

Some measures in CZ15 were observed to have positive electric energy (kWh) savings. This is due to CZ15 having much higher cooling requirements than heating requirements, such that increases in the cooling efficiency offset all added electric load due to heating. For example, per Pacific Energy Center's Climate Zone Guide, CZ15 experiences between 3,952 to 6,565 cooling degree days as compared to 1,080 to 1,295 heating degree days<sup>11</sup>.

<sup>9</sup> Air-Conditioning, Heating, & Refrigeration Institute (AHRI). 2017. "2017 Standard for Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment"

<sup>10</sup> US Department of Energy (DOE) 10 CFR § 429.16.

<sup>11</sup> Pacific Energy Center. 2006. "The Pacific Energy Center's Guide to: California Climate Zones and Bioclimatic Design"

## Residential Thermostat and Vintage Weighted Average

DEER2020 residential thermostat weighting were used to weight energy savings values for each building type, climate zone and vintage<sup>12</sup>. Subsequently, these values were weighted using DEER2020 residential building weights to find the savings for the existing vintage for each building type and climate zone.

Baseline and measure simulations used the DEER 2020 building vintages<sup>13</sup> (see below).

### DEER Building Vintage Codes and Descriptions for Non-Mobile Homes

DEER Vintage Code	Description
Ex	Non-Mobile Homes 2002 - 2016; default vintage for existing buildings
V03	Existing building stock built between 2002 and 2005
V07	Existing building stock built between 2006 and 2009
V11	Existing building stock built between 2010 and 2013
V15	Existing building stock built between 2014 and 2016

### DEER Building Vintage Codes and Descriptions for Mobile Homes

DEER Vintage Code	Description
Ex	Mobile Homes 1995 - 2014; default vintage for existing buildings
MH00	Existing building stock built between 1995 and 2005
MH06	Existing building stock built between 2006 and 2014

## PEAK ELECTRIC DEMAND REDUCTION (KW)

In accordance with the requirements of the CPUC Fuel Substitution Technical Guidance, for Energy Efficiency, October 31, 2019, there will not be any peak demand reduction or penalty towards peak demand goal achievement from fuel substitution measures.<sup>14</sup>

## GAS SAVINGS (THERMS)

Gas savings was calculated using the same methodology as the electric savings. Please refer to the Electric Savings (kWh) section for details.

## LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

Effective Useful Life (EUL) and Remaining Useful Life (RUL) for the split-system heat pump are available in DEER.

<sup>12</sup> California Public Utilities Commission. 2019. MASControl3 "DEER\_Tools\_2019\_09\_30.zip", SupportTables folder, "reststatwt.sql" file.

<sup>13</sup>Southern California Edison (SCE). 2019. "SWHC044-01 Energy Savings Calculations.xlsx"

<sup>14</sup> California Public Utilities Commission. 2019. "Fuel Substitution Technical Guidance for Energy Efficiency".

## Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (Years) (EUL ID: HVAC-airHP)	15.0	California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
RUL (Years) (EUL ID: HVAC-airHP)	N/A	California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."

## BASE CASE MATERIAL COST (\$/UNIT)

Base case costing was obtained through online price research from various retailer websites in the fourth quarter of 2019. Base case equipment costing took into account the capacity and efficiency of the equipment to align it with the baseline measure efficiencies and DEER prototype capacities. Based on unit sizes found in the market and the total capacities that were found in DEER prototypes it was assumed that a single set of wall furnace and window AC units could serve the MFm prototypes, while two units would be needed to serve the SFm and DMO prototypes. Thus, furnaces in the capacity range of 14.9-37.5 kBTUh and the window air conditioner with a capacity in the range of 1.0-2.0 tons were selected for costing. See the table below for details on the system sizing assumptions.

### System Sizing Assumptions

Value	SFm	MFm	DMO	Total Range
Building Cooling Capacity Range (tons)	2.2-4.0	1.0-1.3	3.5	1.0-4.0
Building Heating Capacity Range (kBTUh)	41.3-75.1	14.9-23.9	55.0	14.9-75.1
Assumed No. of Cooling Units per Building	2	1	2	
Assumed No. of Heating Units per Building	2	1	2	
Cooling Capacity per Unit Range (tons)	1.1-2.0	1.0-1.3	1.8	1.0-2.0
Heating Capacity per Unit Range (kBTUh)	20.7-37.5	14.9-23.9	27.5	14.9-37.5

Costing was standardized for wall furnaces due to a large price difference based on furnace type. The base material cost for the furnace was restricted to a single-sided vented gravity wall furnace with horizontal flow, which are the most common types of wall furnaces<sup>15</sup>. Wall furnace and window air conditioner costs were collected only for units within the heating and cooling unit size ranges in the table above. The total cost of the window air conditioner units was normalized on a per ton basis. As furnaces are not categorized by tonnage; however given that the measure case is normalized on a "per-ton" basis, the average cost of furnaces was normalized at the midpoint system size of the window air conditioners which was determined to be 1.5 tons based on DEER prototypical documentation and market availability for this application. See cost calculations for more details.<sup>16</sup>

### Standardized Baseline Equipment Cost

Technology	Normalized Cost per Ton	Sample Count
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<sup>15</sup> Southern California Gas. 2013. "Emerging Technologies Assessment Report. PROJECT ID E12SCG0018. HIGH EFFICIENCY NATURAL GAS WALL FURNACE FIELD EVALUATION"

<sup>16</sup> Southern California Edison. 2019. "SWHC044-01 Ductless HVAC Cost-12-2-2019.xlsx"



Natural Gas Wall Furnace	\$676.90	14
Electric Window AC	\$405.93	11

### MEASURE CASE MATERIAL COST (\$/UNIT)

Measure equipment material costing was obtained through online price research from various retailer websites in the fourth quarter of 2019. Measure case equipment costing was selected based on the capacity and efficiency of the equipment to align it with the measure requirements and DEER prototype total capacities as described in the previous section. Costs for the split systems were observed to vary based on the number of indoor units included. To be consistent with the assumption of the number of HVAC units with the base case systems, only mini-splits with one or two indoor units were included.

The cost of the mini-split heat pumps varied based on SEER and were normalized on a per ton basis. See cost calculations for more details.<sup>17</sup>

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<sup>17</sup> Southern California Edison. 2019. "SWHC044-01 Ductless HVAC Cost-12-2-2019.xlsx"

### Standardized Measure Cost

Technology	Tier	Normalized Cost per Ton	Sample Count
Mini-Split Heat Pump (MSHP)	<b>Tier 1:</b> Ductless Mini-Split Heat Pump (SEER 15, HSPF 8.5)	\$1,016.23	15
Mini-Split Heat Pump (MSHP)	<b>Tier 2:</b> Ductless Mini-Split Heat Pump (SEER 16, HSPF 8.8)	\$1,021.79	29
Mini-Split Heat Pump (MSHP)	<b>Tier 3:</b> Ductless Mini-Split Heat Pump (SEER 17, HSPF 9.4)	\$1,100.88	23
Mini-Split Heat Pump (MSHP)	<b>Tier 4:</b> Ductless Mini-Split Heat Pump (SEER 18, HSPF 9.8)	\$1,155.65	41

Beside measure HVAC equipment costs, there are additional material costs associated with installing a new mini-split heat pump. These include a pad to locate the condenser and conduit for power and refrigerant lines. These costs were estimated using RSMeans online kBTUh, RS Means Construction Cost Data<sup>18</sup> and online retailer costs. The associated costs were normalized based on a midpoint system size of the measure which was found to be 1.5 tons. See cost calculations for more details.<sup>19</sup>

Description	Material Cost
Install: Mini-Split Heat Pump, tube / wiring kit, 50'	\$206.00
Install: Condensing Unit Pad prefabricated, fiberglass reinforced concrete with polystyrene foam core, 2" thick, 24"x42"	\$47.50
Total Associated Cost	\$253.50
Total Normalized Cost	\$169.00

**Infrastructure Costs.** A natural gas wall furnace and electric window air conditioner to mini-split heat pump conversion infrastructure upgrade would include capping off the natural gas line, running wires from the breaker to connect to the mini-split heat pump indoor and outdoor units, and repairing holes in walls from demolished baseline equipment. The section of the wall that needs to be patched and painted was based on the dimensions of typical wall furnaces. These infrastructure costs were estimated using RSMeans online data<sup>20</sup> and online retailer costs. RSMeans hourly labor rates for a residential electrician were used for mechanical labor, while a general laborer was used for wall repair.<sup>21</sup> See the table below for details and the cost calculations for more details.<sup>22</sup>

<sup>18</sup> 2014 RSMeans Facilities Construction Cost Data

<sup>19</sup> Southern California Edison. 2019. "SWHC044-01 Ductless HVAC Cost-12-2-2019.xlsx"

<sup>20</sup> 2019 RSMeans Electrical Cost Data

<sup>21</sup> RSMeans Residential Labor Rates, <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202019%20Labor%20Rates/Residential%20Labor%20Rates.PDF>, "Residential Labor Rates.pdf"

<sup>22</sup> Southern California Edison. 2019. "SWHC044-01 Ductless HVAC Cost-12-2-2019.xlsx"

Description of Work	Labor Hours	Labor Rate	Labor Cost	Material Cost	Total Cost
Demolish Wall Furnace	4.000	\$67.55	\$270.20	\$0.00	\$270.20
Demolish Window AC	0.500	\$67.55	\$33.78	\$0.00	\$33.78
Repair 5/8in thick Dry Wall	0.081	\$45.45	\$3.68	\$13.47	\$17.15
Paint Interior Wall 1 Coat, Smooth Finish with Roller	0.054	\$45.45	\$2.45	\$0.00	\$2.45
Cap Existing Gas Line w/ Brass Plug for Natural Gas Lines	0.250	\$67.55	\$16.89	\$4.00	\$20.89
Mini-Split Heat Pump hook-up, 1-40 & 1-100 amp 2 pole circuit breaker, 40' of #8/2 & 30' of #3/2	7.404	\$67.55	\$500.14	\$550.00	\$1,050.14
Total cost			\$827.14	\$567.47	\$1,394.61
Total Normalized Cost			\$551.43	\$378.31	\$929.74

#### BASE CASE LABOR COST (\$/UNIT)

Labor cost was found from RS Means online database (2019)<sup>23</sup>. RSMeans hourly labor rates for a residential electrician<sup>24</sup> were used to estimate labor costs. All costing included a range of labor hours based on its size, thus the average labor hours per equipment was selected. Similar to the base equipment costs the furnace and window air conditioner costs were normalized based on a midpoint system size of the window air conditioner which was found to be 1.5 tons. See cost calculations for more details.<sup>25</sup>

Description	Min Labor Hours	Max Labor Hours	Average Labor Hours	Residential Electrician Hourly Rate with O&P <sup>26</sup>	Total Labor Cost
Wall Furnace	2.462	4.000	3.230	\$67.55	\$218.25
Window Air AC	2.000	4.000	3.000	\$67.55	\$202.65
Total Cost					\$420.90
Total Normalized Cost					\$280.60

<sup>23</sup> 2019 RSMeans Electrical Cost Data

<sup>24</sup> RSMeans Residential Labor Rates, <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202019%20Labor%20Rates/Residential%20Labor%20Rates.PDF> , "Residential Labor Rates.pdf"

<sup>25</sup> Southern California Edison. 2019. "SWHC044-01 Ductless HVAC Cost-12-2-2019.xlsx"

<sup>26</sup> RSMeans Residential Labor Rates, <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202019%20Labor%20Rates/Residential%20Labor%20Rates.PDF> , "Residential Labor Rates.pdf"

## MEASURE CASE LABOR COST (\$/UNIT)

Labor cost was found from RS Means Online database (2019)<sup>27</sup> and RSMeans Facilities Construction Cost Data<sup>28</sup>. Costing included a range of labor hours based on its size, thus the average labor hours per equipment was selected. The installation includes installing the mini-split heat pump and construction of a concrete pad for the new outdoor condensing unit.

RSMeans hourly labor rates for a residential electrician were used to estimate labor costs for mechanical installations.<sup>29</sup>

The mini-split installation costs were normalized based on a midpoint system size of the measure which was found to be 1.5 tons. See cost calculations for more details.<sup>30</sup>

Description	Labor Hrs Min	Labor Hrs Max	Avg Labor Hrs	Electrician Hourly Rate with O&P <sup>31</sup>	Labor Cost
Install: Mini-Split Heat Pump, ductless, cooling/heating (1-1.5 tons)	9.412	10.667	10.040	\$67.55	\$678.17
Install: Mini-Split Heat Pump, tube / wiring kit, 50'	0.800	0.800	0.800	\$67.55	\$54.04
Install: Condensing Unit Pad prefabricated, fiberglass reinforced concrete with polystyrene foam core, 2" thick, 24"x42"	1.000	1.000	1.000	\$67.55	\$67.55
Total					\$799.76
Total Normalized Cost					\$533.17

## NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. Based on the CPUC's Fuel Substitution Technical Guidance for Energy Efficiency<sup>32</sup> document, the value below should be used for fuel substitution measures until further data is available.

<sup>27</sup> 2019 RSMeans Electrical Cost Data

<sup>28</sup> 2014 RSMeans Facilities Construction Cost Data

<sup>29</sup> RSMeans Residential Labor Rates, <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202019%20Labor%20Rates/Residential%20Labor%20Rates.PDF> , "Residential Labor Rates.pdf"

<sup>30</sup> Southern California Edison. 2019. "SWHC044-01 Ductless HVAC Cost-12-2-2019.xlsx"

<sup>31</sup> RSMeans Residential Labor Rates, <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202019%20Labor%20Rates/Residential%20Labor%20Rates.PDF> , "Residential Labor Rates.pdf"

<sup>32</sup> California Public Utilities Commission. 2019. "Fuel Substitution Technical Guidance for Energy Efficiency".

## Net-to-Gross Ratios

Parameter	Value	Source
NTG – FuelSubst-Default	1.0	California Public Utilities Commission. 2019. Decision 19-08-009. And California Public Utilities Commission. 2019. Fuel Substitution Technical Guidance for Energy Efficiency.

## GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method.

### Gross Savings Installation Adjustment Rates

Parameter	GSIA	Source
Def-GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. Energy Efficiency Policy Manual Version 5. Page 31.

## DEER DIFFERENCES ANALYSIS

### DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes (MASControl version 3 for residential buildings, existing vintage)
DEER Version	N/A
Reason for Deviation from DEER	N/A
DEER Measure IDs Used	N/A
NTG	Source: DEER. The NTG of 1.0 is associated with NTG ID: FuelSubst-Default
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER. EUL of 15 years with EUL ID: HVAC-airHP

## REVISION HISTORY

### Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	12/02/2019	Annie Hur, TRC Lake Casco, PE, TRC	First draft of workpaper.
	05/05/2020	Jesse Manao SCE	<ul style="list-style-type: none"> <li>Added PGE &amp; SDGE Implementation IDs in Implementation tab.</li> <li>Fixed MeasureImpactType in EAD Table</li> </ul>