|  |
| --- |
| hC - HVAC  Ductless heat pump, Residential  SWHC050-02 |

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 11

Data Collection Requirements 11

Use Category 11

Electric Savings (kWh) 11

Peak Electric Demand Reduction (kW) 15

Gas Savings (Therms) 15

Life Cycle 15

Base Case Material Cost ($/unit) 16

Measure Case Material Cost ($/unit) 17

Base Case Labor Cost ($/unit) 17

Measure Case Labor Cost ($/unit) 17

Net-to-Gross (NTG) 17

Gross Savings Installation Adjustment (GSIA) 18

DEER Differences Analysis 18

Revision History 19

Measure Name

HVAC – Ductless Heat Pump, Residential

Statewide Measure ID

SWHC050-02

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) coupled with electric resistance space heater for heating.
* Through the wall or window heat pump (Room HP).
* Ductless air-conditioner providing cooling coupled 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 tiers. 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. The HSPF efficiency levels in each tier are chosen as discussed in the section on Electric Savings (kWh). (These tiers were created solely for this workpaper and are not connected to any other efficiency tier system. Equipment will not have a tier label, but the appropriate tier should be determined from SEER and HSPF ratings.)

Efficiency Tiers

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** | **Measure Tier** | **SEER** | **HSPF** |
| Ductless Heat Pump (mini-split and multi-split) | Tier 1 | ≥ 15 | ≥ 9.0 |
| Tier 2 | ≥ 16 | ≥ 9.2 |
| Tier 3 | ≥ 17 | ≥ 9.5 |
| Tier 4 | ≥ 18 | ≥ 9.8 |
| Tier 5 | ≥ 19 | ≥ 10.0 |
| Tier 6 | ≥ 20 | ≥ 10.3 |
| Tier 7 | ≥ 21 | ≥ 10.6 |
| Tier 8 | ≥ 22 | ≥ 10.9 |

The list of Statewide Offering IDs includes variants based on measure application type, class of equipment being replaced, and efficiency tier of equipment being installed. Note the following excluded combinations: for new construction applications, there are no offerings with room HVAC unit baseline. For multi-split units replacing a room unit, Tier 1 is not offered.

Measure Case Specification – Mini-split Ductless Heat Pumps

| **Statewide Offering ID** | **Existing equipment being replaced** | **Measure case equipment:**  Mini-split Ductless Heat Pumps | **Measure Application Type** |
| --- | --- | --- | --- |
| A | Room unit (HP or AC coupled with electric resistance space heater) | SEER ≥15, HSPF ≥9.0 | Accelerated replacement (AR) |
| B | SEER ≥16, HSPF ≥9.2 |
| C | SEER ≥17, HSPF ≥9.5 |
| D | SEER ≥18, HSPF ≥9.8 |
| E | SEER ≥19, HSPF ≥10.0 |
| F | SEER ≥20, HSPF ≥10.3 |
| G | SEER ≥21, HSPF ≥10.6 |
| H | SEER ≥22, HSPF ≥10.9 |
| I | Ductless unit (HP or AC coupled with electric resistance space heater) | SEER ≥15, HSPF ≥9.0 |
| J | SEER ≥16, HSPF ≥9.2 |
| K | SEER ≥17, HSPF ≥9.5 |
| L | SEER ≥18, HSPF ≥9.8 |
| M | SEER ≥19, HSPF ≥10.0 |
| N | SEER ≥20, HSPF ≥10.3 |
| O | SEER ≥21, HSPF ≥10.6 |
| P | SEER ≥22, HSPF ≥10.9 |
| Q | Ductless HP | SEER ≥15, HSPF ≥9.0 | New construction (NC) |
| R | SEER ≥16, HSPF ≥9.2 |
| S | SEER ≥17, HSPF ≥9.5 |
| T | SEER ≥18, HSPF ≥9.8 |
| U | SEER ≥19, HSPF ≥10.0 |
| V | SEER ≥20, HSPF ≥10.3 |
| W | SEER ≥21, HSPF ≥10.6 |
| X | SEER ≥22, HSPF ≥10.9 |
| Y | Room unit (HP or AC coupled with electric resistance space heater) a | SEER ≥15, HSPF ≥9.0 | Normal replacement (NR) |
| Z | SEER ≥16, HSPF ≥9.2 |
| AA | SEER ≥17, HSPF ≥9.5 |
| AB | SEER ≥18, HSPF ≥9.8 |
| AC | SEER ≥19, HSPF ≥10.0 |
| AD | SEER ≥20, HSPF ≥10.3 |
| AE | SEER ≥21, HSPF ≥10.6 |
| AF | SEER ≥22, HSPF ≥10.9 |
| AG | Ductless unit b | SEER ≥15, HSPF ≥9.0 |
| AH | SEER ≥16, HSPF ≥9.2 |
| AI | SEER ≥17, HSPF ≥9.5 |
| AJ | SEER ≥18, HSPF ≥9.8 |
| AK | SEER ≥19, HSPF ≥10.0 |
| AL | SEER ≥20, HSPF ≥10.3 |
| AM | SEER ≥21, HSPF ≥10.6 |
| AN | SEER ≥22, HSPF ≥10.9 |

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

b Replacement of Ductless AC unit as the existing equipment is not offered through NR application type because incremental measure cost is negative. For costing, the standard baseline includes installation of both Ductless AC coupled with electric resistance space heater, and this standard baseline costs more than installing one Ductless HP. Hence Ductless AC replacement is offered as AR only.

Measure Case Specification – Multi-split Ductless Heat Pumps

| **Statewide Offering ID** | **Existing equipment being replaced** | **Measure case equipment:**  Multi-split Ductless Heat Pumps | **Measure Application Type** |
| --- | --- | --- | --- |
| Not offered | Room unit (HP or AC coupled with electric resistance space heater) | SEER ≥15, HSPF ≥9.0 | Accelerated replacement (AR) |
| AO | SEER ≥16, HSPF ≥9.2 |
| AP | SEER ≥17, HSPF ≥9.5 |
| AQ | SEER ≥18, HSPF ≥9.8 |
| AR | SEER ≥19, HSPF ≥10.0 |
| AS | SEER ≥20, HSPF ≥10.3 |
| AT | SEER ≥21, HSPF ≥10.6 |
| AU | SEER ≥22, HSPF ≥10.9 |
| AV | Ductless unit (HP or AC coupled with electric resistance space heater) | SEER ≥15, HSPF ≥9.0 |
| AW | SEER ≥16, HSPF ≥9.2 |
| AX | SEER ≥17, HSPF ≥9.5 |
| AY | SEER ≥18, HSPF ≥9.8 |
| AZ | SEER ≥19, HSPF ≥10.0 |
| BA | SEER ≥20, HSPF ≥10.3 |
| BB | SEER ≥21, HSPF ≥10.6 |
| BC | SEER ≥22, HSPF ≥10.9 |
| BD | Ductless HP | SEER ≥15, HSPF ≥9.0 | New construction (NC) |
| BE | SEER ≥16, HSPF ≥9.2 |
| BF | SEER ≥17, HSPF ≥9.5 |
| BG | SEER ≥18, HSPF ≥9.8 |
| BH | SEER ≥19, HSPF ≥10.0 |
| BI | SEER ≥20, HSPF ≥10.3 |
| BJ | SEER ≥21, HSPF ≥10.6 |
| BK | SEER ≥22, HSPF ≥10.9 |
| Not offered | Room unit (HP or AC coupled with electric resistance space heater) a | SEER ≥15, HSPF ≥9.0 | Normal replacement (NR) |
| BL | SEER ≥16, HSPF ≥9.2 |
| BM | SEER ≥17, HSPF ≥9.5 |
| BN | SEER ≥18, HSPF ≥9.8 |
| BO | SEER ≥19, HSPF ≥10.0 |
| BP | SEER ≥20, HSPF ≥10.3 |
| BQ | SEER ≥21, HSPF ≥10.6 |
| BR | SEER ≥22, HSPF ≥10.9 |
| BS | Ductless unit b | SEER ≥15, HSPF ≥9.0 |
| BT | SEER ≥16, HSPF ≥9.2 |
| BU | SEER ≥17, HSPF ≥9.5 |
| BV | SEER ≥18, HSPF ≥9.8 |
| BW | SEER ≥19, HSPF ≥10.0 |
| BX | SEER ≥20, HSPF ≥10.3 |
| BY | SEER ≥21, HSPF ≥10.6 |
| BZ | SEER ≥22, HSPF ≥10.9 |

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

b Replacement of Ductless AC unit as the existing equipment is not offered through NR application type because incremental measure cost is negative. For costing, the standard baseline includes installation of both Ductless AC coupled with electric resistance space heater, and this standard baseline costs more than installing one Ductless HP. 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)** | |
| **Cooling efficiency** | **Heating efficiency** | **Cooling efficiency** | **Heating efficiency a** |
| Room AC coupled with electric resistance space heater | 9.8 EER | 100% | 9.8 EER | **<36 kBTU/h:** 8.63 HPSF  **≥36 kBTU/h:** 8.69 HSPFb |
| Room HP | 9.0 EER | **<36 kBTU/h:** 7.92 HPSF  **≥36 kBTU/h:** 7.98 HSPFb | 9.8 EER | **<36 kBTU/h:** 8.63 HPSF  **≥36 kBTU/h:** 8.69 HSPFb |
| Ductless AC coupled with 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 that would be installed to replace an existing room AC (or ductless AC coupled with electric resistance space heater) is deemed to be room HP (or Ductless HP, respectively), hence HSPF applies for heating mode efficiency to all standard base cases.

b For this equipment, code only specifies EER. Here, a standard practice HPSF was defined from typically seen HSPF-to-EER ratios corresponding to the capacity and EER range of SEER-rated ductless heat pumps per analysis in the section below, Electric Savings (kWh).

Due to code requirements (see below), certain types of eligible equipment to be replaced will be treated as if a different type of equipment, for purposes of cost and energy baselines. Hence some measure offerings show multiple types of equipment that can be replaced through the offering.

* Through the wall or window air-conditioner (Room AC) coupled with electric resistance space heater for heating: treated as if a room heat pump due to code requirements limiting the amount of space heating that can be served by electric resistance heating.
* Through the wall or window heat pump (Room HP): unchanged.
* Ductless air-conditioner providing cooling coupled with electric resistance space heater for heating (Ductless AC): treated as if a ductless heat pump due to code requirements limiting the amount of space heating that can be served by electric resistance heating.
* Less efficient (than minimum California Energy Standards) ductless heat pump (Ductless HP): unchanged.

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 HP  January 1, 2015 for central HP |

**California Appliance Efficiency Regulations (Title 20)**[[6]](#footnote-6) 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[[7]](#footnote-7)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***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[[8]](#footnote-8)

|  |  |  |  |
| --- | --- | --- | --- |
| ***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)[[9]](#footnote-9) 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)[[10]](#footnote-10) 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.[[11]](#footnote-11) 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[[12]](#footnote-12)

|  |  |  |
| --- | --- | --- |
| ***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[[13]](#footnote-13)

|  |  |  |  |
| --- | --- | --- | --- |
| ***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)[[14]](#footnote-14) 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/ upstream deliveries for normal replacement, the implementer shall provide the retailer or distribution location where the product was sold and the product type (mini-split/ multi-split), 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. **In cases where the existing HVAC type cannot not be collected, measure savings shall be defaulted to Normal Replacement measure replacing less efficient ductless heat pump.**

Right Sizing Scenarios:

If the installed unit’s 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.

Commissioning and Decommissioning Requirements:

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

Eligible Products

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

Only those ductless heat pump systems covered by AHRI 210/240, AHRI 1230, 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 (type, capacity, age, etc.)
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[[15]](#footnote-15), or similar, should be completed.

Program Exclusions

Fuel substitution measures are not eligible. Please refer to latest version of SWHC044 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. Hence, it is recommended that implementers and program administrators track measure costs, and make that data available for future workpaper updates. However, this recommendation is not a general requirement for programs or implementers following this workpaper.

Relating to harmonization across workpapers, this workpaper applies a data-driven approach for setting efficiency levels of measure tiers (for ductless heat pumps) which could be carried over to other workpapers with ductless heat pump measures.

Use Category

HVAC

Electric Savings (kWh)

The electric savings were calculated following these steps:

1. Gather the rated and off-rated performance data for ductless heat pumps from manufacturers’ survey.
2. Choose efficiency tiers for measure offerings.
3. Develop nominal efficiency levels (EER and COP) as BEM inputs.
4. Develop performance curves in the format required by DOE-2.3/ eQUEST 3.65 energy modeling software.
5. Adapt BEM setup to model variable speed residential systems.
6. Simulate BEMs to get the energy usage of the baseline and measure case equipment using MASControl3.

MASControl3 is the measure analysis software for DEER2020. MASControl3 is built to run DEER2020 building prototypes (building energy models) with the DOE-2.3 simulation engine (compatible with the eQUEST 3.65 user interface), then read out usage and calculate measure impacts. Note that Version 01 of this workpaper relied largely on DEER 2020 measures for residential HVAC systems in order to design efficiency tiers for measure offerings, as well as for a number of key modeling parameters such as nominal efficiency values (EER and COP corresponding to SEER and HSPF), typical number of stages and low stage/unloaded capacity as a function of SEER, and off-design performance curves. However, in developing version 02, it was recognized that the equipment that is subject of this measure (variable speed ductless mini-split and multi-split) is different than the equipment surveyed in DEER 2020 tech workbooks (central split and packaged systems), and hence these steps reflect an effort to update (and improve) the DEER 2020 modeling inputs wherever sufficient data were available specific to variable speed ductless equipment.

Gather performance data for ductless heat pumps

DEER2020 defines building models with performance characteristics for central heat pumps for efficiency up to SEER 18. These performance characteristics were adopted for ductless heat pumps with minor modifications to account for the ductless attributes. Note that measures up to SEER 18 were offered in previous version of this workpaper (SWHC050-01).

Ductless heat pumps with efficiency ratings SEER 19 and above were observed to be very common in the marketplace (per discussion with energy efficiency programs and per number of entries in AHRI product directory). To model energy impacts for specific efficiency tiers at SEER 19 and up, the performance characteristics of these heat pumps were required. Six (6) leading manufacturers of ductless heat pumps were contacted for the performance characteristics of their product offerings. Performance characteristics include performance at AHRI rated conditions and performance at off-rated conditions which is primarily categorized as capacity and power as function of temperatures (ambient and indoor temperature) and part load conditions. Most manufacturers could not provide the off-rated performance at part load conditions because the information is not typically required in the marketplace and by AHRI. One manufacturer representing about 35% of the ductless heat pump market share was able to provide complete information for 10 products covering a range of capacities and efficiency levels. This data was used to develop the performance curves and was deemed appropriate because from the data analysis stage it was observed that these curves behave within similar expected magnitude of existing curves in DEER database. Using partial data from other manufacturers was not deemed appropriate because the performance characteristics of a product work synchronously and cannot be mixed and matched with that of other products. Please refer to the supporting documents[[16]](#footnote-16)[[17]](#footnote-17) of data gathering phase for details.

Design efficiency tiers

Note that code requirements are defined in terms of constraints on both cooling and heating mode efficiency. For consistency with these code requirements and with prior energy efficiency program offerings for similar equipment, the measure offerings were constructed as tiered levels of efficiency. Successive tiers have higher minimum efficiency requirements for both cooling mode (SEER 15, 16, 17, etc.) and heating mode (HSPF 10.85, 10.58, etc.). **A heat pump product is categorized into the highest efficiency tier for which its ratings meet *both* requirements**. The figure below shows the choice for the minimum HSPF level corresponding to each SEER level, as informed by plotting trends in the AHRI/CEE product directory of residential, variable-speed mini-split and multi-split heat pumps. Each point in the background represents a product listing in the database. The highlighted efficiency regions include two regions for baseline levels (SEER 13 and 14) and eight regions for measure case equipment. Distinct tiers are offered up to SEER 22, which was found to represent about 75% of entries in the product directory.[[18]](#footnote-18) For modeling purposes, the bottom left corner in each efficiency region is used as a conservative design point for modeling the impacts of that set of products. For measure offerings, the minimum HSPF requirement is rounded to one decimal, although calculations of impacts preserved additional decimal places as may appear in the discussion below.



*Efficiency regions in terms of SEER and HSPF*

Develop EER and COP inputs to models

Note that the BEM tool (eQUEST/DOE2) does not accept SEER and HSPF as direct inputs. Rather, EER and COP are required inputs, and performance curves and weather will determine how the equipment’s seasonal performance relates to these nominal efficiencies. For baseline models with EER code requirement, the EER requirement can be input directly to the simulation (after converting efficiency to energy input ratio). On the other hand, in order to create building energy models for measure and baseline cases defined in terms of minimum SEER and HSPF constraints, it was necessary to develop a set of EER and COP inputs to the building energy model corresponding to each efficiency region.

To determine the cooling mode EER value to model for each efficiency region, the same AHRI dataset was used again, since each product entry contains a listing for SEER, HSPF, and EER. This dataset is relevant to both measure case and ductless base cases; note that the measure does not include replacement of central, ducted systems that may appear in other AHRI/CEE directory tables. The products were grouped by efficiency region, then aggregated to calculate average (mean) EER for each region. Next, a linear fit was calculated to filter out noise due to differing performance curves and SEER/EER ratios, in other words to coerce EER values to follow a linear trend as a function of minimum SEER for each efficiency region. The linear fit was applied only to measure cases; the AHRI average value was used directly for baseline equipment cases (SEER 13 and 14) in order to avoid skewing the baseline usage. Mini-split (<36 kBTU/h cooling) and multi-split (≥36 kBTU/h) products were treated distinctly for this analysis. For the mini-split SEER 13 category, there were no ductless products in the dataset, so the value was scaled from mini-split SEER 14. The figure and table below illustrate the aggregation and linearization process, and the EER values used for building energy models.[[19]](#footnote-19)

*Plot of mean EER trend across efficiency regions*

*Linearized EER trend across efficiency regions*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Efficiency region | Mean EER of products in AHRI data | | Linearized EER value for BEM input | |
| Mini-split | Multi-split | Mini-split | Multi-split |
| SEER ≥ 22 and HSPF ≥ 10.85 | 14.15 | 15.20 | 13.91 | 13.85 |
| SEER ≥ 21 and HSPF ≥ 10.58 | 12.87 | 13.23 | 13.36 | 13.22 |
| SEER ≥ 20 and HSPF ≥ 10.31 | 12.80 | 12.37 | 12.81 | 12.58 |
| SEER ≥ 19 and HSPF ≥ 10.04 | 12.35 | 11.38 | 12.26 | 11.95 |
| SEER ≥ 18 and HSPF ≥ 9.77 | 11.98 | 10.76 | 11.71 | 11.32 |
| SEER ≥ 17 and HSPF ≥ 9.51 | 11.10 | 9.73 | 11.16 | 10.68 |
| SEER ≥ 16 and HSPF ≥ 9.24 | 10.66 | 9.39 | 10.61 | 10.05 |
| SEER ≥ 15 and HSPF ≥ 8.97 | 10.16 | 9.78 | 10.06 | 9.41 |
| SEER ≥ 14 and HSPF ≥ 8.2 | 9.31 | 9.24 | Not linearized | |
| SEER ≥ 13 and HSPF ≥ 7.7 | 8.65 | 8.90 |

To determine the heating mode COP value to model each efficiency region, the AHRI/CEE directory product dataset could not be used, because although it contains HSPF, it does not contain COP. Rather, the manufacturer data collected for this workpaper effort were used to construct a linear relation[[20]](#footnote-20) between HSPF and heating mode energy input ratio (EIR), which is the value fed to the building energy models. To construct the relation, product ratings were aggregated by HSPF bins (i.e. ≥8 and <9; ≥9 and <10; etc.), and the mean values were fit by linear regression against the midpoint of the bin (8.5; 9.5; etc.). The resulting rule was:

Finally, note that energy codes do not specify HSPF for room type heat pumps (baseline cases). To model these equipment types, it was chosen to use an analogy to the code requirements for split systems, and scale the HSPF value in linear proportion to EER. All cooling mode and heating mode EIR values were entered in the modified tech workbook (refer to “hiseer8” block of TechIDs) for MASControl3,[[21]](#footnote-21) which in turn runs the building energy models.

Note that DEER2020 workbooks by default refer to a SEER to EER ratio and HSPF to COP ratio lookup table, which was based on older data for central heat pumps. This justifies the revisions made to eliminate reference to the lookup table.

Develop performance curves

The raw performance data from the one manufacturer was provided for (4) mini-split 9000 Btu/h models, (4) mini-split 18,000 Btu/h models and (2) multi-split 36,000 Btu/h models. The following steps were followed while developing the performance curves.

* The performance data from the manufacturer was provided for 100%, rated, 75%, 50%, 25% and minimum speed. Rated corresponds to the speed which results in maximum efficiency at rated conditions of 85 oF outdoor dry-bulb temperature and 67 oF indoor wetbulb temperature. The rated speed could be any speed between 100% and minimum. Typically, it was observed that data points corresponding to rated are outliers disturbing the fit of other datapoints. Given that rated is one operating point which is already captured by the performance characteristics of other speeds, a weight of 0.1 was used for this speed compared to a weight of 1.0 for all other speeds.
* For each model, the normalized cooling and heating mode performance curves were developed in the format required by DOE2. Each performance curve was designed to have the least square error in terms of an energy metric comparing raw data for energy usage and the usage that would be calculated using the performance curves, summed over the range of temperature and capacity conditions for which data were supplied.
* For capacity curves, the metric was capacity normalized by the nominal value. For energy input ratio curves, the energy metric was the input power relative to its nominal value at rated temperatures and 100% load. Following regression for the performance curve coefficients that minimize the error between raw data and curve fit, the raw data (x) and curve fit predictions (y) energy metrics were plotted in a scatter plot, typically showing good correlation (all points “close” to the line y=x).
* To quantitatively compare performance curve sets derived from two different models, raw data from one model were plotted against predictions per the second model’s curve fit. Based on correlation of the energy metric scatter plots, it was observed that performance characteristics of mini-split units in the sample set (9000 and 18000 Btu/h models) were highly correlated across SEER ratings and capacities. For example the 9000 Btu/h, SEER 30.5 model is highly correlated with all the models at 9000 Btu/h and 18,000 Btu/h capacity, and varying SEER. However, this model’s energy metric is poorly correlated with performance curves of multi-split units. Hence two distinct groups of performance curves were created, one for mini-split units and a second group for multi-split units.
* Since mini-split heat pumps performances curves were highly correlated across products, the performance curves from one arbitrarily selected product were applied to the building energy models for all the mini-split heat pumps, to eliminate variations across SEER due to performance curves alone.
* For multi-split heat pumps, performance data was available only up SEER 20, and only for two products. Although the hypothesis of strong correlation of performance characteristics across SEER ratings could not be observed multi-split heat pumps (as it was for mini-split systems), the normalized performance curves of the SEER 19.2 product were applied to building energy models across all efficiency tiers for multi-split systems.
* Efficiency and capacity at rated conditions were combined with the normalized performance data to calculate the power input at various operating conditions and are key inputs into the energy model.

For further details of developing the performance curves, please refer to the supporting documents folder. [[22]](#footnote-22)

Building energy models setup

1. Based on residential HVAC systems available in DOE-2.3, DEER 2020 residential prototypes were set up such that within each story of the dwelling unit, all spaces and zones are 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 indoor unit serves each conditioned space in the building and requiring multiple units to condition the entire home. Hence, the building energy model does not exactly replicate the typical as-built scenario. However, this model configuration is thought to closely approximate the energy usage of the as-built equipment for the following reason.

A single PVVT system (as modeled) typically operates at significant partial load hours since not all spaces will be occupied at the same time. This modeled configuration was assumed to be a close proxy to a multiple single zone system (as-built). This assumption was validated by comparing the annual space cooling energy consumption for PVVT as predicted by the model with the Residential Appliance Saturation Study (RASS)[[23]](#footnote-23) space cooling electric Unit Energy Consumption (UEC). Compared to 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[[24]](#footnote-24) and DOE CFR 429.16[[25]](#footnote-25)). 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 and Heating EIR are 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 cooling EIR = 3.413 / EER. A similar formula is used for heating mode. See previous section regarding EER inputs.
6. Variable speed control (entire system) is triggered by an appropriate combination of AIR/TEMP-CONTROL, MIN-FLOW-RATIO, MIN-UNLOAD-RATIO. Since fan energy is lumped in a single energy calculation using EIR and performance curves, models did not need to be adapted for variable speed fan control as a separate modification.

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 or HP – see above (13 SEER) | Room HP – 0.34829 (9.8 EER)  Ductless AC or HP – see above (14 SEER) | See previous section regarding EER & COP |
| 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 – See above  Ductless HP – 0.31341 EIR (7.7 HPSF) | Room HP – See above  Ductless HP – 0.29430 EIR (8.2 HPSF) | See previous section regarding EER & COP |
| AIR/TEMP-CONTROL | TWO-SPEED | VARIABLE-VOL/TEMP | VARIABLE-VOL/TEMP | VARIABLE-VOL/TEMP |
| SYSTEM: MIN-FLOW-RATIO | 1.0 (one-speed) or 0.739 (two-speed) | 0 | 0 | 0 |
| SYSTEM: MIN-UNLOAD-RATIO, MIN-HGB-RATIO, and HEAT-STAGES | 0.999 or 0.686 | 0.3 | 0.3 | 0.3 |
| SYSTEM: HEATING-CAPACITY | Lookup table HtgAreaPerKbtuh | Unused | Unused | Unused |
| SYSTEM: HEAT/COOL-CAP | No effect | 1.08 | 1.08 | 1.08 |

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). The models were run with the 2022 edition weather files (as announced on the DEER website).

MAScontrol3 generated the annual and hourly energy usage (electric) for each measure as an intermediate file[[26]](#footnote-26). 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[[27]](#footnote-27) 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[[28]](#footnote-28) and energy savings output file[[29]](#footnote-29) 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.

Calculate the energy savings using DEER2020 prototypes

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. A ratio of heating capacity to cooling capacity was used based on review of product data from AHRI directory, which was typically 1.08, although in practice, an implementer may choose different ratio based on climate and design considerations. This results in slightly greater heating capacity, compared to DEER2020 defaults using a lookup table for capacity per floor area.

Peak Electric Demand Reduction (kW)

Similar to the process for calculating electric savings (kWh), MASControl3 post-processing scripts were used to calculate the new DEER peak demand savings (kW) by averaging demand across peak hours from 4-9PM on the three-day peak period depending on weather file. Since the simulations used the 2022 edition weather files (as announced on the DEER website), the dates for the three-day peak period were updated based on these 2022 edition weather files. A modified copy of the peak days determination workbook provided with DEER 2020 was used to enter temperature records from the 2022 edition weather files (as announced on DEER website).[[30]](#footnote-30)

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 not the program intervention 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.”[[31]](#footnote-31) This approach provides an RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[[32]](#footnote-32)

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 | 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 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.

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 extrapolated using a linear regression model with R2 of 0.80 for cost and SEER rating for units with SEER rating 17 to 22.

The unit cost was normalized per rated cooling ton. See the cost calculation workbook for details.[[33]](#footnote-33)

Measure Case Material Cost ($/unit)

The measure case material cost was derived from 2020 program data provided by SCE for their mid-stream program of ductless heat pumps. The following data processing steps were performed to determine the material cost incurred by the end customer.

* SCE provided cost data from their 2020 mid-stream program of ductless heat pumps up until September. This data has distributor cost for 2,431 mini-splits units and 1 multi-split unit for about 24 manufacturers covering several models and efficiency ratings from SEER 15 to SEER 38.
* The data was organized into bins of one SEER increments from SEER 15 to SEER 22. The average distributor cost per ton for each SEER bin was calculated. When both SEER and HSPF requirements of each tier were applied, only a few products met the requirements. Because the costs would not be representative with fewer data points, HSPF criteria was not considered. It was verified that the average HSPF for each SEER bin from program data is within 10% of the minimum HSPF threshold for the corresponding efficiency tier.
* It was observed that there were data issues in the bins of SEER 15 and SEER 16: SEER 15 accounted for only 8 products (<1% of total). SEER 16 had data skewed towards more expensive products from a few manufacturers. Hence, for these SEERs, cost data from programs was not used, and the cost was estimated using the trend line discussed below.
* Typically, high SEER products have higher cost. However, per program averages, SEER 20 products have slightly higher cost than SEER 21. To force a strictly increasing trend, the program average cost of SEER 20 was replaced by the average of SEER 19 and SEER 21 equipment costs. A linear regression fit was developed for SEER 17 through SEER 22, which had R2 = 0.82, which seemed acceptable for this purpose given the quantity and range of program data. This linear regression model was used to determine the costs for all SEER ratings from SEER 14 to SEER 22.
* The residential HVAC value chain has contractor between the distributor and the end customer. Hence, contractor mark-up should be applied. From the program data shared by SCE, there are 12 datapoints which also had contractor invoices. Reviewing the contractor invoices, the contractor markups were highly variable ranging between 20% and 332% which an average of 141%. These markups are result of market demand for installations during summer and other factors such as value-added services by contractors. Because only the costs associated with energy efficiency part should be accounted for measure cost, contractor overhead was determined from overhead & profit (O&P) factors from RS Means online database (2019)[[34]](#footnote-34) as observed for wall mounted split ductless units for 1 ton and 1.5 ton capacities. The average O&P factor was applied as contractor mark-up.
* Since the mid-stream program data contained few entries with costs of multi-split systems, the material costs for multi-split heat pumps were determined using a cost multiplier relative to mini-split costs. To determine the multiplier, a comparative analysis of multi-zone and single-zone material costs was performed through sampling of online shopping prices for ductless mini/multi-split heat pumps. The comparison was made at each level of SEER. The variation between costs is typically less than 20%. In most cases, multi-zone systems are offered at higher prices per unit ton cooling (ratio >1), but in some cases at lower prices (ratio <1). Thus, the finding of the comparative analysis (refer to the cost analysis workbook) is that the cost multiplier for multi-zone heat pumps is 1.0. The complexity of multi-split unit design and its installation could balance the benefits from economies of scale of multiple indoor units sharing one outdoor unit and hence averaging to the cost of a mini-split heat pump.

See the cost calculation workbook for details.[[35]](#footnote-35)

Base Case Labor Cost ($/unit)

The base case labor cost was obtained from RS Means online database (2019)[[36]](#footnote-36). RSMeans hourly labor rates for a residential electrician was obtained from RS Means residential labor rates.[[37]](#footnote-37) Labor hours for installing various capacities of window/thru-the wall unit and ductless units for various capacities were 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 |
| 02 | 2021-02-19 | Nicholas Fette / Akhilesh Reddy Endurthy Solaris-Technical, LLC. | Added new measures SEER 19 to 22.  Updated savings for existing SEER15 to 22 measures.  Updated material costs using 2020 program data.  Update weather files and peak period determination. |

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. California Energy Commission (CEC). 2019. California Code of Regulations Title 20 Public Utilities and Energy. CEC-140-2019-002. January. [↑](#footnote-ref-6)
7. 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-7)
8. 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-8)
9. 10 C.F.R. section 430.32(b) and 430.32(c) [↑](#footnote-ref-9)
10. 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-10)
11. California Energy Commission (CEC). 2010. California Code of Regulations Title 20 Public Utilities and Energy. CEC-400-2010-012. December.  [↑](#footnote-ref-11)
12. 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-12)
13. 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-13)
14. 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-14)
15. SWHC050-02-Ductless Heat Pump, Residential - POE Survey.docx [↑](#footnote-ref-15)
16. “SWHC050-02 Performance curves methodology v2” [↑](#footnote-ref-16)
17. “SWHC050-02-Manufacturer survey package.zip” [↑](#footnote-ref-17)
18. “ahri data res minisplit HP 2020-12-01b.xlsx” [↑](#footnote-ref-18)
19. “ahri data res minisplit HP 2020-12-01b.xlsx” [↑](#footnote-ref-19)
20. “Models and HSPF vs Heating-EIR.xlsx” [↑](#footnote-ref-20)
21. “SWHC050-02 MASControl3 Files.zip” [↑](#footnote-ref-21)
22. “Res Ductless Heat Pump - Performance Curves Methods 2020-11-05.zip” [↑](#footnote-ref-22)
23. California Energy Commission. 2010. “2009 California Residential Appliance Saturation Study”. [↑](#footnote-ref-23)
24. Air-Conditioning, Heating, & Refrigeration Institute (AHRI). 2017. “2017 Standard for Performance Rating of Unitary Air-conditioning & Air-source Heat Pump Equipment” [↑](#footnote-ref-24)
25. US Department of Energy (DOE) 10 CFR § 429.16. [↑](#footnote-ref-25)
26. 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-26)
27. California Public Utilities Commission. 2019. MASControl3 “DEER\_Tools\_2019\_09\_30.zip”, SupportTables folder, “reststatwt.sql” file [↑](#footnote-ref-27)
28. Southern California Edison (SCE). 2020. “SWHC050-01 MASControl3 Files.zip” [↑](#footnote-ref-28)
29. Southern California Edison (SCE). 2020. “SWHC050-01 Energy Calculations.xlsx.” [↑](#footnote-ref-29)
30. “2022 Peak Determination - Solaris.xlsm” [↑](#footnote-ref-30)
31. California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32. [↑](#footnote-ref-31)
32. KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc. [↑](#footnote-ref-32)
33. "SWHC050-02 Cost analysis.xlsx." Southern California Edison, 2020. [↑](#footnote-ref-33)
34. 2019 RSMeans Electrical Cost Data [↑](#footnote-ref-34)
35. "SWHC050-02 Cost analysis.xlsx." Southern California Edison, 2020. [↑](#footnote-ref-35)
36. 2019 RSMeans Electrical Cost Data [↑](#footnote-ref-36)
37. 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-37)