|  |
| --- |
| hiHVAC  Conversion to Ductless heat pump, Residential  SWHC050-01 |

CONTENTS

Measure Name 2

Statewide Measure ID 2

Technology Summary 2

Measure Case Description 3

Base Case Description 5

Code Requirements 5

Normalizing Unit 9

Program Requirements 9

Program Exclusions 10

Data Collection Requirements 10

Use Category 11

Electric Savings (kWh) 11

Peak Electric Demand Reduction (kW) 14

Gas Savings (Therms) 14

Life Cycle 14

Base Case Material Cost ($/unit) 16

Measure Case Material Cost ($/unit) 16

Base Case Labor Cost ($/unit) 16

Measure Case Labor Cost ($/unit) 17

Net-to-Gross (NTG) 17

Gross Savings Installation Adjustment (GSIA) 17

DEER Differences Analysis 17

Revision History 18

Measure Name

HVAC – Ductless Heat Pump, Residential

Statewide Measure ID

SWHC050-01

Technology Summary

**Ductless Heat Pump** - A ductless, mini-split or multi-split, heat pump is a non-ducted all-electric heating and cooling system. Like standard air-source heat pumps, ductless heat pumps have two main components - an outdoor compressor/condenser and an indoor air-handling unit. A conduit, which houses the power cable, refrigerant tubing, and a condensate drain, links the outdoor and indoor units. Heat pumps include a reversing valve and outdoor defrost controls so that the system can use the same mechanical compression/evaporator/condenser hardware to provide heating and cooling by reversing the refrigeration cycle.

A heating and cooling system with a ductless unit is distinguished from one with a central unit by having a dedicated indoor coil unit for each zone and hence not requiring ductwork to distribute conditioned air. Each ductless indoor unit can be linked to its own outdoor unit, which is called mini-split; or several indoor units, each serving a zone, can be linked to one or more outdoor unit, which is called multi-split.

Among other energy efficiency features such as variable speed fans and compressors, the main advantage of ductless unit is their flexibility for zoning – each zone has its own thermostat and only the occupied zones are conditioned. Additionally, energy losses through duct work are avoided which can account for more than 30% of the space conditioning energy consumption.[[1]](#footnote-1) In comparison to all-in-one room or window heat pumps, ductless heat pumps do not require the equipment to penetrate the building envelope except for the passage of the refrigerant lines. Considering visual aesthetics and practical issues of space, the use of a remote outdoor unit also allows for that unit to include larger heat transfer components.

Following federal standards for efficiency labeling, a ductless heat pump is rated by a seasonal energy efficiency ratio (SEER) rating for the cooling mode function and a heating seasonal performance factor (HSPF) rating for the heating mode. These ratings essentially represent an average efficiency for conversion of electric energy (kWh) to thermal heat transfer (kBTU) over a range of operating conditions. ENERGYSTAR certifies efficient ductless heat pumps using the same criteria as central heat pumps[[2]](#footnote-2) and listed on Consortium for Energy Efficiency (CEE) online directory under “Variable Speed Mini-Split and Multi-Split Heat Pumps” since typically ductless heat pump is variable speed. The Consortium for Energy Efficiency (CEE) specifies four CEE Tiers, with CEE Tier 1 being equivalent to the ENERGYSTAR specification.[[3]](#footnote-3) The Air Conditioning, Heating, and Refrigeration Institute (AHRI) and CEE maintain a shared online directory of certified product ratings, which can be used to verify efficiency ratings.

**Ductless heat pump systems can be a replacement for the following all-electric air-conditioning and space heating systems.**

* Through the wall or window air-conditioner (Room AC) with built-in electric resistance heating.
* Through the wall or window heat pump (Room HP).
* Ductless air-conditioner providing cooling combined with electric resistance space heater for heating (Ductless AC).
* Less efficient (than minimum California Energy Standards) ductless heat pump (Ductless HP).

While technically a ductless heat pump could replace a central heat pump, this would require significant building envelope modifications such as closing off the vents, removing the existing duct work and air-handling unit, etc. These modifications can be costly and compromise the aesthetics of the home, creating a barrier to adoption of a ductless heat pump system where a central heat pump exists or is already included in late stages of design. Furthermore according to a 2017 study, home builders have reported negative perceptions because ductless systems do not require a semi-conditioned unvented attic (designed around ducted central systems and popularized by marketing campaigns) and in large single family homes with many zones, do require more careful attention to achieve uniform conditioning.[[4]](#footnote-4)

The installation of a ductless heat pump replacing an existing mixed fuel (typically electricity for cooling and gas for heating) unit will be classified as fuel substitution measure, and this measure is available in workpaper SWHC044-01.[[5]](#footnote-5)

Measure Case Description

The measure case is a ductless heat pump (mini or multi-split) with cooling capacity less than 65,000 BTU/h and matching one of the following efficiency levels. The SEER efficiency tiers replicate the DEER2020 efficiency tiers for SEER-rated split Heat Pumps. The HSPF efficiency tiers reflect the average HSPF values for the corresponding SEER ratings from the CEC appliance database[[6]](#footnote-6). Each efficiency tier exceeds code requirements. Equipment should meet or exceed both the SEER and HSPF rating listed in order to qualify under a Statewide Offering ID.

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** | **Measure Tier** | **SEER** | **HSPF** |
| Ductless  Heat Pump | Tier 1 | 15 | 8.5 |
| Tier 2 | 16 | 8.8 |
| Tier 3 | 17 | 9.4 |
| Tier 4 | 18 | 9.8 |

The list of Statewide Offering IDs includes variants based on measure application type, efficiency tier of equipment being installed, and class of equipment being replaced.

Measure Case Specification

| **Statewide Offering ID** | **Measure**  **Application**  **Type** | **Existing equipment being replaced** | **Measure Tier** |
| --- | --- | --- | --- |
| SWHC050A | Accelerated replacement (AR) | Room AC for space cooling and electric resistance space heater | Tier 1 |
| SWHC050B | Tier 2 |
| SWHC050C | Tier 3 |
| SWHC050D | Tier 4 |
| SWHC050E | Room HP | Tier 1 |
| SWHC050F | Tier 2 |
| SWHC050G | Tier 3 |
| SWHC050H | Tier 4 |
| SWHC050I | Ductless AC and electric resistance space heater | Tier 1 |
| SWHC050J | Tier 2 |
| SWHC050K | Tier 3 |
| SWHC050L | Tier 4 |
| SWHC050M | Ductless HP | Tier 1 |
| SWHC050N | Tier 2 |
| SWHC050O | Tier 3 |
| SWHC050P | Tier 4 |
| SWHC050Q | New construction (NC) | Ductless HP | Tier 1 |
| SWHC050R | Tier 2 |
| SWHC050S | Tier 3 |
| SWHC050T | Tier 4 |
| SWHC050U | Normal replacement (NR) | Room unit (HP or AC with electric resistance space heater) a | Tier 1 |
| SWHC050V | Tier 2 |
| SWHC050W | Tier 3 |
| SWHC050X | Tier 4 |
| SWHC050Y | Ductless HP b | Tier 1 |
| SWHC050Z | Tier 2 |
| SWHC050AA | Tier 3 |
| SWHC050AB | Tier 4 |

a Code restricts electric resistance space heater. Hence the savings for these measures would be over a code complaint room HP.

b Ductless AC unit as the existing equipment is not offered through NR application type because incremental measure cost of Ductless AC combined with electric resistance space heater replacing Ductless HP is negative. Hence Ductless AC replacement is offered as AR only.

Base Case Description

For Normal replacement (NC) and New construction (NR) measures, the base case is defined as room heat pump, or ductless heat pump that meets the California Appliance Efficiency Regulations (Title 20) code requirements prevailing in 2020. Where code requirements differ based on size of equipment (under 65,000 BTU/h cooling capacity) or other minor variations, the most stringent requirements are applicable.

For Accelerated replacement (AR) measures, the base case system is the same as above with efficiencies from California Appliance Efficiency Regulations (Title 20) code requirements prevailing 10 years ago. See Code Requirements section for details of the base case.

**Base, Standard Cases**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment type** | **Existing equipment**  **(applied for AR measures 1st baseline)** | | **Standard equipment**  **(applied for NR and NC measures and for the 2nd baseline for AR measures) a** | |
| **Cooling efficiency** | **Heating efficiency** | **Cooling efficiency** | **Heating efficiency** |
| Room AC and electric resistance space heater | 9.8 EER | 100% | 9.8 EER | 7.1 HSPF b |
| Room HP | 9.0 EER | 7.1 HPSF b | 9.8 EER | 7.1 HSPF b |
| Ductless AC and electric resistance space heater | 13.0 SEER | 100% | 14.0 SEER | 8.2 HPSF |
| Ductless HP | 13.0 SEER | 7.7 HSPF | 14.0 SEER | 8.2 HPSF |

a California Building Energy Efficiency Standards (Title 24) restricts using electric resistance space heater for primary heating. Hence, the standard equipment for room AC and ductless AC in combination with electric resistance space heater will be room HP and Ductless HP respectively.

b For this equipment, code only specifies EER. HPSF is determined from typically seen HSPF value corresponding to the EER/SEER range of ductless heat pumps per DEER documentation (specifically, MASControl3 technology workbook for split and packaged cooling systems).

Code Requirements

The residential HVAC equipment designated for this measure must comply with both state and federal efficiency standards. Applicable state and federal codes and standards for base case and measure case are specified below.

Applicable State and Federal Codes and Standards

|  |  |  |  |
| --- | --- | --- | --- |
| **Code** | **Technology** | **Applicable Code Reference** | **Effective Date** |
| CA Appliance Efficiency Regulations – Title 20 | Ductless Heat Pump and Ductless AC | Section 1605.1(c)(1) Table C-3 | January 1, 2019 |
| CA Appliance Efficiency Regulations – Title 20 | Room AC and Room Heat Pump | Section 1605.1(b)(1) Table B-2 | January 1, 2019 |
| CA Appliance Efficiency Regulations – Title 20 | Ductless Heat Pump and Ductless AC | Section 1605.1(c)(1) Table C-2 | December 2010 |
| CA Appliance Efficiency Regulations – Title 20 | Room AC and Room Heat Pump | Section 1605.1(b)(1) Table B-2 | December 2010 |
| CA Building Energy Efficiency Standards – Title 24 | Electric Resistance Space Heater | Section 150.1(c) (6) | January 1, 2020 |
| Federal Standards (Title 10) |  | Section 430.32(b), 430.32(c) | June 1, 2014 for Room AC and HPs  January 1, 2015 for central HP |

**California Appliance Efficiency Regulations (Title 20)**[[7]](#footnote-7) does not specifically identify ductless units. As per ENERGYSTAR ductless units are identified under central air conditioners and heat pumps. Hence, Section 1605.1(c)1 Table C-3 (portions replicated below) which provides standards for single phase air-cooled air conditioners and heat pumps for capacities < 65,000 Btu/hr was referred.

Table C-3: Standards for Single Phase Air-Cooled 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 EPAct[[8]](#footnote-8)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Product Class*** | ***Minimum Efficiency Effective January 1, 2015*** | | | |
| ***Minimum SEER*** | ***Minimum HSPF*** | ***Minimum EER*** | ***Average Off-Mode Power Consumption Pw. pff (watts)*** |
| Split system air conditioners with rated cooling capacity < 45,000 Btu/hour | 14 | - | 12.2 | 30 |
| Split system air conditioners with rated cooling capacity >= 45,000 Btu/hour | 14 | - | 11.7 | 30 |
| Split system heat pumps with rated cooling capacity < 45,000 Btu/hour | 14 | 8.2 | 12.2 | 33 |
| Split system heat pumps with rated cooling capacity >= 45,000 Btu/hour | 11.7 | 33 |
| Single package air conditioners | 14 | - | 11.0 | 30 |
| Single package heat pumps | 14 | 8.0 | - | 33 |

Section 1605.1(b)1 Table B-2 (portions replicated below) provides standards for room air conditioners and room heat pumps manufactured on or after June 1, 2014. The higher among these efficiencies for room air conditioners and room heat pumps were used as code baseline efficiencies.

Table B-2: Standards for Room Air Conditioners and Room Air-Conditioning Heat Pumps Manufactured On or After June 1, 2014[[9]](#footnote-9)

|  |  |  |  |
| --- | --- | --- | --- |
| ***Appliance*** | ***Louvered Sides*** | ***Cooling Capacity (Btu/hr)*** | ***Minimum Combined EER*** |
| Room Air Conditioner | Yes | <6,000 – 7,999 | 11.0 |
| Room Air Conditioner | Yes | ≥ 8,000 – 13,999 | 10.9 |
| Room Air Conditioner | Yes | ≥ 14,000 – 19,999 | 10.7 |
| Room Air Conditioner | Yes | ≥ 20,000 – 27,999 | 9.4 |
| Room Air Conditioning Heat Pump | Yes | <20,000 | 9.8 |
| Room Air Conditioning Heat Pump | Yes | ≥ 20,000 | 9.0 |

Title 10 of the Code for Federal Regulations, section 430.32 (b) and (c)[[10]](#footnote-10) has standards for room air conditioners and heat pumps and split system heat pumps respectively that are equivalent to California Title 20. Hence, the Title 20 standards govern the definition of the base case for this measure.

**Electric resistance space heater for standard baseline.** CA Building Energy Efficiency Standards (Title 24)[[11]](#footnote-11) Section 150.1(c) 6 – performance and prescriptive compliance approaches for low-rise residential buildings, limits using electric resistance space heating for only supplemental heating and requires the installation of a gas heating system or heat pump for primary heating. Hence, heat pump was used for the standard equipment type.

**Existing baseline efficiency.** To determine the existing baseline efficiency used for accelerated replacement applications, previous editions of Title 20 codes were consulted. Since the remaining useful life (RUL) for an accelerated replacement (AR) measure application for this measure is five years (see Life Cycle), the equipment should have been installed around 2010 to have a five-year RUL in 2020. Hence, the Title 20 standard that was applicable in year 2010 was used to set the baseline efficiencies.[[12]](#footnote-12) Section 1605.1(c)1 Table C-2 of the 2010 standards for single phase air-cooled heat pumps for capacities < 65,000 r and Section 1605.1 (b) (1) Table B-2 provides standards for room air conditioners and heat pumps.

|  |  |  |
| --- | --- | --- |
| **Table C-2: Standards for Single Phase Air-Cooled 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 EPAct**[[13]](#footnote-13)***Product Class*** | ***Minimum Efficiency Effective January 23,2006*** | |
| ***Minimum SEER*** | ***Minimum HSPF*** |
| Split system air conditioners | 13 | - |
| Single package heat pumps | 13 | 7.7 |

Table B-2: Standards for Room Air Conditioners and Room Air-Conditioning Heat Pumps Manufactured On or After October 1, 2000[[14]](#footnote-14)

|  |  |  |  |
| --- | --- | --- | --- |
| ***Appliance*** | ***Louvered Sides*** | ***Cooling Capacity (Btu/hr)*** | ***Minimum Combined EER*** |
| Room Air Conditioner | Yes | <6,000 – 7,999 | 9.7 |
| Room Air Conditioner | Yes | ≥ 8,000 – 13,999 | 9.8 |
| Room Air Conditioner | Yes | ≥ 14,000 – 19,999 | 9.7 |
| Room Air Conditioner | Yes | ≥ 20,000 | 9.5 |
| Room Air Conditioning Heat Pump | Yes | <20,000 | 9.0 |
| Room Air Conditioning Heat Pump | Yes | ≥ 20,000 | 8.5 |

**Electric resistance space heater for existing baseline.** CA Building Energy Efficiency Standards (Title 24)[[15]](#footnote-15) Section 151 (f) 6 – performance and prescriptive compliance approaches for low-rise residential buildings, allows electric resistance for space heating. Hence, for AR install type, electric resistance space heater is an eligible baseline for the 1st baseline.

Normalizing Unit

Tons of cooling capacity (Cap-tons).

Program Requirements

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector 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.

Incentivized system capacity is “like-per-like.”

*Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.*

Implementation Eligibility

|  |  |  |
| --- | --- | --- |
| **Measure Application Type** | **Delivery Type** | **Sector** |
| Accelerated replacement | DnDeemDI | Res |
| Accelerated replacement | DnDeemed | Res |
| Normal replacement | UpDeemed | Res |
| Normal replacement | DnDeemDI | Res |
| Normal replacement | DnDeemed | Res |
| New construction | UpDeemed | Res |
| New construction | DnDeemDI | Res |
| New construction | DnDeemed | Res |

For mid-stream deliveries for normal replacement, the implementer shall provide the retailer or distribution location where the product was sold and the product’s rated capacity (e.g., tons) and cooling and heating rated efficiencies (SEER/HSPF). Additionally, the implementer is required to document and track the Residential building type and existing HVAC type (room unit or ductless unit) where the product will be installed. Measure IDs U through X are applicable for room units and Y through AB are applicable for ductless units.

**In cases where the existing HVAC type cannot not be verified and collected such as Midstream/Upstream, measure savings shall be defaulted to Normal Replacement measure replacing less efficient ductless heat pump (Measures Y through AB from Measure Case Specification table).**

If the installed unit’s rated cooling capacity is higher or lower than the existing/ replaced capacity OR for cases in which existing system capacity cannot be validated, the measure shall be eligible as NR only regardless of the measure’s delivery type.

For base case systems where space heating is provided by electric resistance space heater (wall furnace, baseboard heating, etc.), the offering requires for these to be fully decommissioned as part of measure implementation.

For AR measure application type, the verified existing and the installed rated capacity shall be the same.

Eligible Products

The efficiency specification for eligible ductless heat pumps are included in Measure Case Description section.

Only those ductless heat pump systems covered by AHRI 210/240 2017 and/or DOE CFR 429.16 are eligible.

**General Eligibility Requirements**

Eligible Building Types and Vintages

This measure is applicable for all residential building types and all vintages.

Eligible Climate Zones

This measure is applicable in all California climate zones.

*Required Documentation for Accelerated Replacement*

Preponderance of evidence (POE) must be documented. Programs shall document if measure was replaced as a direct result of information, recommendations, and support provided by the Program Administrator, and programs shall require the collection and submission of documentation to ensure proper conformance to eligibility and implementation requirements. The following summarized information that must be required for all projects:

1. Customer/site information
2. Specifications of existing equipment
3. Proof that the existing all electric HVAC system is functional and still operating as intended
4. Existing system nameplate data with manufacturer date to confirm remaining useful life and to include total nominal system capacity being replaced
5. Replacement HVAC System information
6. Verify that the existing equipment is fully decommissioned. Disposal of the existing equipment should comply with the local jurisdiction guidelines.

To document POE, the provided Preponderance of evidence (POE) survey[[16]](#footnote-16), or similar, should be completed.

Program Exclusions

Fuel substitution measures are not eligible. Please refer to SWHC044-01 for fuel substitution measures.

Data Collection Requirements

This section discusses the limitations of data used to analyze the measure described in this workpaper, and the potential need for future data or timeline for updates, so that energy efficiency incentive program administrators can incorporate those requirements into their program designs.

Experience with residential HVAC workpapers suggests that one of the most significant limitations for analysis is the availability of a cost dataset that is up to date and reflects the market. Such a dataset (including material and installation cost) would be representative of customer costs and would be used to measure price variations between installations of similar products. In turn, the amount of variation can be used to determine the confidence associated with cost data collection, for instance, to decide whether additional survey data is needed at the time of the next workpaper update. However, this recommendation is not a general requirement for programs or implementers following this workpaper.

High SEER rated ductless heat pump into SEER rating of 22 are available in the marketplace. However, DEER documentation has performance data and measures only until SEER 18. SCE is working with manufacturers to gather performance data for high SEER rated ducted and ductless heat pump with the intent to support evaluation of measure savings on SEER rated equipment currently not currently supported in DEER.

Use Category

HVAC

Electric Savings (kWh)

MASControl3, an updated version of the measure analysis software for Database for Energy Efficient Resources (DEER) 2020, was used to generate the energy savings values for all measure offerings. MASControl3 is built to run DEER2020 prototypes with DOE-2.3/ eQUEST 3.65 energy modeling software. New measures representing the base case and measure case combinations were added into MASControl3 using MASControl3 supporting workbooks.

DEER Prototype Sizing for Heating and Cooling Capacity

1. Cooling and heating capacity for DEER residential prototypes are fixed prior to simulation using lookup tables that select square feet of conditioned floor area per unit of cooling capacity and area per unit of heating capacity, as a function of building type, HVAC type, vintage, and climate zone. (Although DOE2 has the capability to size conditioning equipment based on design days, that feature is not utilized.) Typical values range from 352 sq. ft. per ton for mobile home; 600 to 980 sq. ft. per ton for single family; and 820 to 1000 sq. ft. per ton for multifamily. Energy efficiency savings require maintaining same level of service. Hence base case and measure case equipment are similarly sized except for electric resistance heating which are limited to 3kW capacity by the code. The savings adjustments for systems with electric resistance heating is discussed towards the end of this section.
2. In all simulations for this measure, the model uses capacity lookup values corresponding to DEER HVAC type for residential heat pump ("rDXHP"). **This is to guarantee that the base case and measure case model share the same cooling capacity and same heating capacity** and applies equally to air conditioning with electric resistance coils for heating, as well as to heat pumps.
3. Coincidentally, in single family and multifamily building model for this measure, the heating capacity is equal to the cooling capacity. In mobile homes, the heating capacity is about 76% of cooling capacity.

Prototype Modifications

1. DEER prototypes are setup such that all the spaces with-in the residential building type are treated as a single zone and served by one Packaged Volume Variable Temperature (PVVT) distribution system. The base case and measure case HVAC system considered in this workpaper are typically installed so that one unit serves each conditioned space in the building and requiring multiple units to condition the entire home.

A single PVVT system typically operates at significant partial load hours since all spaces will not be occupied at the same time was assumed to be the close proxy to multiple single zone systems. This was validated by comparing the annual space cooling energy consumption for PVVT with the Residential Appliance Saturation Study (RASS)[[17]](#footnote-17) space cooling electric Unit Energy Consumption (UEC) for a room AC, the UEC for PVVT was only 3% higher. The additional updates below are made to closely replicate the PVVT system operation to the single zone systems.

1. Return Air Path is set to Direct (within the conditioned space).
2. Duct Air Loss is set to zero to simulate the equipment being in zone only.
3. Fan Power kW/CFM is set to zero because the total per unit efficiency for each system will be captured in the unit’s EIR and HIR (efficiency) values, further described below. This is in keeping with the reporting requirements of common test standards for residential units, which are limited to reporting EER/SEER/HSPF only and no separate detail about fan power (confer AHRI standard 210/240[[18]](#footnote-18) and DOE CFR 429.16[[19]](#footnote-19)). Per these standards, EER/SEER/HSPF values already include fan power as part of the efficiency rating calculation. 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.*”
4. Outside Air Control is set to Fixed Fraction and the Minimum Outside Air Ratio set to zero to simulate that neither the baseline nor measure case systems bring in outside air.
5. Cooling EIR is set directly as a function of EER and fan power. According to DOE2 help files, if fan power is not input separately, then by definition EIR = 3.413 / EER. Since the measure specifies SEER rather than EER, using the SEER-to-EER ratio reference values from DEER, the EER was calculated. DEER residential HVAC measure definitions correlate the number of stages as a function of SEER, so that systems up to SEER 15 are modeled as 1 stage and systems with SEER 16 and above are modeled with 2 stages. Since the ductless heat pumps are typically variable speed for all the SEER rating, SEER-to-EER ratio reference of 2-stage systems were used to calculate the EER for SEER rating of 15 and lower.
6. HSPF values were selected in a similar manner to EER, using the DEER lookup tables and reference values. Similar assumptions to the SEER were made when converting HSPF to Heating EIR.

The following table summarizes the modifications made to the prototypes and the key inputs to model the existing base case, code (standard) base case and measure case.

| **Type (DOE2 Keyword Listed)** | **DEER Prototype Defaulted** | **Base Case (existing)** | **Base Case (code/standard)** | **Measure Case** |
| --- | --- | --- | --- | --- |
| SYSTEM TYPE (A) | Pkdg Vol Var Temp | Pkdg Vol Var Temp | Pkdg Vol Var Temp | Pkdg Vol Var Temp |
| SYSTEM: RETURN-AIR-PATH (B) | Duct | Direct | Direct | Direct |
| SYSTEM: DUCT-AIR-LOSS (B) | 0.15 | 0 | 0 | 0 |
| SYSTEM: SUPPLY-KW/FLOW (C) | 0.000652 | 0 | 0 | 0 |
| SYSTEM: MIN-OUTSIDE-AIR | n/a | 0 | 0 | 0 |
| SYSTEM: OA-CONTROL (D) | OA Temperature | Fixed Fraction | Fixed Fraction | Fixed Fraction |
| SYSTEM: COOLING-EIR (E) | 0.328 | Room AC – 0.34829 EIR (9.8 EER)  Room HP – 0.37929 EIR (9.0 EER)  Ductless AC – 0.33659 EIR (13 SEER)  Ductless HP – 0.33659 EIR (13 SEER) | Room HP – 0.34829 (9.8 EER)  Ductless AC – 0.31255 EIR (14 SEER)  Ductless HP – 0.31255 EIR (14 SEER) | **Tier 1:** 0.29171  **Tier 2:** 0.27348  **Tier 3:** 0.25739  **Tier 4:** 0.24309 |
| SYSTEM: HEAT-SOURCE | Furnace | Electric resistance space heater for Room AC and Ductless AC  Heat Pump for Room HP and Ductless HP | Heat Pump | Heat Pump |
| SYSTEM: FURNACE-HIR | n/a | 1.0 (100% AFUE) for electric resistance heating | n/a | n/a |
| SYSTEM: HEATING-EIR (F) | n/a | Room HP – 0.33990 EIR (7.1 HPSF)  Ductless HP – 0.31341 EIR (7.7 HPSF) | Room HP – 0.33990 EIR (7.1 HPSF)  Ductless HP – 0.29430 EIR (8.2 HPSF) | **Tier 1:** 0.27739 (HSPF=8.7)  **Tier 2:** 0.28571 (HSPF=9.0)  **Tier 3:** 0.27355 (HSPF=9.4)  **Tier 4:** 0.26509 (HSPF=9.7) |
| SYSTEM: HEAT-STAGES, low stage capacity ratio | One stage: 0.999  Two stage: 0.686 (unreachable due to bug) | All baseline systems:  One stage (0.999) | All baseline systems:  One stage (0.999) | **Tier 1:** one stage (0.999)  **Tier 2:** two stage (0.686)  **Tier 3:** two stage (0.686)  **Tier 4:** two stage (0.686) |

The energy simulations for the selected DEER measures were run for all residential building types, for all California climate zones, all residential DEER thermostat settings, and for all representative vintage years that span the median existing era ("Ex", consisting of 2003, 2007, 2011, and 2015 for SFm and MFm prototypes, and MH00 and MH06 for the DMo prototype) and new era ("New", consisting of 2020 and MH15).

MAScontrol3 generated the annual and hourly energy usage (electric) for each measure as an intermediate file[[20]](#footnote-20). Using the post processing scripts that come with MASControl3, the thermostat weighted normalized Unit Energy Consumption (UEC) values and Unit Energy Savings (UES) were calculated. The post processing scripts use DEER2020 residential thermostat weights[[21]](#footnote-21) for the five thermostat settings and generate the normalizing unit (cap-tons), which vary by climate zone, for each building type. Then, for each era (Ex and New) the scripts compute UEC weighted average value over the representative year vintages in that era.

MASControl3 workbooks were setup so that the for normal replacement (NR) measures, the baseline is defined as the code/ standard baseline described in the table above (savings labeled as above standard or "AStd") and for accelerated replacement (AR) measures, the first baseline is the existing baseline (savings labeled as above pre-existing or "APre") and the second baseline is the code/standard baseline described in the table above. See the MASControl3 setup[[22]](#footnote-22) and energy savings output file[[23]](#footnote-23) for details.

Typically, electric resistance heating is used for focused heating rather than heating the entire space. On the other hand, the measure technology, ductless heat pump is sized to heat the entire space it is designed for. Hence, replacing electric resistance heating with heat pump heating will provide higher level of service by heating spaces not heated before. Given that energy efficiency savings require similar level of service in the base and measure case, the savings from replacing systems with electric resistance space heating were approximated to the savings from replacing room or ductless heat pump systems which are two to three times more efficient during the heating mode than electric resistance heating but are sized to meet the loads of the entire space.

Peak Electric Demand Reduction (kW)

Like kWh savings, MASControl3 post processing scripts were used to calculate the new DEER2020 peak kW savings by considering peak hours from 4-9PM for the specified periods.

Gas Savings (Therms)

There are no gas savings from the proposed measures.

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.

The RUL is only applicable to the first baseline period for a retrofit or accelerated replacement measure with an applicable code baseline. The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.”[[24]](#footnote-24) This approach provides an RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[[25]](#footnote-25)

The EUL and RUL specified for this measure are presented below. The estimated lifetime can be traced to values adopted for the California PY 2001 programs and was adopted for commercial AC measures for DEER 2005.

Effective Useful Life and Remaining Useful Life

| **Parameter** | **Value** | **Source** |
| --- | --- | --- |
| EUL (yrs)  *HV-ResHP* for Heat Pumps | 15.0 | Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), California Energy Commission (CEC), Office of Ratepayer Advocates (CPUC ORA), and Natural Resources Defense Council (NRDC). 1998. Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs. Revised March 1998 and March 1999. Appendix F.  Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SCG). 2000. “Proposed Effective Useful Life for Measures for PY2001 Program Elements. Report Issued Prior to Public Meeting. Response to Ordering Paragraph #8, Discussion Paper 2.” September 5.  Itron, Inc. 2005. 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report. Prepared for Southern California Edison. Table 11-1.  California Public Utilities Commission (CPUC), Energy Division. 2008. “EUL\_Summary\_10-1-08.xls.” |
| RUL (yrs)  *HV-ResHP* for heat pumps and *HV-ResAC* for air conditioners plus electric resistance heating | 5.0 | EUL/3 |

Base Case Material Cost ($/unit)

The base case material cost, which is the cost of code complaint base case equipment was obtained from a few resources based on the type of the base case equipment.

For room air-conditioner with electric resistance heating and room heat pump, cost was through online price research from various retailer websites in the second quarter of 2020 for cooling capacities ranging from 0.7 to 2 tons, the capacities typically installed in residential applications.

Ductless air-conditioners providing cooling only are combined with electric furnaces for heating. Only electric furnaces were considered in this workpaper since fuel substitution measures were not addressed here. The material cost of ductless air-conditioners was obtained through online price research from various retailer websites in the second quarter of 2020 for cooling capacities ranging from 1.0 to 2 tons. The cost of electric furnaces was obtained from RS Means online database (2019)[[26]](#footnote-26). The rated capacity of electric furnaces in the units of MBH was converted to equivalent cooling tons by applying the ratio of heating to cooling capacity observed in the ductless heat pumps products in the market. From the online research of SEER 16 rated ductless heat pumps, the ratio was calculated as 1.04 indicating that the rated heating capacities are 4% higher than the rated cooling capacities.

For ductless heat pumps with SEER rating of 14, the code complaint equipment, there were no representative cost resources. It has been the observation that because base case equipment tends to be older, it is hard to find the cost from current cost sources. Hence, the cost of SEER14 ductless heat pumps was linearly extrapolated from the measure case cost of SEER 15 and SEER 16 ductless heat pumps.

The unit cost was normalized per rated cooling ton. See the cost calculation workbook for details.[[27]](#footnote-27)

Measure Case Material Cost ($/unit)

The measure case material cost was obtained through online price research from various retailer websites in the second quarter of 2020. The unit cost was normalized per rated cooling ton. See the cost calculation workbook for details.[[28]](#footnote-28)

Base Case Labor Cost ($/unit)

The base case labor cost was obtained from RS Means online database (2019)[[29]](#footnote-29). RSMeans hourly labor rates for a residential electrician was obtained from RS Means residential labor rates.[[30]](#footnote-30) Labor hours for installing various capacities of window/thru-the wall unit and ductless units for various capacities was obtained from RS Means. Using the average labor hours and labor rate, the average labor cost was calculated. The normalized labor cost per ton of cooling capacity was calculated by using the average capacity of 1.5 tons for these units from RS Means.

For ductless units, in addition to installing the unit itself, labor cost for installing tube/ wiring kit of 50’ and condensing unit pad were considered as identified in RS Means.

Measure Case Labor Cost ($/unit)

The same sources used for the base case material cost were used to define measure case labor cost. The labor cost remains the same for all the efficiency tiers of ductless heat pumps.

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. The NTG value for upstream and downstream delivery varies and are based on CPUC, 2018. Resolution E-4952

Net-to-Gross Ratios

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| NTG - residential, upstream delivery | 0.65 | Adopted by: CPUC, 2018. *Resolution E-4952: DEER2020 and Revised DEER2019*. Page A-36, Table 7.  Based on: Impact Evaluation of 2015 Upstream HVAC Programs (HVAC1), prepared for California Public Utilities Commission by DNVGL, CALMAC ID CPU0116.03, April 4, 2017. |
| NTG - residential, downstream delivery | 0.60 | Adopted by: CPUC, 2018. *Resolution E-4952: DEER2020 and Revised DEER2019*. Page A-50, attachment "SupportTable-NTG2020.xlsx.". |

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. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

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

DEER Differences Analysis

This section provides a summary of Database for Energy Efficient Resources (DEER) -based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

| **DEER Item** | **Comment / Used for Workpaper** |
| --- | --- |
| Modified DEER methodology | Yes |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | 2020 |
| Reason for Deviation from DEER | The measures are not available on DEER |
| DEER Measure IDs Used | No. Statewide measure ID were used |
| NTG | Source: DEER2020. The NTG of 0.65 is associated with NTG ID: *Res-sAll-mHVAC-DX-up*. The NTG of 0.60 is associated with NTG ID: *Res-sAll-mHVAC-Pkg-dn*. |
| GSIA | Source: DEER2011. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA* |
| EUL/RUL | Source: DEER2014. The value of 15 years is associated with *EUL\_ID: HV-ResHP.* |

Revision History

Measure Characterization Revision History

| **Revision Number** | **Revision Complete Date** | **Primary Author, Title, Organization** | **Revision Summary and Rationale for Revision**  **Effective Date and Approved By** |
| --- | --- | --- | --- |
| 01 | 2020-07-02 | Nicholas Fette / Akhilesh Reddy Endurthy Solaris-Technical, LLC. | New Workpaper based on DEER2020 prototypes |

1. <https://www.energy.gov/energysaver/heat-pump-systems/ductless-mini-split-heat-pumps#261509-tab-2> [↑](#footnote-ref-1)
2. [ENERGYSTAR](https://www.energystar.gov/products/heating_cooling/heat_pumps_air_source/key_product_criteria) FAQ.pdf - Are there ENERGY STAR certified ductless split-system air conditioners (mini splits)? [↑](#footnote-ref-2)
3. <https://library.cee1.org/content/cee-residential-high-efficiency-central-air-conditioners-and-air-source-heat-pumps-specifica> [↑](#footnote-ref-3)
4. Anastasia Herk, 2017, Mini-Split Heat Pump Evaluation and Zero Energy Ready Home Support. <https://www.nrel.gov/docs/fy17osti/64855.pdf> [↑](#footnote-ref-4)
5. SWHC044-01 – Ductless HVAC, Residential – Fuel Substitution [↑](#footnote-ref-5)
6. The HSPF tiers defined here for ductless heat pumps slightly deviate from the DEER2020 definitions for SEER-rated split heat pumps which have HSPF of 8.7, 9.0, 9.4 and 9.7 for SEER rating of 15,16, 17 and 18 respectively. This slight deviation will have negligible impact on the energy savings. [↑](#footnote-ref-6)
7. California Energy Commission (CEC). 2019. California Code of Regulations Title 20 Public Utilities and Energy. CEC-140-2019-002. January. [↑](#footnote-ref-7)
8. California Energy Commission (CEC). 2019. California Code of Regulations Title 20 Public Utilities and Energy. CEC-140-2019-002. January. Table C-3 [↑](#footnote-ref-8)
9. California Energy Commission (CEC). 2019. California Code of Regulations Title 20 Public Utilities and Energy. CEC-140-2019-002. January. Table B-2 [↑](#footnote-ref-9)
10. 10 C.F.R. section 430.32(b) and 430.32(c) [↑](#footnote-ref-10)
11. California Energy Commission (CEC). 2019. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2018-020-CMF. Section 150.1(c)6. Page 280. [↑](#footnote-ref-11)
12. California Energy Commission (CEC). 2010. California Code of Regulations Title 20 Public Utilities and Energy. CEC-400-2010-012. December.  [↑](#footnote-ref-12)
13. California Energy Commission (CEC). 2010. California Code of Regulations Title 20 Public Utilities and Energy. CEC-400-2010-012. December. Table C-2 [↑](#footnote-ref-13)
14. California Energy Commission (CEC). 2010. California Code of Regulations Title 20 Public Utilities and Energy. CEC-400-2010-012. December. Table B-2 [↑](#footnote-ref-14)
15. California Energy Commission (CEC). 2005. *2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2006-015. Section 150.1(c)6. Page 280. [↑](#footnote-ref-15)
16. SWHC050-01-Ductless Heat Pump, Residential - POE Survey.docx [↑](#footnote-ref-16)
17. California Energy Commission. 2010. “2009 California Residential Appliance Saturation Study”. [↑](#footnote-ref-17)
18. Air-Conditioning, Heating, & Refrigeration Institute (AHRI). 2017. “2017 Standard for Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment” [↑](#footnote-ref-18)
19. US Department of Energy (DOE) 10 CFR § 429.16. [↑](#footnote-ref-19)
20. The calculations use DEER2020 tiers for HSPF rating which are slightly different (<2.5% difference in HSPF rating) than the HSPF tiers used in the measure description. This difference will have negligible impact on the savings present here. [↑](#footnote-ref-20)
21. California Public Utilities Commission. 2019. MASControl3 “DEER\_Tools\_2019\_09\_30.zip”, SupportTables folder, “reststatwt.sql” file [↑](#footnote-ref-21)
22. Southern California Edison (SCE). 2020. “SWHC050-01 MASControl3 Files.zip” [↑](#footnote-ref-22)
23. Southern California Edison (SCE). 2020. “SWHC050-01 Energy Calculations.xlsx.” [↑](#footnote-ref-23)
24. California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32. [↑](#footnote-ref-24)
25. KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc. [↑](#footnote-ref-25)
26. 2019 RSMeans Electrical Cost Data [↑](#footnote-ref-26)
27. "SWHC050-01 Cost analysis.xlsx." Southern California Edison, 2020. [↑](#footnote-ref-27)
28. "SWHC050-01 Cost analysis.xlsx." Southern California Edison, 2020. [↑](#footnote-ref-28)
29. 2019 RSMeans Electrical Cost Data [↑](#footnote-ref-29)
30. RSMeans Residential Labor Rates, https://www.rsmeansonline.com/References/LABORRATE/2-Year%202019%20Labor%20Rates/Residential%20Labor%20Rates.PDF , “Residential Labor Rates.pdf” [↑](#footnote-ref-30)