Work Paper PGECOHVC172

**Revision #1**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Single Package Vertical Heat Pump**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | PG&E: HV371, HV372, HV373  SCE: AC-20015, AC-20016, AC-20017, AC-20018, AC-20019 |
| **Measure Description** | Replacement of a standard single package vertical air-cooled heat pump (SPVHP) with high efficiency (above code) single package vertical air-cooled heat pump with the option of included air-side economizer and demand control ventilation (DCV) controls. |
| **Base Case Description** | Existing standard efficiency SPVHP |
| **Units** | per ton of cooling capacity |
| **Energy Savings** | Refer to Excel Calculation Attachment 1 |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 1 |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 1 |
| **Effective Useful Life** | 15 years (DEER EUL ID: HVAC-airAC) |
| **Measure Installation Type** | Normal Replacement and Accelerated Replacement |
| **Net-to-Gross Ratio** | 0.85 (DEER NTGR ID: K-12School-ComCollege) |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 9/15/17 | Henry Liu (PG&E)  Andres Fergadiotti (SCE)  Phil Jordan (CLEAResult) | New work paper: PGECOHVC172 Single Package Vertical Heat Pump |
| 1 | 9/6/18 | Jia Huang (PG&E)  Phil Jordan (CLEAResult) | Measure costs updated to more accurately reflect costs associated with EE benefits. |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
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Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This Single Package Vertical Heat Pump workpaper contains five measures that reduce the energy associated with providing conditioned air to a building via single package vertical heat pumps (SPVHP). The Air-Conditioning, Heating, & Refrigeration Institute (AHRI) defines this equipment as a “type of air-cooled small or large package air conditioning and heating equipment; factory assembled as a single package having its major components arranged vertically.”[[1]](#endnote-1) The SPVHP uses reverse cycle refrigeration as the primary heat source, with electric resistance supplemental heating, and the system is intended for exterior mounting through an outside wall. This type of HVAC system is typically found serving portable school classrooms, offices, and/or administrative spaces, and the measures contained herein are tailored for the education sector. The measures constitute replacement of a standard SPVHP with a high efficiency SPVHP with the option of included air-side economizer and demand controlled ventilation (DCV) controls. The tables below list the measure names as described above and their respective solution codes.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | High efficiency SPVHP with or without economizer and DCV  (ex. 11.5 EER, 3.25 COP, economizer and DCV) |
| Existing Condition | Standard (below current code) efficiency SPVHP without economizer and DCV  (ex. 9.0 EER, 3.00 COP, no economizer or DCV) |
| Code/Standard | Minimally code compliant SPVHP without economizer and DCV  (10.0 EER, 3.00 COP, no economizer or DCV) |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | AC-20015 |  | Install 10.00 EER, 3.00 COP SPVHP without economizer or DCV |
|  |  | AC-20016 |  | Install 10.00 EER, 3.00 COP SPVHP (≤54,000 Btu/h) with economizer and DCV |
|  |  | AC-20017 | HV371 | Install 11.00 EER, 3.25 COP SPVHP without economizer or DCV |
|  |  | AC-20018 | HV372 | Install 11.00 EER, 3.25 COP SPVHP (≤54,00 Btu/h) with economizer and DCV |
|  |  | AC-20019 | HV373 | Install 11.50 EER, 3.25 COP SPVHP (≤54,000 Btu/h) with economizer and DCV |

**Eligibility Requirements**

* Existing system must be single package vertical heat pump (SPVHP)

# The measures described in this workpaper are only applicable for the building types shown in

Section 3. Load Shapes.

**Measure Requirements**

The system being installed must be of the type SPVHP and meet the efficiency requirements of the measure code. Equipment used for the measures with economizer must have an operable air-side economizer installed, and economizer high limit must be optimized for climate per Title 24 2016 Table 140.4-B[[2]](#endnote-2), adapted in the below table for reference.

|  |  |  |
| --- | --- | --- |
| **Device Type** | **Climate Zone** | **High Limit Equation**  **(Economizer Off When)** |
| Fixed Dry Bulb | 1, 3, 5, 11-16 | Toa>75°F |
| 2, 4, 10 | Toa>73°F |
| 6, 8, 9 | Toa>71°F |
| 7 | Toa>69°F |

Equipment used for the measures with DCV must meet the following qualifications for rebate eligibility. The requirements below draw on Title 24 2016 §120.1(c)4.

* For each system with demand control ventilation, CO2 sensors shall be installed in each room with no less than one sensor per 10,000 ft² of floor space. When a zone or a space is served by more than one sensor, signal from any sensor indicating that CO2 is near or at the set point within a space, shall trigger an increase in ventilation to the space.
* Upon detection of sensor failure, the system shall provide a signal which resets to supply the minimum quantity of outside air to the level required if DCV were not installed.
* CO2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 and 1000 ppm concentration when measured at sea level and 25°C, factory calibrated, and certified by the manufacturer to require calibration no more frequently than once every 5 years.

For SCE only, for the Accelerated Replacement installation type to be claimed the attached survey must be completed (*Worksheet in StatusOfSeekingClarityPoints22Aug2016-ER\_POE.XLSX*, Attachment 2).

## 1.2 Technical Description

The base case for this measure is a standard efficiency single package vertical heat pump without air-side economizer or DCV controls. Each measure case is a higher efficiency SPVHP; cooling energy savings result from an improved energy efficiency ratio (EER) and heating energy savings result from an improved coefficient of performance (COP) over the base case. For those measure cases having an economizer, energy savings are realized when ambient conditions are suitable for free or assisted cooling and ventilation, minimizing compressor operation. For those measure cases having DCV, energy savings are achieved by reducing the minimum amount of ventilation supplied to the space during periods below peak occupancy. This reduces the amount of outside air brought into the space that would otherwise have to be conditioned, minimizing compressor operation.

## 1.3 Installation Types and Delivery Mechanisms

An installation type describes the scenario in which the measure is applied, thus guiding energy savings and measure cost methodology. There are two installation types being made available for the measures in this workpaper: Normal Replacement (NR; previously known as ROB, as shown in the table below, but terminology updated per CPUC Resolution E-4818[[3]](#endnote-3)) and Accelerated Replacement (AR; previously known as RET/ER as shown in the table below, but terminology updated per CPUC Resolution E-4818).

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Replace on Burnout (ROB) | Above Code or Standard | N/A | EUL | N/A |
| New Construction (NEW/NC) | Above Code or Standard | N/A | EUL | N/A |
| Retrofit or Early Replacement (RET/ER) | Above Customer Existing | Above Code or Standard | RUL | EUL-RUL |
| Retrofit First Baseline Only (REF) | Above Customer Existing | N/A | EUL | N/A |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | EUL | N/A |

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings. See the tables below for descriptions of available delivery methods and incentive methods.

**SCE Delivery Mechanism:** Financial Supportpaired withDown-Stream Incentive – Deemed

**PG&E Delivery Mechanism:** Financial Support paired with Down-Stream Incentive – Deemed

**Delivery Method Descriptions**

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Appliance Turn-in and Recycling | The program motivates customers, through financial incentives, to recycle appliances that are functional but inefficient. This prevents the continued use of those appliances, by both the current owner and potential future owners. |
| Audit/Information/Testing Services | The program performs a free assessment of a customer’s facility and provides the customer with information and guidance on energy efficiency opportunities. |
| Commissioning and Retrocommissioning | The program modifies or repairs existing equipment to ensure that it works as intended. |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |
| Innovative Design | The program funds new ideas that meet reasonable scientific scrutiny for potential energy savings. These innovative measures typically have small market penetration (less than 5%) or are targeted toward relatively unreached market segments. |
| New Construction | The program offers financial incentives and/or design assistance to customers involved with new building construction. This is intended is to motivate customer to exceed Title 24 building energy efficiency requirements (residential or nonresidential). |
| Partnership | The program implements projects through a partnership between the utility and an institutional, government, or community-based organization. |
| Performance Based | The program offers financial incentives that vary based on the energy efficiency performance of specific projects. |
| Up-Stream Programs | See Up-Stream Incentive and Up-Stream Buy Down in the Incentive Method table. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |
| Mid-Stream Incentive | The program gives a financial incentive to a midstream market actor, such as a retailer or contractor, to encourage the promotion of efficient measures. The incentive may or may not be passed on to the end-use customer. |
| Up-Stream Incentive | The program gives a financial incentive to an upstream market actor, such as a manufacturer or distributor, to encourage the manufacture, provision, or distribution of an efficient measure. The incentive may or may not be passed on to the end-use customer. |
| Up-Stream Buy Down | The program gives a financial incentive to an upstream market actor, such as a manufacturer or distributor, with specific requirements to pass down the incentive to the end use customer. Such an incentive buys-down the cost of an efficient measure for the end-use customer by at least the amount of the financial incentive. |
| Giveaway | The program provides customers with energy efficiency equipment or services for free. |
| Exchange/Replacement | The utility program holds events where customers can trade functional equipment for similar but more energy efficient equipment, free of charge. |
| On-bill Finance/Loan | The program offers financing for the cost an efficient measure as part of the utility bill. This can be an add-on option to an existing program or can serve as an organizing principle for its own program. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

The measures contained in this workpaper are not included in the Database for Energy Efficient Resources (i.e., they are non-DEER measures).

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **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, with modifications; see Section 2. Calculation Methodology |
| DEER Version | DEER 2017, READI v2.4.7 |
| Reason for Deviation from DEER | DEER does not contain this type of measure |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| K-12School-ComCollege | All K-12 and community college projects | Com | ERC | All Delivery Strategies | 0.85 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HVAC-airAC | Air Conditioners (air-cooled, split and unitary) | Com | HVAC | 15 | 5 |

### 1.4.2 Codes and Standards Analysis

The code baseline of a SPVHP with 10.0-EER cooling mode efficiency, 3.0-COP heating mode efficiency, and no air-side economizer or DCV controls comes from the 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (aka, Title 24 2016). The minimum cooling and heating efficiencies are given in Table 110.2-E Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps – Minimum Efficiency Requirements. Per Section 140.4(e)1, air economizers are not required on a cooling air handler with a cooling capacity 54,000 Btu/hr or less. Per EXCEPTION 1 to Section 120.1(c)3, classrooms are not required to have demand control ventilation. These findings are summarized in the Code Summary table below.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | Table 110.2-E Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps – Minimum Efficiency Requirements | January 1, 2017 |
| Title 24 (2016) | Section 140.4(e)1 | January 1, 2017 |
| Title 24 (2016) | EXCEPTION 1 to Section 120.1(c)3 | January 1, 2017 |

## 1.5 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

There are no further data or calculations provided for the support of the measures in this workpaper.

## 1.6 Data Quality and Future Data Needs

Additional study of existing units through comprehensive IOU program data could provide an update on the existing conditions baseline assumption for the Accelerated Replacement installation type.

Any code changes for the next version of Title 24 (2019) are unknown at this time. The baseline assumptions for this workpaper should be reviewed against the next version of Title 24 once available.

# Section 2. Calculation Methodology

Energy savings and demand reduction for the measures contained in this workpaper were estimated using eQUEST version 3.64.7130 energy modeling software. DEER prototypes were generated using MASControl v3.00.28 for the 2008 Title-24 (C08) case of the Tech ID D08-NE-HVAC-airHP-Pkg-55to64kBtuh-15p0seer-8p2hspf with a 2007 vintage. These prototypes were used with some modification as shown in the Baseline Modifications to eQUEST Keywords table below.

**Baseline Modifications to eQUEST Keywords**

|  |  |  |
| --- | --- | --- |
| **eQUEST Keyword** | **DEER Value** | **Modified Baseline Value** |
| **Duct keywords** |  |  |
| SYSTEM:RETURN-AIR-PATH | Duct | Direct |
| SYSTEM:DUCT-ZONE | Varies | Null |
| SYSTEM:DUCT-AIR-LOSS-OA | 0 | Null |
| SYSTEM:DUCT-DT | 1 | Null |
| **Return fan keyword** |  |  |
| SYSTEM:RETURN-EFF | 0.53 | Null |
| **Performance curve keywords** |  |  |
| SYSTEM:COOL-CAP-FT | 1SpSPkHPS13 – Cool Cap f(T) | PTAC-Cool-Cap-fEWB&OAT |
| SYSTEM:COOL-EIR-FT | 1SpSPkHPS13 – EIR f(T) | PTAC-EIR-fEWB&OAT |
| SYSTEM:COOL-EIR-FPLR | 1SpSPkHPS13 – EIR f(PLR) | PTAC-EIR-fPLR |
| SYSTEM:COOL-SH-FT | 1SpSPkHPS13 – Sens Cap f(T | PTAC-Sens-Cap-fEWB&OAT |
| SYSTEM:COIL-BF-FFLOW | 1SpSPkHPS13 – BF f(Flow) | PTAC-Bypass-Factor-fAirFlow |
| SYSTEM:COIL-BF-FT | 1SpSPkHPS13 – Coil BF f(T) | PTAC-Bypass-Factor-fEWB&EDB |
| SYSTEM:COOL-CLOSS-FPLR | 1SpSPkHPS13 – C-Loss f(PLR) | DX-Cool-CycleLoss-fPLR |
| SYSTEM:HEAT-CAP-FT | 1SpSPkHPS13 – Heat Cap f(T) | DX-Heat-Cap-fEDB&OAT |
| SYSTEM:HEAT-EIR-FT | 1SpSPkHPS13 – Heat EIR f(T) | DX-Heat-EIR-fEDB&OAT |
| SYSTEM:HEAT-EIR-FPLR | 1SpSPkHPS13 – Heat EIR f(PLR) | DX-Heat-EIR-fPLR |
| **System efficiency keywords** |  |  |
| SYSTEM:COOLING-EIR | 0.287822 | Varies by Installation Type |
| SYSTEM:HEATING-EIR | 0.30445 | Varies by Installation Type |
| **Economizer limit keywords** |  |  |
| SYSTEM:ECONO-LIMIT-T | Varies | Varies by climate zone from 69°F to 75°F depending on Title 24 2016 Table 140.4-B requirement |
| **Occupancy keywords** |  |  |
| For Occ schedules DAY-SCHEDULE:VALUES[X] | If >0.9 | 0.9 |

Duct keywords were modified to simulate the absence of ductwork, which is common for the SPVHP system type. Return fan keywords were modified to simulate the absence of return fans, consistent with the SPVHP system type. Package terminal heat pump (PTHP) performance curves were chosen over the DEER default performance curves, as the SPVHP system type is closer in operation to a package terminal unit than a single package unit. The system efficiencies were modified to match the baseline values appropriate for the Installation Type, per the Measure Base Case tables that follow. Economizer dry-bulb changeover temperatures were set in accordance with Title 24 2016 Table 140.4-B. Hourly occupancy as a percentage of peak design occupancy was reduced to 90% in cases where the DEER occupancy schedule exceeded 90%. This change is consistent with workpaper SCE13HC061[[4]](#endnote-4), which reasons that most buildings do not reach 100% occupancy on a typical day. With these prototype modifications in place, measure options were simulated per the following Measure Base Case tables.

**Measure Base Case and Proposed Tier Levels for Normal Replacement Installation Type**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Option** | **Base Case**  **(Title 24 2016)** | **Tier 0** | **Tier 1** | **Tier 2** |
| Cooling mode efficiency | 10.00 EER  (0.288 EIR) | 11.00 EER  (0.258 EIR) | 11.00 EER  (0.258 EIR) | 11.50 EER  (0.245) |
| Heating mode efficiency | 3.00 COP  (0.304 EIR) | 3.25 COP  (0.278 EIR) | 3.25 COP  (0.278 EIR) | 3.25 COP  (0.278 EIR) |
| Economizer | No | No | Yes | Yes |
| DCV | No | No | Yes | Yes |

**Measure Base Case and Proposed Tier Levels for Accelerated Replacement Installation Type**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Option** | **Base Case** | **Tier 0**  **(Title 24 2016)** | **Tier 1** | **Tier 2** | **Tier 3** |
| Cooling mode efficiency | 9.00 EER  (0.324 EIR) | 10.00 EER  (0.288 EIR) | 10.00 EER  (0.288 EIR) | 11.0 EER  (0.258 EIR) | 11.5 EER  (0.245 EIR) |
| Heating mode efficiency | 3.00 COP  (0.304 EIR) | 3.00 COP  (0.304 EIR) | 3.00 COP  (0.304 EIR) | 3.25 COP  (0.278 EIR) | 3.25 COP  (0.278 EIR) |
| Economizer | No | No | Yes | Yes | Yes |
| DCV | No | No | Yes | Yes | Yes |

The cooling mode efficiency is modeled via the COOLING-EIR keyword and the heating mode efficiency is modeled via the HEATING-EIR keyword. The modeled system efficiencies include corrections to account for removal of fan energy from these electric input ratio (EIR) keyword values, so that supply fan electrical energy is not double counted. Absence of air-side economizer is modeled by setting the OA-CONTROL keyword to “Fixed Fraction”, and the presence of a functioning air-side economizer is modeled by setting the OA-CONTROL keyword to “OA Temperature” with the appropriate economizer high limit set to the DRYBULB-LIMIT keyword per Title 24 2016 Table 140.4-B. Absence of DCV controls is modeled by setting the MIN-OA-METHOD keyword to “Fraction of Design Flow”, and the presence of functioning DCV controls is modeled by setting the MIN-OA-METHOD keyword to “DCV Return Sensor”. These measure-case eQUEST keyword modifications are summarized in the following table.

**Measure Modifications to eQUEST Keywords**

| **eQUEST Keyword** | **Baseline Value** | **Measure Value** |
| --- | --- | --- |
| **System efficiency keywords** |  |  |
| SYSTEM:COOLING-EIR | Varies by Installation Type per above tables | Varies by measure tier per above tables |
| SYSTEM:HEATING-EIR | Varies by Installation Type per above tables | Varies by measure tier per above tables |
| **Economizer limit keywords** |  |  |
| SYSTEM:OA-CONTROL | Fixed Fraction | OA Temperature |
| SYSTEM:DRYBULB-LIMIT | N/A | Varies by climate zone from 69°F to 75°F depending on Title 24 2016 Table 140.4-B requirement |
| **DCV keywords** |  |  |
| SYSTEM:MIN-OA-METHOD | Fraction of Design Flow | DCV Return Sensor |

The electric energy savings are represented in the calculations below.

*Where:*

*kWh per ton savings = annual unit energy savings*

*baseline kWh = annual building energy consumption of customer average baseline*

*measure kWh = annual building energy consumption of measure*

*cooling tons = cooling capacity of units measure was applied to (Btu/h) divided by 12,000 (Btu/h per ton)*

Demand reduction is calculated similarly to electric energy savings, however there is an additional calculation step required to estimate peak demand reduction in accordance with DEER peak period definitions. The DEER demand reduction estimation protocol requires average hourly peak demand from a defined time period that varies by climate zone to be determined for the baseline and measure. The time period defined by climate zone is shown in the following table:

|  |  |
| --- | --- |
| **Climate Zone** | **3-Weekday Period** |
| 1 | Sep 16 – Sep 18 |
| 2 | July 8 – July 10 |
| 3 | July 8 – July 10 |
| 4 | Sep 1 – Sep 3 |
| 5 | Sep 8 – Sep 10 |
| 6 | Sep 1 – Sep 3 |
| 7 | Sep 1 – Sep 3 |
| 8 | Sep 1 – Sep 3 |
| 9 | Sep 1 – Sep 3 |
| 10 | Sep 1 – Sep 3 |
| 11 | July 8 – July 10 |
| 12 | July 8 – July 10 |
| 13 | July 8 – July 10 |
| 14 | Aug 26 – Aug 28 |
| 15 | Aug 25 – Aug 27 |
| 16 | July 8 – July 10 |

Hourly peak demand from the nine hours defined for each climate zone is averaged for each climate zone. The following equation is then used to determine demand reduction per ton of cooling capacity.

*Where:*

*kW per ton savings = annual unit demand reduction*

*baseline kW = average demand for DEER peak period of customer average baseline*

*measure kW = average demand for DEER peak period of measure*

*cooling tons = cooling capacity of units measure was applied to (Btu/h) divided by 12,000 (Btu/h per ton)*

# 

# Section 3. Load Shapes

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Education – Relocatable Classroom | DEER:HVAC\_Eff\_AC | NON\_RES |

# Section 4. Costs

To develop cost estimates, distributor costs were gathered for SPVHP units of various system capacities (3, 3.5 and 4 tons) and system efficiencies (10.0 EER, 11.0 EER and 11.5 EER), as well as economizer add-ons and CO2 sensors for DCV, made by multiple manufacturers. Estimates of installation time were also provided, and a base labor rate was developed from RSMeans Online[[5]](#endnote-5), assuming standard union labor type; the average labor rate with overhead and profit (O&P) for various installation scenarios is $109.39/hr. To reference cost with the same base unit as UES values (per ton) an average capacity of 3.5 tons was assumed to be the average capacity to which the measures would be applied. Detailed cost calculations are documented in *SPVHP\_Cost Estimate Summary.xlsx* (Attachment 3).

## 4.1 Base Case Cost

The baseline cost is based on pricing obtained for a 10.00 EER, 3.00 COP SPVHP. The equipment cost is $5,582.33 and the labor cost is $875.15.

## 4.2 Measure Case Cost

Measure costs were determined for each measure option separately and are summarized in the Full and Incremental Costs table in the following subsection. HVAC contactors updated quotes of the baseline and proposed equipment with and without economizers. The originally quoted economizer adder costs were high due to the curb. The curb function reduces noise, but it does not increase efficiency of the system. The updated quotes for the high efficiency units were without a curb - a non-low noise option that does not require a curb.

## 4.3 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |
| RET/ER | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| REF | (MEC + MLC) – (BEC + BLC) | MEC + MLC | N/A |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Measure Option** | **Incremental Measure Cost ($/ton)** | **Full Measure Cost ($/ton)** | |
| **1st Baseline** | **2nd Baseline** |
| ROB\* | 11.00 EER, 3.25 COP | $150.86 | $150.86 | N/A |
| ROB\* | 11.00 EER, 3.25 COP, econ & DCV | $583.80 | $583.80 | N/A |
| ROB\* | 11.50 EER, 3.25 COP, econ & DCV | $704 | $704 | N/A |
| RET/ER\*\* | 10.00 EER, 3.00 COP | $0.00 | $1,844.99 | $0.00 |
| RET/ER\*\* | 10.00 EER, 3.00 COP, econ & DCV | $432.94 | $2,277.93 | $432.94 |
| RET/ER\*\* | 11.00 EER, 3.25 COP, econ & DCV | $583.80 | $2,428.79 | $583.80 |
| RET/ER\*\* | 11.50 EER, 3.25 COP, econ & DCV | $704 | $2,548.99 | $704 |

\* *Terminology updated to Normal Replacement (NR) per CPUC Resolution E-4818*

*\*\* Terminology updated to Accelerated Replacement (AR) per CPUC Resolution E-4818*

# References

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