



eTRM
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H V A C
ECONOMIZER CONTROLS, COMMERCIAL
SWSV010-01

C O N T E N T S

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MEASURE NAME

Economizer Controls, Commercial

STATEWIDE MEASURE ID

SWSV010-01

TECHNOLOGY SUMMARY

The economizer control measure improves economizer performance while maintaining comfort by optimizing the changeover setpoint. Energy savings are achieved by allowing the economizer operation during system calls for cooling at higher but still advantageous cool outside air temperatures prior to mechanical cooling.

This measure supports HVAC quality maintenance (QM) programs as well as HVAC tune-up programs.

An HVAC program impact evaluation completed by DNV GL in 2014 (“WO32 Study”)¹ evaluated statewide, third-party, and local programs that targeted unitary HVAC systems during the 2010-2012 program cycle, including Commercial Quality Maintenance (CQM). The WO32 Study evaluated gross energy savings and installation rates through activities including on-site field evaluations, sampling and monitoring the performance and energy use of units enrolled in the programs before and after CQM maintenance, and additional laboratory testing of existing HVAC units. The study highlights findings for key QPM treatments (and parameters) including, but not limited to, recognition of typical damper leakage characteristics, non-functional economizer conditions and performance, and adjusting refrigerant charge.

The economizer damper leakage observed during laboratory testing suggests that existing economizers generally allow 15% outdoor air flow with closed dampers, 20% outdoor air flow with the commonly applied “finger open” methodology for minimum ventilation, and 62% outdoor air flow with dampers completely open. The damper leakage rate can greatly vary energy savings results and have been incorporated into building energy modeling methodology

Additionally, WO32 Study findings include as-found non-functional economizer conditions for which “approximately 74% of observed units in the programs after maintenance had economizer or make-up air dampers set to one or more fingers open after maintenance was completed.” The prevalence of non-functional economizers failing partially open as opposed to failing closed has been incorporated into the final weighted savings calculations for this measure.

MEASURE CASE DESCRIPTION

This measure is defined as the replacement of an existing economizer control sensor or the optimization of the existing economizer controls by adjusting the changeover setpoint. Measure offerings are defined by whether an economizer is replaced or optimized as well as the host equipment type.

¹ DNV GL. 2014. *HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report*. Prepared for California Public Utilities Commission (CPUC). January 28.

Measure Offerings

| Statewide Measure Offering ID | Measure Offering Description |
|-------------------------------|---|
| SWSV010A | Economizer Control Adjustment on AC Only Units |
| SWSV010B | Economizer Control Adjustment on AC Unit with Gas Heat |
| SWSV010C | Economizer Control Adjustment on Heat Pump |
| SWSV010D | Economizer Control Adjustment on Variable Volume AC Unit with Gas Heat |
| SWSV010E | Economizer Control Replacement on AC Only Units |
| SWSV010F | Economizer Control Replacement on AC Unit with Gas Heat |
| SWSV010G | Economizer Control Replacement on Heat Pump |
| SWSV010H | Economizer Control Replacement on Variable Volume AC Unit with Gas Heat |

Base, Standard, and Measure Cases

| Case | Description of Typical Scenario |
|----------------------------|---|
| Measure | Replace existing economizer control sensor or optimizing existing economizer controls by adjusting the changeover setpoint |
| Existing Condition | Existing economizer is either equipped with a snapdisc or malfunctioning analog sensor or has a fully operational analog sensor but requires adjustment |
| Code/Standard | Not applicable. |
| Industry Standard Practice | Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems ² |

BASE CASE DESCRIPTION

The base case is defined as the existing economizer that is either equipped with a snapdisc or malfunctioning analog sensor or has a fully operational analog sensor but requires adjustment.

This measure assumes the existing unit is equipped with a fully operational economizer with un-optimized economizer controls by either low economizer changeover setpoint or inadequate sensors.

CODE REQUIREMENTS

The economizer replacement and optimization measure is a maintenance measure and thus not governed by either state or federal codes and standards. The California Building Energy Efficiency Standards (Title 24)³ provides control requirements for air economizers, but compliance is not required for maintenance measures.

² American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and Air Conditioning Contractors of America (ACCA). 2008. *Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*.

³ California Energy Commission (CEC). 2018. *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)*. CEC-400-2018-020-CMF.

The Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems⁴ may be used by Quality Maintenance (QM) programs as a guide for measure implementation.

Only licensed California contractors will be permitted to implement this measure. As required by the California State Licensing Board (CSLB), contractors are responsible for meeting all applicable codes. In general, maintenance and repairs do not require permits.

Applicable State and Federal Codes and Standards

| Code | Applicable Code Reference | Effective Date |
|---|---|-----------------|
| CA Appliance Efficiency Regulations – Title 20 | None | n/a |
| CA Building Energy Efficiency Standards – Title 24 (2019) | Section 140.4(e) Economizers, Table 140.4-E Air Economizer High Limit Shut Off Control Requirements | January 1, 2020 |
| Federal Standards | None | n/a |

NORMALIZING UNIT

Per ton cooling capacity (Cap-ton)

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.

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

⁴ American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and Air Conditioning Contractors of America (ACCA). 2008. *Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*.

Implementation Eligibility

| Measure Application Type | Delivery Type | Sector |
|--------------------------|---------------|--------|
| BRO-RCx | DnDeemDI | Com |
| BRO-RCx | DnDeemed | Com |
| BRO-RCx | DnDeemDI | Ag |
| BRO-RCx | DnDeemed | Ag |
| BRO-RCx | DnDeemDI | Ind |
| BRO-RCx | DnDeemed | Ind |

Contractors and technicians implementing the measure must meet all certification and training requirements in accordance with program requirements. Other terms and conditions are set by individual programs.

Eligible Products

This measure requires field documentation of the existing conditions that verify the measure was necessary and that the measure was successfully applied.

Additional technician verification of thermostat wiring and the number of cooling stages that should be performed to ensure that the first stage of cooling is dedicated to economizer operation and two-stage thermostat operation is enabled where possible.

The controller changeover setpoint should be adjusted appropriately based on the available number of thermostat cooling stages.

Eligible Building Types and Vintages

This measure is applicable for all nonresidential buildings served by unitary direct expansion (DX) and split systems that do not serve process or refrigeration loads.

Eligible Climate Zones

This measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

This measure does not apply if the rooftop unit (RTU) has a fully operational and/or non-snapdisc sensor and is adjusted to the appropriate changeover setpoint based on the number of thermostat stages available for cooling.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (kWh)

The electric unit energy savings (UES) and demand reduction for non-refrigeration models were derived from unit energy consumption (UEC) estimated with the eQUEST version 3.65 energy modeling software and DOE-2.2R version 52h energy modeling simulation engine for refrigeration models.

Prototypes from the Database of Energy Efficient Resources (DEER) were utilized for the building energy use simulations. The DEER prototypes were generated using MASControl v3.00.00. The DEER 2020 prototypes for existing building vintages 2003, 2007, 2011 and 2015 for Tech IDs shown below were used to develop base and measure case unit energy consumption (UEC) and demand estimates.

Statewide Measure Offering IDs and DEER Prototype Tech IDs

| Statewide Measure Offering ID | Measure Offering Description | DEER Prototype Tech ID |
|-------------------------------|---|---|
| SWSV010F | Economizer Control Replacement on AC Unit with Gas Heat | All: NE-HVAC-airAC-SpltPkg-65to134kBtuh-11p5eer-wPreEcono MASControl v3.00.00 |
| SWSV010B | Economizer Control Adjustment on AC Unit with Gas Heat | |
| SWSV010E | Economizer Control Replacement on AC Only Unit | All: NE-HVAC-airAC-SpltPkg-65to134kBtuh-11p5eer-wPreEcono MASControl v3.00.00 |
| SWSV010A | Economizer Control Adjustment on AC Only Unit | |
| SWSV010G | Economizer Control Replacement on Heat Pump | Non-Education Relocatable Classroom: NE-HVAC-airHP-SpltPkg-65to134kBtuh-11p5eer-3p4cop-wPreEcono MASControl v3.00.00 Education Relocatable Classroom: NE-HVAC-airHP-Pkg-55to65kBtuh-15p0seer-8p2hspf-wPreEcono MASControl v3.00.00 |
| SWSV010C | Economizer Control Adjustment on Heat Pump | |
| SWSV010H | Economizer Control Replacement on Variable Volume AC Unit with Gas Heat | All: NE-HVAC-airAC-SpltPkg-240to759kBtuh-10p8eer_SZ MASControl v3.00.00 |
| SWSV010D | Economizer Control Adjustment on Variable Volume AC Unit with Gas Heat | |

With the exception of the education relocatable classroom building type with heat pumps, the DEER prototypes for AC and Heat Pump measures were created using the “65to134kBtuh” cooling capacity range. This capacity range allows prototypes to be generated for the widest range of building types. 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. In addition, larger systems generally operate less efficiently than systems in the selected size range. Savings for larger

units of these types are therefore slightly conservative. Variable air volume (VAV) AC units were not available in the “110to134kBtuh” range and were created using “240to759kBtuh”.

The following tables describe the building types, building vintages and climate zones modeled.

Building Description and Used Models

| Building Type | BT Code | Modeled |
|--------------------------------|---------|---------|
| Assembly | Asm | Yes |
| Primary School | EPr | Yes |
| Secondary School | Ese | Yes |
| Community College | ECC | Yes |
| University | EUn | Yes |
| Grocery | Gro | Yes |
| Hospital | Hsp | Yes |
| Nursing Home | Nrs | Yes |
| Hotel | Htl | Yes |
| Motel | Mtl | Yes |
| Bio/Tech Manufacturing | MBT | Yes |
| Light Industrial Manufacturing | MLI | Yes |
| Large Office | OfL | Yes |
| Small Office | OfS | Yes |
| Sit-Down Restaurant | RSD | Yes |
| Fast-Food Restaurant | RFF | Yes |
| Department Store | Rt3 | Yes |
| Big Box Retail | RtL | Yes |
| Small Retail | RtS | Yes |
| Conditioned Storage | SCn | Yes |
| Unconditioned Storage | Sun | No |
| Refrigerated Warehouse | WRF | Yes |

Climate Zone

| Climate Zone | Climate Zone Description | Modeled |
|--------------|----------------------------|---------|
| 1 | Arcata Area (CZ01) | Yes |
| 2 | Santa Rosa Area (CZ02) | Yes |
| 3 | Oakland Area (CZ03) | Yes |
| 4 | Sunnyvale Area (CZ04) | Yes |
| 5 | Santa Maria Area (CZ05) | Yes |
| 6 | Los Angeles Area (CZ06) | Yes |
| 7 | San Diego Area (CZ07) | Yes |
| 8 | El Toro Area (CZ08) | Yes |
| 9 | Pasadena Area (CZ09) | Yes |
| 10 | San Bernardino Area (CZ10) | Yes |
| 11 | Red Bluff Area (CZ11) | Yes |
| 12 | Sacramento Area (CZ12) | Yes |
| 13 | Fresno Area (CZ13) | Yes |
| 14 | China Lake Area (CZ14) | Yes |
| 15 | Blythe Area (CZ15) | Yes |

| Climate Zone | Climate Zone Description | Modeled |
|--------------|--------------------------|---------|
| 16 | Mount Shasta Area (CZ16) | Yes |

Vintage

| Vintage Era | Vintage | Vintage Code | Modeled |
|---------------|---------|---|---------|
| Existing (ex) | V03 | Existing building stock built between 2002 and 2005 | Yes |
| | V07 | Existing building stock built between 2006 and 2009 | Yes |
| | V11 | Existing building stock built between 2010 and 2013 | Yes |
| | V15 | Existing building stock built between 2014 and 2016 | Yes |

HVAC Type

cDXGF (AC Unit with Gas Heat)

cNCGF (AC Only Unit)

cDXHP (Heat Pump)

cPVVG (Variable Volume AC Unit with Gas Heat)

Thermostat Options

Not applicable.

Case Options

| Description | Code | Modeled |
|--------------------|------|---------|
| Customer Average | CAv | No |
| 2005 Code/Standard | C05 | No |
| 2008 Code/Standard | C08 | No |
| 2013 Code/Standard | C13 | No |
| Market Average | MAv | No |
| Measure | Msr | No |

DEER Prototype Modifications

The previous version of the workpaper made modifications to the DEER prototypes to simulate outside air damper leakage, return air damper leakage, and exhaust re-entrainment issues with unitary package units. The leakage and re-entrainment issues were identified in *The HVAC Impact Evaluation FINAL Report*

WO32 HVAC conducted by DNV GL (“WO32 Study”).⁵ Ideally, the findings of the WO32 Study should have been addressed in DEER 2020 prototype models. A review of DEER 2020 prototypes confirmed that the findings of the WO32 Study related to damper leakage and exhaust re-entrainment were partially addressed. The changes to MASControl V3.00.00 output structure made it complex to manually update the input files for a large volume of prototypes. Therefore, it was decided to use DEER prototypes with no modifications.

Base Case Energy Use Simulation

The base case energy use simulation methodology begins with the DEER prototypes and alters the models to simulate faults representing HVAC units in an as-found condition. The table below specifies the modeled and represented as-found changeover setting faults covered by this economizer control measure.

Modeled and Represented As-Found Conditions

| Modeled Faults | Represented As-Found Conditions |
|---------------------------|---|
| 55 °F Dry Bulb High Limit | Integrated or non-integrated economizer with 55 °F dry bulb high limit |
| | Integrated or non-integrated Integrated economizer with electronic enthalpy “D” setting |
| 63 °F Dry Bulb High Limit | Integrated or non-integrated economizer with 63 °F dry bulb high limit |
| | Integrated or non-integrated economizer with electronic enthalpy “C” setting |
| 68 °F Dry Bulb High Limit | Integrated economizer with 68 °F dry bulb high limit |
| | Integrated economizer with electronic enthalpy “B” setting |

To implement these fault simulations in the Damper Leakage prototypes, specific modifications to eQUEST keywords (below) were performed to all non-PTAC system types.

Baseline Modifications to eQUEST Keywords

| Modeled Faults | eQUEST Keyword | DEER Value | Modified Baseline Value |
|---------------------------|----------------------|------------|-------------------------|
| 55 °F Dry Bulb High Limit | SYSTEM:DRYBULB-LIMIT | Varies | 55 |
| 63 °F Dry Bulb High Limit | SYSTEM:DRYBULB-LIMIT | Varies | 63 |
| 68 °F Dry Bulb High Limit | SYSTEM:DRYBULB-LIMIT | Varies | 68 |

The final economizer control measures are a combination of the modeled faults weighted by the corresponding frequency of that fault seen in AirCare Plus (ACP) database provided by the PGECOHC138 Nonresidential HVAC Quality Maintenance workpaper.⁶ (See Electric Unit Energy Savings Calculation for the weight factors derived for the UES calculations.)

⁵ DNV GL. 2014. *HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report*. Prepared for California Public Utilities Commission (CPUC). January 28.

⁶ Pacific Gas and Electric Company (PG&E). 2012. “Workpaper PGECOHC138 Revision 0 Nonresidential HVAC Quality Maintenance.”

The following table shows how the base case eQUEST HVAC Systems inputs were modified to develop the measure case. The Field and eQUEST Keyword columns list the keywords exactly how they are listed in the input files for both cases. The Large Retail (RtL) Building type, Climate Zone 12 and Vintage 2015 was chosen as an example to specifically compare the base case and measure case models. This example pertains to the following measure offerings: Economizer Control Adjustment on AC Only Units, Economizer Control Adjustment on AC unit with Gas Heat, Economizer Control Replacement on AC Only Units and Economizer Control Replacement on AC with Gas Heat.

eQUEST Keyword Comparison of Base Cases and Measure Case

| Field | eQUEST Keywords | Base Case | Measure Case |
|----------------------|-----------------|-----------|--------------|
| HVAC Systems / Zones | ECONO-LIMIT-T | 55 | 75 |
| | ECONO-LIMIT-T | 63 | 75 |
| | ECONO-LIMIT-T | 68 | 75 |

Measure Case Energy Use Simulation

The DEER prototypes used as the reference models for the measure case buildings are unmodified. The high limit settings for the measure case vary by climate zone as shown in below. Most of these settings are consistent with the California Title 24 Building Energy Efficiency Standards (Title 24).

ECONO-LIMIT-T Values from DEER2020 Prototypes

| Climate Zone | Vintage | | | |
|--------------|---------|-----|-----|-----|
| | V03 | V07 | V11 | V15 |
| 1 | 75 | 75 | 75 | 75 |
| 2 | 73 | 73 | 73 | 73 |
| 3 | 75 | 75 | 75 | 75 |
| 4 | 73 | 73 | 73 | 73 |
| 5 | 75 | 75 | 75 | 75 |
| 6 | 71 | 71 | 71 | 71 |
| 7 | 71 | 71 | 71 | 71 |
| 8 | 71 | 71 | 71 | 71 |
| 9 | 71 | 71 | 71 | 71 |
| 10 | 73 | 73 | 73 | 73 |
| 11 | 75 | 75 | 75 | 75 |
| 12 | 75 | 75 | 75 | 75 |
| 13 | 75 | 75 | 75 | 75 |
| 14 | 75 | 75 | 75 | 75 |
| 15 | 75 | 75 | 75 | 75 |

Electric Unit Energy Savings Calculation

The electric unit energy savings (UES) is calculated as the difference between the modeled baseline and measure UEC, then normalized by the system cooling capacity. Savings were calculated for a weighted average of the DEER2020 vintages using the utility-specific weights provided below.

$$UES_{kWh} = \frac{UEC_{baseline\ wtd\ kWh} - UEC_{measure\ kWh}}{CoolTons}$$

$UES =$ Annual unit energy savings, kWh/ton

$UEC_{baseline\ wtd\ kWh} =$ Annual building energy consumption from each modeled fault weighted by the frequency distribution the corresponding as-found condition

$UEC_{measure\ kWh} =$ Annual building energy consumption of measure

$CoolTons =$ Design cooling capacity of base case non-PTAC systems

Weight Factors for Savings Calculations

| Fault Distribution | Fault Weight | Source |
|---------------------------|--------------|--|
| 55 °F Dry Bulb High Limit | 0.56 | Pacific Gas and Electric Company (PG&E). 2012. "Workpaper PGECOHVC138 Revision 0 Nonresidential HVAC Quality Maintenance." |
| 63 °F Dry Bulb High Limit | 0.34 | |
| 68 °F Dry Bulb High Limit | 0.10 | |

Derived from AirCare Plus data.

Sample Calculation

A sample calculation using a 2007 vintage small office (OfS) prototype with AC and Gas Heat located in climate zone 1 is provided below. This includes the modeling results for building energy use and cooling system tonnage. For building types that have PTAC systems, the cooling tonnage was calculated as the sum of non-PTAC systems individual tonnages.

OfS-w01-v07-airAC Prototype Electric Energy Use and Cooling Capacity Data

| | 55 °F Dry Bulb High Limit | 63 °F Dry Bulb High Limit | 68 °F Dry Bulb High Limit | Measure |
|------------------------------------|---------------------------|---------------------------|---------------------------|---------|
| Whole building energy use (kWh/yr) | 74,122 | 71,327 | 71,130 | 71,127 |
| System cooling capacity (Btu/hr) | 349,888 | 349,888 | 349,888 | 349,888 |

$$59.87 \left(\frac{kWh}{ton \times year} \right) = \frac{\left(74,122 \left(\frac{kWh}{year} \right) \times 0.56 + 71,327 \left(\frac{kWh}{year} \right) \times 0.34 + 71,130 \left(\frac{kWh}{year} \right) \times 0.10 \right) - 71,127 \left(\frac{kWh}{year} \right)}{349,888 \left(\frac{Btu}{h} \right) / 12,000 \left(\left(\frac{Btu}{h} \right) / ton \right)}$$

PEAK ELECTRIC DEMAND REDUCTION (kW)

Peak demand reduction was derived using the same methodology to derive electric unit energy savings (UES). The peak demand reduction was estimated using energy modeling software, eQUEST version 3.65. The Database of Energy Efficient Resources (DEER) prototypes were developed using MASControl v3.00.00, the .INP file was then imported into eQUEST and modifications were made to develop the base case and the measure case. (See Electric Savings.)

However, the DEER demand reduction estimation protocol requires using the average hourly peak demand for the 15 hours of the peak period from 4 p.m. to 9 p.m. during the three consecutive weekday period between June 1 through September 30.⁷

The following calculation determined the demand reduction per ton of cooling capacity was calculated as the different between the baseline and measure case demand, divided by cooling capacity.

$$DemandReduction_{kW} = \frac{Demand_{Baseline} - Demand_{Measure}}{CoolTons}$$

DemandReduction = Annual unit demand reduction

Demand_{Baseline} = Average demand for DEER peak period of customer average from each modeled fault weighted by the frequency distribution the corresponding as-found condition.

Demand_{Measure} = Average demand for DEER peak period of measure

CoolTons = Design cooling capacity of base case non-PTAC systems

A sample calculation using a 2007 vintage small office (Ofs) prototype located in climate zone 1 is provided below. The following table specifies the electric energy use and cooling capacity data for the baseline and measure case on the Ofs prototype approximating a building constructed in 2007 in climate zone 1.

Ofs-w01-v07-airAC Prototype Electric Demand and Cooling Capacity Data

| | 55 °F Dry Bulb High Limit | 63 °F Dry Bulb High Limit | 68 °F Dry Bulb High Limit | Measure |
|------------------------|------------------------------|------------------------------|------------------------------|---------|
| 9/16 4-5pm demand (kW) | 24.19 | 24.47 | 21.61 | 21.61 |
| 9/16 5-6pm demand (kW) | 18.05 | 15.36 | 15.36 | 15.36 |
| 9/16 6-7pm demand (kW) | 7.00 | 7.00 | 7.00 | 7.00 |
| 9/16 7-8pm demand (kW) | 3.85 | 3.85 | 3.85 | 3.85 |
| 9/16 8-9pm demand (kW) | 3.40 | 3.40 | 3.40 | 3.40 |
| 9/17 4-5pm demand (kW) | 23.08 | 23.26 | 20.13 | 20.13 |
| 9/17 5-6pm demand (kW) | 17.21 | 17.30 | 14.55 | 14.55 |
| 9/17 6-7pm demand (kW) | 7.00 | 7.00 | 7.00 | 7.00 |
| 9/17 7-8pm demand (kW) | 3.85 | 3.85 | 3.85 | 3.85 |
| 9/17 8-9pm demand (kW) | 3.40 | 3.40 | 3.40 | 3.40 |
| 9/18 4-5pm demand (kW) | 27.41 | 27.45 | 27.48 | 27.53 |
| 9/18 5-6pm demand (kW) | 21.78 | 21.80 | 21.81 | 21.84 |
| 9/18 6-7pm demand (kW) | 7.20 | 7.20 | 7.21 | 7.21 |

⁷ California Public Utilities Commission (CPUC). 2018. *Resolution E-4952*. October 11. OP 1.

| | 55 °F Dry Bulb High Limit | 63 °F Dry Bulb High Limit | 68 °F Dry Bulb High Limit | Measure |
|----------------------------------|------------------------------|------------------------------|------------------------------|--------------|
| 9/18 7-8pm demand (kW) | 3.85 | 3.85 | 3.85 | 3.85 |
| 9/18 8-9pm demand (kW) | 3.40 | 3.40 | 3.40 | 3.40 |
| DEER Demand Average (kW) | 11.64 | 11.51 | 10.93 | 10.93 |
| System cooling capacity (Btu/hr) | 349,888 | 349,888 | 349,888 | 349,888 |

$$0.02 \left(\frac{kW}{ton} \right) = \frac{(11.64(kW) \times 0.56 + 11.51(kW) \times 0.34 + 10.93(kW) \times 0.10) - 10.93(kW)}{349,888 \left(\frac{Btu}{h} \right) / 12,000 \left(\left(\frac{Btu}{h} \right) / ton \right)}$$

GAS SAVINGS (THERMS)

The gas unit energy savings (UES) and demand reduction for non-refrigeration models were derived from unit energy consumption (UEC) estimated with the eQUEST version 3.65 energy modeling software and DOE-2.2R version 52h energy modeling simulation engine for refrigeration models.

Prototypes from the Database of Energy Efficient Resources (DEER) were utilized for the building energy use simulations. The DEER prototypes were generated using MASControl v3.00.00. The DEER 2020 prototypes for existing building vintages 2003, 2007, 2011 and 2015 for Tech IDs shown below were used to develop base and measure case UEC and demand estimates.

See Electric Savings for description of the eQUEST models.

The gas UES was calculated as the difference between the baseline and measure UEC, normalized by the system cooling capacity.

$$UES_{therms} = \frac{UEC_{baseline\ wtd\ therms} - UEC_{measure\ therms}}{CoolTons}$$

$UES_{therms} =$ Annual unit energy savings, therms/ton

$UEC_{baseline\ wtg\ therms} =$ Annual building energy consumption from each modeled fault weighted by the frequency distribution the corresponding as-found condition.

$UEC_{measure\ therms} =$ Annual building energy consumption of measure

$CoolTons =$ Design cooling capacity of base case non-PTAC systems

Weight Factors for Savings Calculations

| Fault Distribution | Fault Weight | Source |
|---------------------------|--------------|---|
| 55 °F Dry Bulb High Limit | 0.56 | Derived from AirCare Plus data. PGECO HVC138 Nonresidential HVAC RTU Quality Maintenance workpaper. |
| 63 °F Dry Bulb High Limit | 0.34 | |
| 68 °F Dry Bulb High Limit | 0.10 | |

A sample calculation using a 2007 vintage small office (OfS) prototype with AC and Gas Heat located in climate zone 1 is provided below. The table below displays modeling results for building energy use and cooling system tonnage. For building types that have PTAC systems, the cooling tonnage was calculated as the sum of non-PTAC systems individual tonnages.

OfS-w01-v96-airAC Prototype Natural Gas Energy Use and Cooling Capacity Data

| | 55 °F Dry Bulb High Limit | 63 °F Dry Bulb High Limit | 68 °F Dry Bulb High Limit | Measure |
|---------------------------------------|---------------------------|---------------------------|---------------------------|---------|
| Whole building energy use (therms/yr) | 1915.88 | 1915.88 | 1915.88 | 1915.88 |
| System cooling capacity (Btu/hr) | 349,888 | 349,888 | 349,888 | 349,888 |

$$0.000 \left(\frac{\text{Therms}}{\text{ton} \times \text{year}} \right) = \frac{\left(1915.9 \left(\frac{\text{Therms}}{\text{year}} \right) \times 0.56 + 1915.9 \left(\frac{\text{Therms}}{\text{year}} \right) \times 0.34 + 1915.9 \left(\frac{\text{Therms}}{\text{year}} \right) \times 0.10 \right) - 1915.9 \left(\frac{\text{Therms}}{\text{year}} \right)}{2349,888 \left(\frac{\text{Btu}}{\text{h}} \right) / 12,000 \left(\left(\frac{\text{Btu}}{\text{h}} \right) / \text{ton} \right)}$$

Vintage Weighted Average

Baseline and measure simulations used the DEER 2020 building vintages⁸ for both customer average and code prototypes.

DEER Building Vintage Codes and Descriptions

| DEER Vintage Code | Description |
|-------------------|--|
| Ex | Non-Mobile Homes 2002 - 2016; default vintage for existing buildings |
| V03 | Existing building stock built between 2002 and 2005 |
| V07 | Existing building stock built between 2006 and 2009 |
| V11 | Existing building stock built between 2010 and 2013 |
| V15 | Existing building stock built between 2014 and 2016 |
| 2020 (New) | New Construction (not yet built) |

DEER 2020 vintage weighting tables and procedures were used to appropriately weight all measure electric and demand reduction savings according to each vintage per IOU, building type, and climate zone. The following equation describes the DEER 2020 weighting methodology.

$$\text{final weighted value} = \frac{\sum_{i=75}^7 W_i \times V_i}{\sum_{i=75}^7 W_i}$$

$$\text{final weighted value} = \text{Reported energy savings value (kWh/ton, kW/ton, or therms/ton)}$$

⁸ Pacific Gas and Electric Company (PG&E). 2019. "SWSV010-01 Econ Control Vintage Weighted Savings.xlsx"

| | |
|-------|---|
| $i =$ | <i>Vintage 03, 07, 11, 15</i> |
| $W =$ | <i>Weight for a given vintage i</i> |
| $V =$ | <i>Unit energy savings value for a given vintage (kWh/ton, kW/ton, or therms/ton)</i> |

LIFE CYCLE

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

The 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.”⁹ This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.¹⁰ Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on equipment measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component.¹¹

The EUL and RUL specified for this measure are presented below.

Effective Useful Life and Remaining Useful Life

| Parameter | Value | Source |
|-----------|-------|--|
| EUL (yrs) | 3.0 | California Public Utilities Commission (CPUC). 2018. <i>Resolution E-4952</i> . October 11. Page A-37. |
| RUL (yrs) | n/a | - |

BASE CASE MATERIAL COST (\$/UNIT)

The base case is the existing equipment; therefore, the base case cost is \$0.00.

MEASURE CASE MATERIAL COST (\$/UNIT)

The economizer control adjustment measure offerings do not require the purchase of materials or equipment, thus the measure case material cost is equal to \$0.

⁹ California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

¹⁰ KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

¹¹ California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

The equipment cost of the economizer control replacement measure offering was derived from contractor survey responses with eight contractors in 2018.¹²

(Costs for these measures are not included in the *2010-2012 WO017 Ex Ante Measure Cost Study* conducted by Itron, Inc.¹³)

BASE CASE LABOR COST (\$/UNIT)

The base case is the existing equipment; therefore, the base case labor cost is \$0.00.

MEASURE CASE LABOR COST (\$/UNIT)

The installation labor cost of the economizer control adjustment measure offering was derived from contractor survey responses with eight contractors and labor time estimates from CLEAResult field staff obtained in 2018.¹⁴

The installation labor cost of the economizer control replacement measure offering was obtained from contractor survey responses with eight contractors.

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 adopted for this measure is the NTG value stipulated for refrigerant charge adjustment in Resolution E-4952.¹⁵ This NTG is based upon results of an impact evaluation study of commercial sector HVAC quality maintenance programs implemented in California.¹⁶

Net-to-Gross Ratios

| Parameter | Value | Source |
|---|-------|---|
| NTG – HVAC Maintenance: Refrigerant Charge Adjustment | 0.45 | DNV GL. 2017. <i>Impact Evaluation of 2015 Commercial Quality Maintenance Programs (HVAC3)</i> . Prepared for the California Public Utilities Commission. April 7. Table 5. Page 7. |

¹² Pacific Gas and Electric Company (PG&E). 2018. "HVAC QM measure costs.xlsx"

¹³ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

¹⁴ Pacific Gas and Electric Company (PG&E). 2018. "HVAC QM measure costs.xlsx"

¹⁵ California Public Utilities Commission (CPUC). 2018. *Resolution E-4952*. October 11. Page A-35.

California Public Utilities Commission (CPUC). 2019. "Errata and Clarifications for the DEER2020 Update Documentation." January 18.

¹⁶ DNV GL. 2017. *Impact Evaluation of 2015 Commercial Quality Maintenance Programs (HVAC3)*. Prepared for the California Public Utilities Commission. April 7. Table 5. Page 7.

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 | Value | Source |
|-----------|-------|---|
| GSIA - | 1.0 | California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31. |

NON-ENERGY IMPACTS

Non-energy benefits for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

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

DEER Difference Summary

| DEER Item | Comment / Used for Workpaper |
|--------------------------------|--|
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes, with modifications |
| DEER Version | DEER 2020, READI v2.5.1 |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| DEER Measure IDs Used | n/a |
| NTG | Source: Reference HVAC3, Table 7, Resolution E-4952. The NTG of 0.45 is associated with NTG ID: <i>NonRes-HVAC-maint</i> |
| GSIA | Source: READI v.2.5.1 DEER2014. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i> |
| EUL/RUL | Source: Resolution E-4952The value of 3 years is associated with EUL ID: <i>HVAC-RepEcono</i> . |

REVISION HISTORY

Measure Characterization Revision History

| Revision Number | Revision Complete Date | Primary Author, Title, Organization | Revision Summary and Rationale for Revision |
|-----------------|------------------------|-------------------------------------|--|
| 01 | 09/30/2018 | Jennifer Holmes, Cal TF Staff | Draft of consolidated text for this statewide measure is based upon: PGE3PHVC152, Revision 4 (August 1, 2016) Consensus reached among Cal TF members. |
| | 6/13/2019 | Sergio Corona TRC | The following updates were made: Code requirement updated to reflect 2019 Title 20 and 2019 Title 24 versions. The delivery mechanism and sector were updated. DEER prototype IDs used in the model was updated. HVAC types used in the modeling were updated. Building vintages were updated as per latest available DEER guidelines Net -to-gross ratio and Effective-useful-life were updated as per latest available DEER guidelines. Measure costs of equipment and labor were updated using the PGE3PHVC152 attachment. |
| | 06/28/2019 | Jennifer Holmes Cal TF Staff | Revisions for submittal of version 01 |