**Work Paper PGECOHVC168**

**Demand Controlled Ventilation**

**Revision # 0**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Demand Controlled Ventilation for Single Zone Packaged HVAC**

**Measure Codes HV026, HV027, HV028, HV029, HV030, HV031**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | **HV026, HV027, HV028, HV029, HV030, HV031** |
| **Measure Description:** | Add Demand Controlled Ventilation (DCV) to an existing packaged single zone direct expansion (DX) HVAC unit with an economizer. |
| **Energy Impact Common Units:** | State work paper units: per ton cooling capacity |
| **Base Case Description:** | Fixed position ventilation corresponding to Title 24 2013 requirement or 20% of supply air, whichever is greater |
| **Base Case Energy Consumption:** | Source: DEER 2014 Prototype energy use with modifications described in §1.4.1. Varies by building type, climate zone, system type |
| **Measure Energy Consumption:** | Source: DEER 2014 Prototype energy use with modifications described in §1.4.1 Varies by building type, climate zone, system type |
| **Energy Savings**  **(Base Case – Measure):** | Source: Base Case – Measure (see above)Varies by building type, climate zone, system type. Averages: 82.119 kWh/ton, 5.848 therms/ton, |
| **Costs Common Units:** | per ton cooling capacity |
| **Base Case Equipment Cost ($/unit):** | $0 |
| **Measure Equipment Cost ($/unit):** | Source: Estimate, see §4.2 for estimate detail. Add ADEC and CO2 sensor to existing system: $97.62/ton  Add CO2 sensor to existing system with ADEC: $32.48/ton |
| **Gross Measure Cost ($/unit)** | Add ADEC and CO2 sensor to existing system: $162.05/ton  Add CO2 sensor to existing system with ADEC: $64.69/ton |
| **Measure Incremental Cost ($/unit):** | Source: Estimate, see §4.2 for estimate detail.  Add ADEC and CO2 sensor to existing system: $162.05/ton  Add CO2 sensor to existing system with ADEC: $64.69/ton |
| **Effective Useful Life (years):** | Source: DEER 5 Years |
| **Measure Application Type:** | Retrofit Add-On (REA) |
| **Net-to-Gross Ratios:** | Source: DEER |
| **Important Comments:** |  |

# Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # 2014-38006

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| **Grant Brohard**  Manager, Technical Product Support |
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| **Carolyn Weiner**  Manager, Products and Programs |
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# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Revision Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| **Revision 0** | **04/09/2014** | **Demand Controlled Ventilation** | **Sherry Hu (PG&E); Benjamin Lipscomb (PECI)** |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description –***

Add Demand Controlled Ventilation (DCV) to an existing packaged single zone direct expansion (DX) HVAC unit with an economizer. The specific DCV application uses a carbon dioxide (CO2) sensor to inform economizer outside air damper position. HV026, HV028, and HV030 are for adding an Advanced Digital Economizer Controller (ADEC) with DCV capability as well as a CO2 sensor. HV027, HV029, and HV031 are for adding a CO2 sensor only assuming a DCV-enabling digital controller is already installed. The three measure codes for each case distinguish between cooling units with gas heat, cooling only units, and heat pumps, respectively. The ADEC must have the capability to control the damper in response to a CO2 sensor signal.

The rebate is downstream provided to the contractor at the time of installation upon receipt of application and invoice. This is a Direct Install program.

***Program Restrictions and Guidelines***

The target market for DCV is spaces in commercial buildings served by packaged single zone DX HVAC units, sometimes referred to as rooftop units (RTU) and split systems.

This control upgrade for existing units is an Retrofit Add-on (REA) application, meaning Unit Energy Savings (UES) values provided are for an existing system without DCV as the baseline. There are no above-code savings reported as Title 24 2013 §120.11 requires DCV in most of the building types and activity area types considered. The UES values are not appropriate for Replace on Burnout (ROB) or New Construction (NC) applications.

The DVC measures described in this workpaper are available only for below 12 DEER building types: Asm (Assembly), EPr (Education – Primary School), ERC(Education - Relocatable Classroom), ESe(Education – Secondary School), EUn (Education – University), MBT (Manufacturing Biotech), OfS (Office - Small), RFF (Restaurant – Fast Food), RSD (Restaurant – Sit-Down), Rt3 (Retail – Multistory Large ), RtL(Retail – Single-Story Large), RtS (Retail – Small).

***Terms and Conditions:***

The following eligibility requirements must be satisfied prior to application of the measure:

* Existing system must be packaged single zone DX cooling unit with gas heat [HV026, HV027], cooling only unit [HV028, HV029], or heat pump [HV030, HV031]
* Existing system must have an operable airside economizer installed, and economizer high limit must be optimized for the climate per Title 24 2013 Table 140.4-B1, adapted below in Table 1 for reference.
* Existing system must ventilate continuously during occupied hours, and may not have any other device previously installed that is intended to perform DCV such as an occupancy sensor that controls ventilation rate.
* The measure shall only be applied where it will result in a reduction to the overall ventilation that is supplied for the space.

Table 1 Economizer High Limit Shut Off Control Requirements\*

|  |  |  |
| --- | --- | --- |
| Device Type | Climate Zones | Economizer 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 |
| Differential Dry Bulb | 1, 3, 5, 11-16 | Toa>Tra°F |
| 2, 4, 10 | Toa>Tra-2°F |
| 6, 8, 9 | Toa>Tra-4°F |
| 7 | Toa>Tra-6°F |
| Fixed Enthalpy + Fixed Dry Bulb | All | Hoa>28Btu/lb or Toa>75°F |

\*Adapted from Title 24 2013 Table 140.4-B1. Refer to source for additional detail.

Table 2 provides data required for calculation of energy savings estimates and incentives, and verification of installation and setup requirements.

Table 2 Required Data

|  |  |
| --- | --- |
| Required Data | Eligible Values |
| Actual or proxy building type | See Table 3 building type codes |
| Unit type | Packaged single zone DX - cooling unit with gas heat, cooling only unit, or heat pump |
| Nominal cooling capacity | Any |
| As-found minimum ventilation position | >0% open |
| As-found occupied fan operation | Continuous/On |
| As-left minimum ventilation position | Less than as-found position |
| Sensor location | Wall in zone or return duct |
| CO2 concentration high limit | 1000 ppm without direct measurement of outdoor air concentration or dynamically adjusted to 600 ppm above measured outdoor air concentration |

Equipment used for the measure must meet the following qualifications for rebate eligibility. The requirements below draw on Title 24 2013 §120.1(a)41 requirements for DCV, although they deviate slightly in some respects since the application of retrofit controls on a packaged unit is not considered a code-triggering event. One primary deviation from Title 24 20131 requirements is that a return air duct-mounted CO2 sensor is allowed whereas Title 24 20131 specifies that the sensor must be mounted in the zone and include a display. This allows for the measure to be installed more easily when site conditions or operational constraints are physically or cost-prohibitive to installation of a sensor in the zone.

* To be eligible for CO2 sensor-only rebate existing economizer control must be a digital type control and must have the capability to control the damper in response to a CO2 sensor signal.
* To be eligible for ADEC with CO2 sensor rebate a program-qualifying ADEC or Enhanced Ventilation controller must be installed in addition to the CO2 sensor. See bullet above for qualifying ADEC specification.
* 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 setpoint 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.

***Market Applicability:***

This upgrade measure for existing equipment provides a direct install rebate to contractors participating in a utility rebate program. Commercial utility customers are the ultimate consumers of the measure. Contractors may use the rebate in any way they would like, including but not limited to passing through to customer, discounting cost to customer, increasing sales and marketing efforts related to the measure, et cetera.

UES values are applicable to any existing commercial utility customer building in any California climate zone and of any vintage. All California utilities may not provide a rebate for the measure, and rebate offerings may vary between those that do. Although some areas or specific customers for which the measure is available could be designated as hard-to-reach, this measure is not assigned a hard-to-reach designation.

Savings estimation includes simulation of the measure in the specific building type and activity area combinations shown in Table 3, however the measure is applicable in any commercial building or activity area within where it reduces the overall amount of outside ventilation air that is supplied to the space. The UES estimates are provided by building type, and include savings for a mix of the activity area types for which the measure results in a reduction in the allowable minimum outside air ventilation required per Title 24 2013 §120.1[[1]](#endnote-1),[[2]](#endnote-2). The building type that contains activity areas that are closest to the actual application in terms of weekly occupied hours and peak occupant density shown in Table 3 shall be selected as a proxy for UES estimation. Values in Table 3 were extracted from default DEER prototype data[[3]](#footnote-1). It is expected that some contractor discretion will be required when selecting proxy building types for building types that are not explicitly included, and the UES values shall not be considered in the decision. Rebates are not dependent on UES values, so there is not a monetary motivation for the contractor to select one building type proxy over another due to it having a higher UES value.

Table 3 - Building Types and Activity Area Types Simulated

|  |  |  |  |
| --- | --- | --- | --- |
| Building Type Code | Activity Area Type | Weekly Occupied Hours | Peak Occupant Density (people per kSF) |
| Asm | Auditorium | 98 | 95.2 |
| EPr | Classroom / Lecture | 69 | 33.4 |
| EPr | Dining Area | 15 | 44.5 |
| EPr | Exercising Center / Gym | 55 | 13.3 |
| ERC | Classroom / Lecture | 69 | 33.3 |
| ESe | Classroom / Lecture | 69 | 33.3 |
| ESe | Dining Area | 59 | 44.5 |
| ESe | Exercising Center / Gym | 74 | 13.3 |
| ESe | Classroom / Lecture (93%) | 69 | 31.5 |
| ESe | Computer (Instruc/PC Lab) | 69 | 13.0 |
| EUn | Classroom / Lecture | 99 | 33.3 |
| EUn | Dining Area | 40 | 44.5 |
| EUn | Computer (Instruc/PC Lab) | 55 | 13.3 |
| GRo | Retail Sales, Grocery | 112 | 22.2 |
| Hsp | Dining Area | 168 | 44.3 |
| Hsp | Laboratory, Medical | 168 | 13.6 |
| MBT | Conference Room | 35 | 44.5 |
| MBT | Dining | 75 | 44.5 |
| Nrs | Dining Area | 77 | 44.5 |
| OfS | Corridor | 65 | 10.8 |
| RFF | Dining Area | 133 | 43.8 |
| RFF | Lobby (Main Entry/Assem) | 133 | 96.7 |
| RFF | Restrooms | 133 | 20.0 |
| RSD | Dining Area | 112 | 44.3 |
| RSD | Lobby (Main Entry / Assem) | 112 | 94.9 |
| RSD | Restrooms | 112 | 20.0 |
| Rt3 | Retail / Wholesale Showrm | 94 | 19.4 |
| RtL | Retail / Wholesale Showrm | 98 | 22.2 |
| RtS | Retail / Wholesale Showrm | 88 | 22.2 |

## 1.2 Product Technical Description

Constant volume single zone packaged HVAC systems provide a fixed amount of outside air ventilation to a space, with the exception of systems with airside economizers which are intended to provide up to 100% outside air for cooling when outside air conditions permit. When not economizing, most systems that do have economizers provide a fixed minimum amount of outside air. For systems that do not have the ability to adjust ventilation in response to occupancy, Title 24 20131 requires the minimum outside air to be determined based on the greater of:

1. The floor area-dependent ventilation rate required by Title 24 Table 120.1-A1 (CFM/sq. ft.)
2. 15 CFM per person using peak design occupancy for the space per Title 24 §120.1(b)21

This requirement results in a safe and healthy level of ventilation being supplied to the space during times of peak occupancy, but may result in over-ventilation during times when the space has fewer occupants. When the occupant-dependent rate is greater than the floor-area dependent rate, DCV may be used to reduce the minimum amount of ventilation that must be supplied to the space. DCV allows the system to provide additional ventilation up to the occupant-dependent rate only when necessary for periods of high occupancy.

The particular application of DCV covered by this work paper operates an existing economizer outside air damper based on measured CO2 concentration in the space or return duct, which serves as a proxy for the occupant density in the space. Other applications may use occupancy sensors, other types of gas concentration sensors, or other means to vary outside air damper position and/or total supply air and outside air flow rates. These other applications are outside the scope of this work paper.

Implementation of DCV in this application requires installation of a CO2 sensor in the zone or return duct at a minimum. If an economizer controller with the ability to control damper position based on a CO2 sensor signal is already installed there are no additional hardware requirements beyond field wiring. HV029, HV030, and HV031 provide rebates for this situation. For units that do not have a suitable economizer controller with DCV capability, an ADEC with DCV capability may be retrofit to the existing economizer. HV026, HV027, and HV028 provide rebates for the installation of ADEC with a CO2 sensor.

## 1.3 Measure Application Type

The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under DEER2011 Database Format hyperlink, DEER2011 for 13-14, spreadsheet SPTdata\_format-V0.97.xls, defines the measure application type terms as follows:

Table 4 Measure Application Type[[4]](#endnote-3)

*Identifies the measure application type in the Measure Implementation table in DEER2011.*

|  |  |  |
| --- | --- | --- |
| Code | Description | Comment |
| REA | Retrofit Add-on | *Measure did not exist and was not requested by codes* |

Because this measure is a control upgrade for existing units it is a Retrofit Add-on (REA) application, meaning UES values provided are for an existing system without DCV as the baseline. There are no above-code savings reported as Title 24 2013 §120.11 requires DCV in most of the building type and activity area types where DCV is beneficial. The UES values are not appropriate for ROB or NC applications.

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

### Base Case Simulations

The DEER data do not contain the appropriate information for this measure. Energy savings and demand reduction were estimated using eQUEST version 3.64[[5]](#endnote-4) energy modeling software. The DEER 2014[[6]](#endnote-5) prototypes for the customer average case of the Tech IDs shown in Table 5 were used with some modification to develop baseline energy use and demand estimates. All DEER prototypes were generated using MASControl v3.00.19[[7]](#endnote-6), and used the CZ2010 weather files[[8]](#endnote-7).

Table 5 DEER Prototype Tech ID by Measure

|  |  |  |
| --- | --- | --- |
| Measure Code | Measure | DEER Prototype Tech ID |
| HV026 | Add ADEC and CO2 Sensor to AC unit with Gas Heat | D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p5eer |
| HV027 | Add CO2 Sensor to AC unit with Gas Heat with ADEC | D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p5eer |
| HV028 | Add ADEC and CO2 Sensor to AC only unit | \*D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p5eer |
| HV029 | Add CO2 Sensor to AC only unit with ADEC | \*D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p5eer |
| HV030 | Add ADEC and CO2 Sensor to HP | D08-NE-HVAC-airHP-SpltPkg-110to134kBtuh-11p5eer-3p4cop |
| HV031 | Add CO2 Sensor to HP with ADEC | D08-NE-HVAC-airHP-SpltPkg-110to134kBtuh-11p5eer-3p4cop |

\* for AC only units, the electric energy savings and demand reduction were assumed to be the same as values for AC units with Gas Heat. Gas energy savings for AC only units were set to zero.

The DEER prototypes for the “110to134kBtuh” cooling capacity range were chosen as the representative prototypes for systems to which the measure would apply. Initially simulations included DEER prototypes for smaller and larger cooling capacities, but DCV savings were not sensitive to small differences in performance for different capacity ranges. Savings variation between the size ranges simulated was minimal, and results from a single size range were determined to be an adequate representation for all applicable system size ranges.

Upon examination of the DEER prototypes it was found that several modifications were necessary to estimate baseline energy use for the DCV measure. Work paper authors met with a consultant (Kevin Madison) from the Energy Division Ex-Ante Review Team to develop appropriate baseline assumptions and resulting modifications to the DEER prototypes. The following modifications were agreed upon.

1. A minimum outside air fraction of 20% was used instead of 0% due to emerging research (not yet published) that indicates closed damper leakage for packaged HVAC systems are higher than previously thought.
2. A maximum outside air fraction of 70% was used instead of 100% due to emerging research (not yet published) that indicates return air damper leakage and exhaust air re-entrainment for packaged HVAC systems are higher than previously thought, leading to inability of most systems to provide 100% outside air.
3. Hourly occupancy as a percentage of peak design occupancy was reduced to 90% in cases where the DEER occupancy schedule exceeded 90%. DCV savings are sensitive to occupancy, and work paper authors and other collaborators recognized that most buildings do not reach 100% occupancy on a typical day. Parties involved came to the consensus that an average daily maximum occupancy percentage of 90% would be appropriate in these cases. The existing default DEER peak occupant densities were retained.
4. Economizer dry-bulb changeover temperatures were set in accordance with Title 24 2013 Table 140.4B1

To implement these modifications to the DEER prototypes the specific modifications to eQUEST keywords shown in Table 6 were performed for the baseline.

Table 6 Baseline modifications to eQuest keywords

|  |  |  |
| --- | --- | --- |
| eQuest Keyword | DEER Value | Modified Baseline Value |
| SYSTEM:MIN-OUTSIDE-AIR | Varies | 0.2 |
| ZONE:OA-FLOW/AREA | Keyword not used | Set such that ZONE:OA-FLOW/AREA x Zone Area = Maximum of:   1. 0.2 x Supply Air Flow Rate 2. Title 24 Table 120.1-A1 Minimum Ventilation Rate 3. 15 CFM/person\* x Peak Occupancy # of People |
| SYSTEM:MAX-OA-FRACTION | 1.0 | 0.7 |
| *For Occ schedules* DAY-SCHEDULE:VALUES[X] | If >0.9 | 0.9 |
| SYSTEM:ECONO-LIMIT-T | Varies | Varies by climate zone from 69°F to 75°F depending on Title 24 2013 Table 140.4B1 requirement |

\*Outside air ventilation rate per person required by Title 24 2013 §120.1(b)2B1

### Measure Simulations

To develop measure-case energy use and demand estimates the modified baseline files were further modified to simulate application of DCV to each system for which DCV would result in the benefit of reduced ventilation supplied to the space. To determine the specific systems and zones for which DCV would provide a benefit it was necessary to determine the minimum ventilation rate that could be supplied for each zone based on the maximum of:

1. 20% of the supply airflow (assumed physical limitation of dampers)
2. Title 24 Table 120.1-A1 Minimum Ventilation Rate (code-required minimum)

Wherever this value resulted in a lower value than the minimum outdoor air flow rate for the baseline the DCV measure was simulated. Table 3 lists the building types and activity area types within each building where this condition was met. For these areas the zone minimum outside airflow was adjusted to the minimum rate that could be supplied. eQUEST includes built-in functionality to simulate DCV by varying outside air flow rate based on the maximum of the rate required for the area and the rate required for the number of occupants in a given hour as described in the DOE-2.2 dictionary pp. 362-363[[9]](#endnote-8). Specific keywords modified to represent the measure are shown in Table 7. All other keywords remained consistent from the baseline to the measure.

Table 7 Measure-case eQUEST keyword modifications

|  |  |  |
| --- | --- | --- |
| eQuest Keyword | Baseline Value | Measure Value |
| ZONE:OA-FLOW/AREA | Set such that ZONE:OA-FLOW/AREA x Zone Area = Maximum of:   1. 0.2 x Supply Air Flow Rate 2. Title 24 Table 120.1-A1 Minimum Ventilation Rate 3. 15 CFM/person\* x Peak Occupancy # of People | Set such that ZONE:OA-FLOW/AREA x Zone Area = Maximum of:   1. 0.2 x Supply Air Flow Rate 2. Title 24 Table 120.1-A1 Minimum Ventilation Rate |
| SYSTEM:MIN-OA-METHOD | FRACTION-OF-DESIGN | DCV-ZONE-SENSORS |

\*Outside air ventilation rate per person required by Title 24 2013 §120.1(b)2B1

### Net-to-Gross Assumption: *List and Cite source(s) from DEER data base or Spreadsheet*

*DEER spreadsheet DEER2011\_NTGR\_2012-05-16.xls*

Table 8 below summarizes all applicable DEER based Net-to-Gross ratios for programs that may be used by this measure.

Table 8 DEER Net-to-Gross Ratios

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **DEER Spreadsheet** | |  |
| Program Approach | NTG ID | NTG Description | Version | NTG |
| Demand controlled ventilation for single zone packaged HVAC | Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | DEER2011  D11 v4.00 | 0.6 |

The NTG Ratios in Table 8 are appropriate for the measure(s) because:

* This is a commercial program with no evaluated NTGR.
* The same program delivery mechanism has been in place for more than 2 years.

### Effective Useful Life / Remaining Useful Life:

Since this measure is a retrofit on an existing system the RUL of the existing system is used as the EUL for the measure. The EUL for the measure is 5 years. Table 9 provides DEER EUL and RUL data for packaged HVAC systems.

Table 9 Effective Useful Life: DEER Version and Impact IDs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Building type | Bldg Vintage | Climate Zone | EUL (yrs) | RUL (yrs) | DEER Version | Impact IDs |
| **All** | **All** | **All** | **15** | **5** | **2014** | **HVAC-airHP,**  **HVAC-airAC** |

### In-service rate/first year installation rate:

Since this is a new measure with no available DEER or energy measurement and verification (EM&V) data available the In-service rate is 1.0.

## 1.4.2 Codes & Standards Requirements Base Case and Measure Information

This measure is a retrofit to an existing system, and is not governed by either state or federal codes and standards as long as the project does not include other code-triggering activities such as replacement of HVAC systems. However, Title 24 2013 provides economizer control, general ventilation, and DCV requirements that are considered to be best practice and are provided here for reference.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Title 24 Std. Description | Base or Measure Case | Value | Units | Code Source or Reference |
| Economizer high limit control | Base Case | High limit shut-off control requirements by device type and climate zone | °F, Btu/lb | Title 24 2013 Table 140.4-B1 |
| Ventilation requirements | Both Base and Measure Case | Minimum ventilation requirements | CFM/Sq. Ft., CFM/Person | Title 24 2013 §120.11 |
| DCV requirements | Measure Case | DCV ventilation and sensor requirements | PPM, Sq. Ft. | §120.1(c)3 and 41 |

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

Data currently being finalized in Work Order 32 EM&V[[10]](#endnote-9) research of HVAC programs informed assumptions for economizer minimum and maximum outside air rate assumptions discussed in 1.4.1.

## 1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

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

***1.4.5 Time-of-Use Adjustment Factor***

CPUC decision 06-06-063 dated June 29, 2006 requires time-of-use (TOU) adjustment factors on residential A/C and commercial A/C (packaged and split-system direct-expansion cooling) measures only. Additionally, if a measure is assigned a DEER08 load shape, i.e. the load shape starts with “DEER:” the TOU assigned to that measure should also be zero. Since these measures are assigned a DEER08 load shape, the TOU assigned to the measures is zero as shown in Table 4 below.

Table 10 TOU Adjustment Factors

|  |  |  |  |
| --- | --- | --- | --- |
| Measure | kWAC | kWTotal | % |
| Add ADEC and CO2 Sensor to AC unit with Gas Heat | 0 | 0 | 0 |
| Add CO2 Sensor to AC unit with Gas Heat with ADEC | 0 | 0 | 0 |
| Add ADEC and CO2 Sensor to AC only unit | 0 | 0 | 0 |
| Add CO2 Sensor to AC only unit with ADEC | 0 | 0 | 0 |
| Add ADEC and CO2 Sensor to HP | 0 | 0 | 0 |
| Add CO2 Sensor to HP with ADEC | 0 | 0 | 0 |

***1.5 Summary of Inputs for Savings Calculations***

The following table provides references to sections that document the inputs for calculation:

Table 11 Inputs for Calculation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Input Variable** | **Variations** | **Base Case 1 Average Value** | **Base Case 2 Average Value** | **Measure Case Average Value** | **Reference Section** |
| **Electric Savings** | CZ, BT, Utility | 0 | 0 | 82.119 | *Section 1.4.1* |
| **Gas Savings** | CZ, BT, Utility | 0 | 0 | 5.848 | *Section 1.4.1* |
| **Hours of operation** | BT | 88 | 88 | 88 |  |
| **Full Cost** | Measure Code | 0 | 0 | 162.05, 64.69 | *Section 4.3.1* |
| **Incremental Cost** | Measure Code | 0 | 0 | 162.05, 64.69 | *Section 4.3.2* |
| **EUL /RUL** | One | 5 | 15 | 5 | *Section 1.4.1* |
| **NTG** | One | TBD | TBD | TBD | *Section 1.4.1* |
| **ISR** | Yes | 1 | 1 | 1 | *Section 1.4.1* |
| **TOU Factor** | One | 0 | 0 | 0 | *Section 1.4.5* |

# Section 2. Calculation Methods

Since this is an ER (early retirement) measure, the first baseline period uses the customer average baseline. The second baseline uses the code baseline. It is assumed that there are no above code savings since Title 24 2013 §120.11 requires DCV for most space types in which it is beneficial. Table 12 compares the baselines used for the ER measure application types to other measure application types.

Table 12 Baseline by Measure Application Type

|  |  |  |  |
| --- | --- | --- | --- |
| ****Measure Application Type**** | ****Measure Life Basis**** | ****First Baseline Period: Energy Savings Baseline**** | ****Second Baseline Period: Energy Savings Baseline**** |
| REA (retrofit add-on) | **EUL** | Customer Average Baseline | Code Baseline |

Notes:

* For ROB measures, First Baseline is the baseline for the full EUL. There is no second baseline.
* For ER measures, First Baseline Period is the period for the RUL(remaining useful life),defined by the CPUC as RUL=1/3 EUL. Second baseline period for ER is Code baseline for the period EUL-RUL.

## 2.1 Electric Energy Savings Estimation Methodologies

As an Early Retirement Measure, there are two mandated baselines as defined earlier in this workpaper. Since there are no above code energy savings for most applications, the second baseline savings are set to zero. The electric energy savings from the first baseline 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)*

A sample calculation using a 1985 vintage assembly (Asm) prototype using AC with gas heat located in climate zone 11 is provided below.

The DEER Asm prototype consists of five zones total as depicted in Figure 1. The four smaller zones in the corners of the building represent office spaces with peak occupant densities of under 7 people per 1000 square feet. The central zone represents an auditorium space with a peak occupant density of over 95 people per 1000 square feet. For assembly buildings it was determined that DCV could be used to reduce the minimum ventilation rate required for the central auditorium zone, but that DCV could not be used effectively in the corner office zones. The DCV measure was therefore simulated only on the central auditorium zone, and the savings were divided by the cooling capacity in tons of the system that serves only that zone.



Figure 1 DEER Asm Prototype with DCV Zone Outlined

Table 13 provides electric energy use and cooling capacity data for the baseline and measure case on the Asm prototype approximating a building constructed in 1986 in climate zone 11.

Table 13 Asm cz11 v85 AC with Gas Heat Electric Energy Use and Cooling Capacity Data

|  |  |  |
| --- | --- | --- |
|  | Baseline | Measure |
| Whole building energy use (kWh/yr) | 795,732.0 | 775,703.6 |
| System cooling capacity (Btu/h) | 2,485,200 | 2,485,200 |

## 2.2. Demand Reduction Estimation Methodologies

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 Table 14[[11]](#endnote-10).

Table 14 DEER 2014 Peak Demand Periods

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CZ | start month | start day | end month | end day | start hour | end hour |
| 1 | 9 | 16 | 9 | 18 | 15 | 17 |
| 2 | 7 | 8 | 7 | 10 | 15 | 17 |
| 3 | 7 | 8 | 7 | 10 | 15 | 17 |
| 4 | 9 | 1 | 9 | 3 | 15 | 17 |
| 5 | 9 | 8 | 9 | 10 | 15 | 17 |
| 6 | 9 | 1 | 9 | 3 | 15 | 17 |
| 7 | 9 | 1 | 9 | 3 | 15 | 17 |
| 8 | 9 | 1 | 9 | 3 | 15 | 17 |
| 9 | 9 | 1 | 9 | 3 | 15 | 17 |
| 10 | 9 | 1 | 9 | 3 | 15 | 17 |
| 11 | 7 | 8 | 7 | 10 | 15 | 17 |
| 12 | 7 | 8 | 7 | 10 | 15 | 17 |
| 13 | 7 | 8 | 7 | 10 | 15 | 17 |
| 14 | 8 | 26 | 8 | 28 | 15 | 17 |
| 15 | 8 | 25 | 8 | 27 | 15 | 17 |
| 16 | 7 | 8 | 7 | 10 | 15 | 17 |

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)*

A sample calculation using a 1985 vintage assembly (Asm) prototype using AC with gas heat located in climate zone 11 is provided below. Table 13 provides electric energy use and cooling capacity data for the baseline and measure case on the Asm prototype approximating a building constructed in 1986 in climate zone 11.

Table 15 Asm cz11 v85 AC with Gas Heat Demand and Cooling Capacity Data

|  |  |  |
| --- | --- | --- |
|  | Baseline | Measure |
| 7/8 hour 15 demand (kW) | 286.719 | 250.359 |
| 7/8 hour 16 demand (kW | 316.716 | 301.368 |
| 7/8 hour 17 demand (kW) | 322.775 | 314.32 |
| 7/9 hour 15 demand (kW | 337.251 | 286.901 |
| 7/9 hour 16 demand (kW) | 354.335 | 338.351 |
| 7/9 hour 17 demand (kW | 352.816 | 344.157 |
| 7/10 hour 15 demand (kW) | 371.397 | 311.799 |
| 7/10 hour 16 demand (kW | 380.605 | 368.995 |
| 7/10 hour 17 demand (kW) | 375.689 | 374.239 |
| **DEER Demand Average (kW)** | **344.256** | **321.165** |
| System cooling capacity (Btu/h) | 2,485,200 | 2,485,200 |

Gas energy savings were set to zero for AC only system types.

## 2.3. Gas Energy Savings Estimation Methodologies

Gas energy savings are calculated similarly to electric energy savings. The gas energy savings from the first baseline are represented in the calculations below.

*Where:*

*therms per ton savings = annual unit energy savings*

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

*measure therms = 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)*

A sample calculation using a 1985 vintage assembly (Asm) prototype using AC with gas heat located in climate zone 11 is provided below.

Table 13 provides electric energy use and cooling capacity data for the baseline and measure case on the Asm prototype approximating a building constructed in 1986 in climate zone 11.

Table 16 Asm cz11 v85 AC with Gas Heat Gas Energy Use and Cooling Capacity Data

|  |  |  |
| --- | --- | --- |
|  | Baseline | Measure |
| Whole building energy use (therms/yr) | 20,613.92 | 11,879.14 |
| System cooling capacity (Btu/h) | 2,485,200 | 2,485,200 |

Gas energy savings were set to zero for AC only system types.

## Vintage Weighted Average

Baseline and measure simulations used prototypes for the following 6 DEER vintages: v75, v85, v96, v03, v07, and v11. The weighted average electric and gas energy savings, and demand reduction for application of the measure to any vintage were then developed using DEER 2014 vintage weighting tables and procedures. The following equation provides the methodology used to apply the DEER 2014 weights. **Table 17** provides sample data showing savings by vintage and the final weighted values using DEER weights for PG&E territory assembly buildings in climate zone 11.

*Where:*

*final weighted value=reported UES value (kWh/ton, kW/ton, or therms/ton)*

*i=vintage 75, 85, 96, 03, 07, or 11*

*W=Weight for a given vintage i*

*V=UES Value for a given vintage (kWh/ton, kW/ton, or therms/ton)*

Table 17 Sample Vintage Weights for PG&E Asm CZ11

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| WtSet | Vintage | DEER Weight | Savings kWh/ton | Demand Reduction kW/ton | Savings Therms/ton |
| PGEAsmCZ11 | v75 | 2.968267 | 107.303 | 0.126274 | 39.634 |
| PGEAsmCZ11 | v85 | 1.9187 | 96.709 | 0.111494 | 42.177 |
| PGEAsmCZ11 | v96 | 1.142333 | 101.457 | 0.113065 | 46.305 |
| PGEAsmCZ11 | v03 | 0.5821 | 92.062 | 0.103053 | 47.454 |
| PGEAsmCZ11 | v07 | 0.324233 | 92.155 | 0.103242 | 47.550 |
| PGEAsmCZ11 | v11 | 0.324233 | 96.003 | 0.105622 | 52.554 |
| **Final Weighted Savings** | **Existing** |  | **101.18** | **0.11648** | **42.913** |

# *Section 3. Load Shapes*

## 3.1 Base Case Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles for some sectors are available. Therefore, the closest load shape chosen for this measure is the DEER:HVAC\_Eff\_AC load shape as shown in Table 8.

Table 18 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **E3 Alt. Building Type** | **Load Shape** |
| All | Non\_Res | DEER:HVAC\_Eff\_AC |

## 3.2 Measure Load Shapes

There are no measure case load shapes applicable to this(ese) measure(s). The base case shapes are to be used in the cost avoidance calculation.

# Section 4. Base Case & Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Measure Life Basis** | **First Baseline Period Gross Measure Cost (RUL)** | **Second Baseline Period Gross Measure Cost (EUL – RUL)** |
| ***REA (Retrofit Add-on)*** | RUL/  EUL-RUL | Calculated as Full Gross Measure Cost | Calculated as Negative Full Gross Base Case Cost |

## 4.1 Base Case(s) Costs

The following Measure Application Types is are appropriate to these measures. The Base Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Measure Codes* | Measure Application Type | Baseline | Equipment Cost ($) | Labor / Installation Cost ($) | Maintenance / Other Cost ($) | Total Base Case Cost ($) |
| HV026 – HV031 | REA | Existing | 0 | 0 | 0 | 0 |

*All costs are noted as $ per measure unit*

Since this is an ER application for a retrofit on existing equipment, the base case cost is zero.

## 4.2 Measure Case Costs

To develop measure cost estimates a combination of retail, manufacturer suggested retail, and distributor costs were gathered for ADEC and CO2 sensors made by multiple manufacturers. Estimates of installation time were developed based on author’s direct experience working with contractors to install ADEC and DCV in field tests of the technology. A base labor rate of $86.93 per hour was used, and was adjusted to account for local variation. A weighted average cost for the state was developed based on the methodology used for the Draft DEER Measure Cost Update[[12]](#endnote-11)The base labor rate and adjustments are in alignment with the methodology presented in the Draft DEER Measure Cost Update. As a controls upgrade, measure costs do not scale strongly with cooling capacity. To reference cost with the same base unit as UES values (per ton) an average capacity of 12.5 tons was assumed to be the average capacity to which the measure would be applied. Detailed cost calculations are documented in *DCV\_CO2+ADEC cost data.xlsx[[13]](#endnote-12).*Table 19provides calculated costs adjusted for local labor rates and weighted by deemed HVAC claims.

Table 19 Measure Cost Data

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Codes | Measure | Measure Material Cost ($) | Labor Cost ($) | Measure Cost ($) | Avg. tonnage | Measure Material Cost ($/ton) | Labor Cost ($/ton) | Measure Cost ($/ton) |
| HV026, HV028, HV030 | Add ADEC and CO2 sensor to existing system | 1220.25 | 805.38 | 2025.63 | 12.5 | 97.62 | 64.43 | 162.05 |
| HV027, HV029, HV031 | Add CO2 sensor to existing system with ADEC | 406.00 | 402.63 | 808.63 | 12.5 | 32.48 | 32.21 | 64.69 |

The Draft DEER Cost Update includes cost for Demand Controlled Ventilation. For a single zone wall mounted unit with digital display application the equipment cost is $440.08, the labor cost is $651.98, and there is a miscellaneous cost of $1192.13. A comment has been submitted inquiring about specific costs included in the miscellaneous cost. In total, the Draft DEER measure cost is $2,284.19 using the base labor rate of $86.93 before labor rate adjustments are applied. In comparison the cost calculated for this measure prior to labor rate adjustments was $1935.41, or about 15% lower than the Draft DEER cost. The calculated cost compares reasonably well to the total Draft DEER cost, and will be used until the Draft DEER Cost Update Study is finalized and published. At that point it will be determined if it is appropriate or necessary to revise costs to align with the DEER cost.

## 4.3 Incremental & Full Measure Costs

Since the base case is the existing equipment and has no cost, the incremental and full measure costs are equivalent.

Table 20 Incremental & Full Measure Costs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Measure Codes | Measure Application Type | Measure Cost | Base Case Cost | Incremental Measure Cost |
| HV026, HV028, HV030 | REA | 162.05 | 0 | 162.05 |
| HV027, HV029, HV031 | REA | 64.69 | 0 | 64.69 |

# *4.3.1 Gross Measure Cost*

Gross Measure Cost is the cost to install an energy efficient measure per the CPUC calculators. This definition implies a different meaning depending on the Measure Application type.

This measure Measure Application Type is **ER** for the First baseline period only (RUL), so the Gross Measure Cost (GMC) is represented by the equation below:

GMC = Measure Equipment Cost + Measure Labor Cost

*GMC = $ per (unit) + $ per (unit) = $ per(unit)*

For **ER** in the second baseline period (EUL – RUL) period, GMC is represented by the equation below:

GMC = (-1) x (Base Equipment Cost + Base Labor Cost)

*GMC = (-1) x ($ per (unit) + $ per (unit)) = $ per (unit) $*

\*Note: Various complicated price fluctuations are not addressed in these equations, such as future costs due to inflation in labor, future costs due to deflation in material cost, and other variables that cannot be accurately described at this time.

# *4.3.2 Incremental Measure Costs*

Incremental Measure Cost is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. While IMC has a straightforward definition depending on the Measure Application type, the equation does vary.

This Measure Application Types is **ER.** There is no base case to which to compare the measure, so the Incremental Measure Cost (IMC) is represented by the equation below:

IMC = Measure Equipment Cost + Measure Labor Cost

*IMC = $ per (unit)+ $ per (unit) = $ per (unit)*

Table 21 Summary Table for Section 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Measure ID | Measure Application Types | Base Case Total Cost ($) | Measure Case Total Cost[[14]](#endnote-13) ($) | Gross Measure Case Cost ($) | Incremental Measure Cost ($) |
| HV026, HV028, HV030 | REA | 0 | 162.05 | 162.05 | 162.05 |
| HV027, HV029, HV031 | REA | 0 | 64.69 | 64.69 | 64.69 |

# 

# References

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3. See 1.4.1 DEER Base Case and Measure Case Information for description of DEER Prototypes [↑](#footnote-ref-1)
4. The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata\_format-V0.97.xls.* [↑](#endnote-ref-3)
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     [↑](#endnote-ref-12)
14. SCE, Measure Cost Revision 5 revised for PG&E by S.L. Blanc 2012

     [↑](#endnote-ref-13)