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**HVAC**  
**SUPPLY FAN CONTROLS, COMMERCIAL**  
SWHC009-01

**C O N T E N T S**

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## MEASURE NAME

Supply Fan Controls, Commercial

## STATEWIDE MEASURE ID

SWHC009-01

## TECHNOLOGY SUMMARY

Supply fan controls modify existing thermostat settings during unoccupied periods from continuous fan operation to intermittent fan operation. Energy savings are achieved as a result of the reduction of unoccupied supply fan runtime unless zone conditions call for cooling or heating. Reduction in unoccupied supply fan runtime can also prevent the introduction of unfavorable outside air into the conditioned space through leaky economizer dampers, causing an unnecessary increase in space heating or cooling.

This measure supports HVAC Quality Maintenance (QM) programs as well as HVAC tune-up programs.

The *HVAC Impact Evaluation Final Report WO32 HVAC* conducted by DNV GL<sup>1</sup> (“WO32 Study”) 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 Economizer Repair weighted savings calculations for this measure.

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<sup>1</sup> DNV GL. 2014. *HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report*. Prepared for California Public Utilities Commission. January 28.

## MEASURE CASE DESCRIPTION

This measure is defined as a supply fan that is set to “Auto” or intermittent during unoccupied periods. Measure offerings (below) are defined by the host equipment type.

### Measure Offerings

Statewide Measure Offering ID	Measure Offering Description
SWHC009A	Unoccupied Fan Control, AC Only Unit
SWHC009B	Unoccupied Fan Control, AC Unit with Gas Heat
SWHC009C	Unoccupied Fan Control, Heat Pump
SWHC009D	Unoccupied Fan Control, Variable Volume AC Unit with Gas Heat

### Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Set supply fan to “Auto” or intermittent during unoccupied periods
Existing Condition	Existing HVAC equipment with the supply fan operating continuously during unoccupied periods
Code/Standard	Not applicable.
Industry Standard Practice	Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems <sup>2</sup>

## BASE CASE DESCRIPTION

The base case is defined as the existing HVAC equipment with the supply fan operating continuously during unoccupied periods.

## CODE REQUIREMENTS

The supply fan control 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) provides control requirements for air economizers, but compliance is not required for maintenance measures.

The Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems<sup>3</sup> may be used by Quality Maintenance (QM) programs as a guide for measure implementation.

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<sup>2</sup> 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*.

<sup>3</sup> 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*.

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 (2013)	None	July 1, 2014
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.*

**Implementation Eligibility**

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

*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.

Contractors and technicians that implement the measure must meet all certification and training requirements in accordance with program requirements.

Contractors and technicians that implement this measure must ensure that the existing unit does not already have the supply fan in automatic mode or switched OFF during unoccupied periods.

Other terms and conditions are set by individual programs.

#### *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 load. The measure SWHC009C (cDXHP) excludes building type WRf.

#### *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.

This measure does not apply if the unoccupied supply fan operation is already set to “Auto” or intermittent.

### USE CATEGORY

HVAC

### DATA COLLECTION REQUIREMENTS

The “Workpaper Disposition for Non-Residential Quality Maintenance” issued by the Energy Division of the California Public Utilities Commission (CPUC)<sup>4</sup> stipulated the adjustment to decrease modeled savings by 50%. Programmable thermostats are required by all of the investor-owned utility (IOU) programs and have requirements on the length of unoccupied setback overrides, only allowing override for a set time period well within the course of a day. Comprehensive analysis on the prevalence of timeclocks being

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<sup>4</sup> California Public Utilities Commission (CPUC), Energy Division. 2013. “Workpaper Disposition for Non-Residential HVAC Rooftop Quality Maintenance.” May 2.

California Public Utilities Commission (CPUC), Energy Division. 2013. “20132014-ResidentialHVACMaintenance-SavingsValues-April2013-v1-2.xlsx”

systematically overridden within the commercial HVAC quality maintenance programs will inform more accurate analysis for this measure.

### 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 3.65.7175 energy modeling software and eQUEST Refrigeration version 3.65-7175 for the refrigeration models.<sup>5</sup>

Prototypes from the Database of Energy Efficient Resources (DEER) were utilized for the building energy use simulations.

The DEER 2020 base case prototypes of the Measure IDs shown below were used to develop base and measure case energy use and demand estimates. The DEER prototypes were generated using MASControl3 software, and all modeling was conducted using the Title 24 CZ2010 weather files.

#### DEER Prototype MASControl3 Measure IDs

Measure	DEER MASControl3 Measure_ID
Unoccupied Fan Control on AC Unit with Gas Heat	<b>Non-Motel:</b> NE-HVAC-airAC-SpltPkg-135to239kBtuh-11p5eer
	<b>Motel:</b> Com-lltg-dWatt-EX-All
Unoccupied Fan Control on AC Only Unit	<b>Non-Motel:</b> NE-HVAC-airAC-SpltPkg-135to239kBtuh-11p5eer
	<b>Motel:</b> Com-lltg-dWatt-EX-All
Unoccupied Fan Control on Heat Pump	<b>Non-Education Relocatable Classroom:</b> NE-HVAC-airHP-SpltPkg-135to239kBtuh-11p5eer-3p2cop
	<b>Education Relocatable Classroom:</b> NE-HVAC-airHP-Pkg-55to65kBtuh-15p0seer-8p2hspf
Unoccupied Fan Control on Variable Volume AC Unit with Gas Heat	<b>All:</b> NE-HVAC-airAC-SpltPkg-240to759kBtuh-10p8eer_MZ

With the exception of the motel building type and education relocatable classroom building type with heat pumps, DEER prototypes for air conditioning (AC) and heat pump measures were created using the “135to239kBtuh” cooling capacity range. This capacity range allows prototypes to be generated for the widest range of building types. Variable Volume AC units were not available in the “110to134kBtuh” range and were created using “240to759kBtuh”.

The baseline models for the unoccupied fan control measures are simulated with a fault representing HVAC units in an as-found condition – in this case the fault is a supply fan schedule operating 24/7 incongruously with occupancy. To implement unoccupied fan control fault simulations, specific

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<sup>5</sup> Pacific Gas & Electric Company (PG&E). 2018. “SWHC009-01 Model Files.zip.”

modifications to eQUEST keywords shown below were performed on all system types serving conditioned spaces.

#### Baseline Modifications to eQuest Keywords

Modeled Faults	eQUEST Keyword	DEER Value	Modified Baseline Value
24/7 Continuous Supply Fan Operation	SYSTEM:FAN-SCHEDULE	Varies	Hourly Report Schedule
	SYSTEM:INDOOR-FAN-MODE	CONTINUOUS	CONTINUOUS

The SYSTEM:INDOOR-FAN-MODE keyword identifies continuous or intermittent supply fan operation during occupied periods. It is set as CONTINUOUS in both the baseline and measure case. The SYSTEM:FAN-SCHEDULE keyword assigns an ON/OFF schedule which requires the supply fan to follow occupied operation set by SYSTEM:INDOOR-FAN-MODE. An hour set to ON results in continuous supply fan operation during that hour while an hour set to OFF results in intermittent operation corresponding to calls for cooling or heating. The DEER value for SYSTEM:FAN-SCHEDULE varies by prototype but all employ schedules that align the supply fan occupied operation with the building occupancy schedules. The base case assigns the SYSTEM:FAN-SCHEDULE keyword value to “Hourly Report Schedule” which has all hours set to ON, resulting in 24 hours per day supply fan operation regardless of building occupancy.

The following building types already utilize 24/7 occupied schedules in which case the modeled fault results in the same energy use as the measure scenario: hospitals (Hsp), motels (Mtl), and nursing homes (Nrs). These building types were therefore not simulated and can be reported as having zero energy savings.

The DEER prototypes were used as the reference models for the measure case buildings and are unmodified.

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

#### Building Description and Models

Building Type	Building Type 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	No
Nursing Home	Nrs	No
Hotel	Htl	No
Motel	Mtl	No
Bio/Tech Manufacturing	MBT	No
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	No

Building Type	Building Type Code	Modeled
Big Box Retail	RtL	Yes
Small Retail	RtS	Yes
Conditioned Storage	SCn	No
Unconditioned Storage	SUn	No
Refrigerated Warehouse	WRF	Yes

### Climate Zones

Climate Zone	Climate Zone Description	Modeled
1	Arcata Area (CZ01)	No
2	Santa Rosa Area (CZ02)	Yes
3	Oakland Area (CZ03)	Yes
4	Sunnyvale Area (CZ04)	Yes
5	Santa Maria Area (CZ05)	No
6	Los Angeles Area (CZ06)	Yes
7	San Diego Area (CZ07)	No
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
16	Mount Shasta Area (CZ16)	No

### Vintage Weighted Average

Baseline and measure simulations used the DEER building vintages<sup>6</sup> (below) 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)

<sup>6</sup> California Public Utilities Commission (CPUC). 2014. "DEER2014 Energy Impact Weights Tables v2."

DEER 2020 vintage weighting tables<sup>7</sup> 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 weighting methodology.

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

*final weighted value* = *Reported energy savings value (kWh/ton, kW/ton, or therms/ton)*  
*i* = *Vintage*  
*W* = *Weight for a given vintage i*  
*V* = *Unit energy savings value for a given vintage (kWh/ton, kW/ton, or therms/ton)*

### HVAC Type

DXGF (Packaged DX with Gas Furnace)

### Thermostat Options

Programmable thermostat

### Case Options

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

### DEER Prototype Modifications

Modifications were made to the DEER prototypes to simulate outside air damper leakage, return air damper leakage, and exhaust re-entrainment. These modified DEER prototypes were then used to develop the base and measure case eQUEST energy use simulation models. The rationale for the damper leakage modifications is described below.

In consultation with a representative of the California Public Utilities Commission (CPUC) Energy Division Ex-Ante Review Team, the following DEER prototype modifications to develop appropriate baseline assumptions were agreed upon:

1. A minimum outside air fraction of 20% was used instead of 0% due to emerging research (not yet published at the time of the meeting) that indicates closed damper leakage for packaged HVAC systems are higher than previously thought.

<sup>7</sup> California Public Utilities Commission (CPUC), Energy Division. (n.d.) "DEER2020-Building-Weights.xlsx."

2. A maximum outside air fraction of 70% was used instead of 100% due to emerging research (was 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.

The *HVAC Impact Evaluation FINAL Report WO32 HVAC* conducted by DNV GL (“WO32 Study”)<sup>8</sup> confirmed that these outside air assumptions are consistent with the best available laboratory data and were therefore used to adjust baseline assumptions for this measure.

Specific modifications to eQUEST keywords shown below were performed to implement these DEER prototype modifications. These modified DEER prototype models are referred to as the “Damper Leakage” prototypes.

### Base Case Energy Use Simulation

The base case energy use simulation methodology begins with the Damper Leakage prototypes and alters the models to simulate faults representing HVAC units in an as-found condition.

To implement Unoccupied Fan Control fault simulations to the Damper Leakage prototypes, specific modifications to eQUEST keywords shown below were performed on all systems types serving conditioned spaces.

#### Baseline Modifications to eQUEST Keywords

Modeled Faults	eQUEST Keyword	DEER Value	Modified Baseline Value
24/7 Continuous Supply Fan Operation	SYSTEM:FAN-SCHEDULE	Varies	Hourly Report Schedule
	SYSTEM:INDOOR-FAN-MODE	CONTINUOUS	CONTINUOUS

The SYSTEM:INDOOR-FAN-MODE keyword identifies continuous or intermittent supply fan operation during occupied periods. It is set as CONTINUOUS in both the Damper Leakage prototypes and the fault case. The SYSTEM:FAN-SCHEDULE keyword assigns an ON/OFF schedule which requires the supply fan to follow occupied operation set by SYSTEM:INDOOR-FAN-MODE. An hour set to ON results in continuous supply fan operation during that hour while an hour set to OFF results in intermittent operation corresponding to calls for cooling or heating. The Damper Leakage prototype value for SYSTEM:FAN-SCHEDULE varies by prototype but all employ schedules that align the supply fan occupied operation with the building occupancy schedules. The base case assigns the SYSTEM:FAN-SCHEDULE keyword value to “Hourly Report Schedule” which has all hours set to ON, resulting in 24 hours per day supply fan operation regardless of building occupancy.

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<sup>8</sup> DNV GL. 2014. *HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report*. Prepared for California Public Utilities Commission. January 28.

The following building types already utilize 24/7 occupied schedules in which case the modeled fault results in the same energy use as the Damper Leakage prototypes: hospitals (Hsp), motels (Mtl), nursing homes (Nrs), and conditioned storage (SCn).

### Measure Case Energy Use Simulation

The Damper Leakage prototypes were used as the reference models for the measure case buildings were unmodified.

### Electric Unit Energy Savings Calculation

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

$$UES_{kWh} = \left[ \frac{UEC_{baseline\ wtd\ kWh} - UEC_{measure\ kWh}}{CoolTons} \right] \times TStatReprog$$

- UES = Annual unit energy savings, kWh/ton*
- UEC<sub>baseline wtd kWh</sub> = Annual building energy consumption from each modeled fault weighted by the frequency distribution the corresponding as-found condition*
- UEC<sub>measure kWh</sub> = Annual building energy consumption of measure*
- CoolTons = Design cooling capacity of base case non-PTAC systems*
- TStatReprog = Multiplier applied to thermostat reprogramming to adjust for non-continuous operation and inappropriate setpoints*

The thermostat reprogramming multiplier is applied to UES in conformance with the “Workpaper Disposition for Non-Residential Quality Maintenance” issued by the Energy Division of the California Public Utilities Commission (CPUC) in May 2013.

#### Thermostat Reprogramming Multiplier

Parameter	Value	Source
Thermostat Reprogramming Multiplier	0.50	California Public Utilities Commission (CPUC), Energy Division. 2013. “Workpaper Disposition for Non-Residential HVAC Rooftop Quality Maintenance.” May 2. Page 11.

### Sample Calculation

A sample calculation using a 1996 vintage small office (Ofs) prototype with AC and Gas Heat located in climate zone 1 is provided below.

## OfS-w01-v96-airAC Prototype Electric Energy Use and Cooling Capacity Data

	24/7 Continuous Supply Fan Operation	Measure
Whole building energy use (kWh/yr)	120,995	105,149
System cooling capacity (Btu/hr)	261,909	261,909

$$363.01 \left( \frac{kWh}{ton \times year} \right) = \left( \frac{120,995 \left( \frac{kWh}{year} \right) - 105,149 \left( \frac{kWh}{year} \right)}{261,909 \left( \frac{Btu}{h} \right) / 12,000 \left( \left( \frac{Btu}{h} \right) / ton \right)} \right) \times 0.5$$

## 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) 2015 prototypes were developed for the CAV (Customer Average) case using MASControl v3.00.27, the .INP file was then imported into eQUEST and modifications were made to develop the base case and the measure case. (See Electric Savings.)

The demand reduction was estimated using the average hourly peak demand for the 15 hours of the DEER peak period from 4:00 p.m. to 9:00 p.m. during the three consecutive weekday period within the dates of June 1<sup>st</sup> through September 30<sup>th</sup>.<sup>9</sup>

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.

$$DemandReduction_{kW} = \left[ \frac{Demand_{Baseline} - Demand_{Measure}}{CoolTons} \right] \times TStatReprog$$

*DemandReduction* = Annual unit demand reduction

*Demand<sub>Baseline</sub>* = Average demand for DEER peak period of customer average from each modeled fault weighted by the frequency distribution the corresponding as-found condition.

*Demand<sub>Measure</sub>* = Average demand for DEER peak period of measure

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

*TStatReprog* = Multiplier applied to thermostat reprogramming to adjust for non-continuous operation and inappropriate setpoints

<sup>9</sup> California Public Utilities Commission (CPUC). 2018. *Resolution E-4952*. October 11.

A sample calculation using a 1996 vintage small office (OfS) prototype located in climate zone 1 is provided below. The table below provides electric energy use and cooling capacity data for the baseline and measure case on the Asm prototype approximating a building constructed in 1996 in climate zone 11.

#### OfS-w01-v96-airAC Prototype Electric Demand Use and Cooling Capacity Data

	24/7 Continuous Supply Fan Operation	Measure
9/16 2-3pm demand (kW)	30.32	31.43
9/16 3-4pm demand (kW)	29.90	30.90
9/16 4-5pm demand (kW)	23.33	24.29
9/17 2-3pm demand (kW)	29.28	30.30
9/17 3-4pm demand (kW)	29.03	30.02
9/17 4-5pm demand (kW)	22.84	23.76
9/18 2-3pm demand (kW)	37.78	38.50
9/18 3-4pm demand (kW)	36.53	37.14
9/18 4-5pm demand (kW)	30.75	31.28
<b>DEER Demand Average (kW)</b>	<b>29.97</b>	<b>30.85</b>
System cooling capacity (Btu/hr)	261,909	261,909

$$-0.0200 \left( \frac{kW}{ton} \right) = \left( \frac{29.97(kW) - 30.85(kW)}{261,909 \left( \frac{Btu}{h} \right) / 12,000 \left( \frac{Btu}{h} \right) / ton} \right) \times 0.5$$

#### GAS SAVINGS (THERMS)

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 3.65.7175 energy modeling software and eQUEST Refrigeration version 3.65-7175 for the refrigeration models.<sup>10</sup>

Prototypes from the Database of Energy Efficient Resources (DEER) were utilized for the building energy use simulations. See Electric Savings for details for the building simulation models.

The gas unit energy savings (UES) is calculated as the difference between the baseline and measure UEC, then normalized by the system cooling capacity.

$$UES_{therms} = \left[ \frac{UEC_{baseline \text{ wtd therms}} - UEC_{measure \text{ therms}}}{CoolTons} \right] \times TStatReprog$$

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

<sup>10</sup> Pacific Gas & Electric Company (PG&E). 2018. "SWHC009-01 Model Files.zip."

*UEC<sub>baseline wtg therms</sub>* = Annual building energy consumption from each modeled fault weighted by the frequency distribution the corresponding as-found condition

*UEC<sub>measure therms</sub>* = Annual building energy consumption of measure

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

*TStatReprog* = Multiplier applied to thermostat reprogramming to adjust for non-continuous operation and inappropriate setpoints

The thermostat reprogramming multiplier is applied to UES in conformance with the “Workpaper Disposition for Non-Residential Quality Maintenance” issued by the Energy Division of the California Public Utilities Commission (CPUC) in May 2013.

**Thermostat Reprogramming Multiplier**

Parameter	Value	Source
Thermostat Reprogramming Multiplier	0.50	California Public Utilities Commission (CPUC), Energy Division. 2013. “Workpaper Disposition for Non-Residential HVAC Rooftop Quality Maintenance.” May 2. Page 11.

**Sample Calculation**

A sample calculation using a 1996 vintage small office (OfS) prototype with AC and Gas Heat located in climate zone 1 is provided below.

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

	24/7 Continuous Supply Fan Operation	Measure
Whole building energy use (Therms/yr)	1,651.58	1,007.32
System cooling capacity (Btu/hr)	261,909	261,909

$$14.8 \left( \frac{\text{Therms}}{\text{ton} \times \text{year}} \right) = \left( \frac{1,651.58 \left( \frac{\text{Therms}}{\text{year}} \right) - 1,007.32 \left( \frac{\text{Therms}}{\text{year}} \right)}{261,909 \left( \frac{\text{Btu}}{\text{h}} \right) / 12,000 \left( \left( \frac{\text{Btu}}{\text{h}} \right) / \text{ton} \right)} \right) \times 0.5$$

**Vintage Weighted Average**

Baseline and measure simulations used the DEER building vintages<sup>11</sup> (below) 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

<sup>11</sup> California Public Utilities Commission (CPUC). 2014. “DEER2014 Energy Impact Weights Tables v2.”

DEER Vintage Code	Description
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 2014 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 2014 weighting methodology.

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

*final weighted value* = *Reported energy savings value (kWh/ton, kW/ton, or therms/ton)*  
*i* = *Vintage 75, 85, 96, 03, 07, 11, 14*  
*W* = *Weight for a given vintage i*  
*V* = *Unit energy savings value for a given vintage (kWh/ton, kW/ton, or therms/ton)*

### 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 EUL and RUL specified for this measure are presented below. Note that RUL is only applicable for add-on equipment and accelerated replacement measures thus not applicable for this measure.

#### 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-36 – A-37.
RUL (yrs)	n/a	

### BASE CASE MATERIAL COST (\$/UNIT)

The base case is the existing equipment; therefore, the base case cost is equal to \$0.

### MEASURE CASE MATERIAL COST (\$/UNIT)

This measure does not require the purchase of materials or equipment; thus, the measure case material cost is equal to \$0.

### BASE CASE LABOR COST (\$/UNIT)

The base case is the existing equipment; therefore, the base case labor cost is equal to \$0.

### MEASURE CASE LABOR COST (\$/UNIT)

The measure case installation labor cost is based upon the nonresidential miscellaneous (NR-Misc) labor rate specified in the Database for Energy Efficient Resources (DEER).<sup>12</sup> Labor cost inputs are specified below.

#### Measure Installation Labor Cost Inputs

Parameter	Value	Source
Hourly Labor Rate (\$/hour)	\$67.88	Keneipp, F. and M. Yim. (Summit Blue Consulting, LLC). 2008. 2008 DEER Measure Cost Documentation.
Labor Hours (hours)	1.0	Pacific Gas & Electric Company (PG&E). 2018. "HVAC QM measure costs_05102018.xlsx."
Average Rooftop Unit Tonnage	12.5	

### 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 ratio for nonresidential HVAC refrigerant charge adjustment (RCA) is adopted for this measure. This value, stipulated in Resolution E-4952,<sup>13</sup> is based upon results of an impact evaluation study of commercial sector HVAC quality maintenance programs implemented in California.<sup>14</sup>

#### Net-to-Gross Ratios

Parameter	Value	Source
NTG – HVAC Maintenance:	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.

### 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.

<sup>12</sup> Pacific Gas & Electric Company (PG&E). 2018. "HVAC QM measure costs\_05102018.xlsx."

<sup>13</sup> 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.

<sup>14</sup> 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 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 impacts for this measure have not been quantified.

**DEER DIFFERENCES ANALYSIS**

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

**DEER Difference Summary**

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	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 2015 and DEER 2017, READI v2.2.0
Reason for Deviation from DEER	DEER does not contain this type of measure.
DEER Measure IDs Used	n/a
NTG	Source: E-4952 (Errata). The NTG of 0.45 is associated with NTG ID: <i>NonRes- HVAC-maint</i>
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: E-4952. The value of 3.0 years is associated with EUL ID: <i>NonRes- RCx-Operational</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: PGE3PHVC157, Revision 2 (October 8, 2015) Consensus reached among Cal TF members.
	06/06/2019	Tai Voong (PG&E) CLEAResult	Updates for: PGE3PHVC157, Revision 4 (November 20, 2018) 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 PGE3PHVC157R4.
	06/11/2019	Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.