



**eTRM**

*best in class*

## SERVICE ECONOMIZER REPAIR

SWSV005-01

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**MEASURE NAME**

Economizer Repair

**STATEWIDE MEASURE ID**

SWSV005-01

**TECHNOLOGY SUMMARY**

The Economizer Repair measure guides the technician to address common problems leading to a non-functional economizer. Energy savings are achieved by restoring economizer functionality, thus allowing the HVAC unit to utilize cool outside air prior to mechanical cooling below the high limit setpoint as well as reducing unnecessary conditioning of outside air above the high limit setpoint.

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

**HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report<sup>1</sup> (2014, DNV GL).** This document (the “WO32 Study”) is a study of 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 the restoration of economizer functionality through repairs. The economizer should be repaired to a functional state and economizers with existing analog controllers have the option of adding an advanced digital economizer controller (ADEC). As such, measure offerings are defined by the presence of an advanced digital economizer controller (ADEC), as well as the host equipment type.

### Measure Case Specification

Measure Type	Host Equipment Type
Economizer Repair (ADEC)	AC Only Unit
	AC Unit with Gas Heat
	Heat Pump
	Variable Volume AC Unit with Gas Heat
Economizer Repair (Non-ADEC)	AC Only Unit
	AC Unit with Gas Heat
	Heat Pump
	Variable Volume AC Unit with Gas Heat

### Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Restore economizer functionality through repairs
Existing Condition	Existing HVAC equipment with non-functional economizer
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 a non-functional economizer. This measure assumes the existing unit is equipped with a non-functional economizer with the outside air dampers either failed closed or partially open. These scenarios address common as-found conditions in the field including broken or worn linkages, stuck dampers, inadequate wiring, inoperable damper actuators, or malfunctioning controllers.

## CODE REQUIREMENTS

The economizer repair 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.

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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*.

The Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems<sup>2</sup> 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	Jan 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.*

#### Implementation Eligibility

Measure Application Type	Delivery Type	Sector
BRO-RCx	Direct Install	Com
BRO-RCx	Down-Stream Incentive	Com
BRO-RCx	Direct Install	Ag
BRO-RCx	Down-Stream Incentive	Ag
BRO-RCx	Direct Install	Ind
BRO-RCx	Down-Stream Incentive	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. This measure applies to existing building vintages 2003, 2007, 2011 and 2015.

*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.

The DEER prototypes for the Refrigerated Warehouse (WRf) building type did not include the Heat Pump HVAC system type. Thus, heat pump measures are not included for that building type.

**DATA COLLECTION REQUIREMENTS**

While WO32<sup>1</sup> is useful in quantifying outdoor air flow and characterizing non-functional economizer conditions, additional data would corroborate and further characterizing the findings. For example, the laboratory testing referenced in WO32<sup>1</sup> was conducted on one 7.5-ton two-compressor commercial packaged unit; this could be expanded to encompass packaged units from other manufacturers for additional data points to quantify outdoor air flow at varying damper positions. Regarding further characterization of existing non-functional economizer conditions, WO32 provides the fault distribution for economizers failing closed or partially open but could be broken down further into each typical setting (i.e., 1-finger, 2-finger, 3-finger, fully open).

**USE CATEGORY**

Service

## 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 2020 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 with some modification (see DEER Prototype Modifications) to develop base and measure case unit energy consumption (UEC) and demand estimates.

### DEER Prototype Tech ID by Measure

Measure	DEER Prototype Tech ID
Economizer Repair (non-ADEC) on AC unit with gas heat Economizer Repair (ADEC) on AC unit with gas heat	<b>All:</b> NE-HVAC-airAC-SpltPkg-65to134kBtuh-11p5eer-wPreEcono MASControl v3.00.00
Economizer Repair (non-ADEC) on AC Only Unit Economizer Repair (ADEC) on AC Only Unit	<b>All:</b> NE-HVAC-airAC-SpltPkg-65to134kBtuh-11p5eer-wPreEcono MASControl v3.00.00
Economizer Repair (non-ADEC) on Heat Pump Economizer Repair (ADEC) on Heat Pump	<b>Non-Education Relocatable Classroom:</b> NE-HVAC-airHP-SpltPkg-65to134kBtuh-11p5eer-3p4cop-wPreEconoMASControl v3.00.20
	<b>Education Relocatable Classroom:</b> NE-HVAC-airHP-Pkg-55to65kBtuh-15p0seer-8p2hspf-wPreEconoMASControl v3.00.00
Economizer Repair (non-ADEC) on Variable Volume AC Unit with Gas Heat Economizer Repair (ADEC) on Variable Volume AC Unit with Gas Heat	<b>All:</b> NE-HVAC-airAC-SpltPkg-240to759kBtuh-10p8eer_SZ MASControl v3.00.00

With the exception of the education relocatable classroom building type with heat pumps, 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

Building Type	BT Code	Modeled
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	No

#### 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
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**

N/A

**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**

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 stated in the *HVAC Impact Evaluation FINAL Report WO32 HVAC* conducted by DNV GL



(2014)) 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 (was not yet published stated in the *HVAC Impact Evaluation FINAL Report WO32 HVAC* conducted by DNV GL (2014)) 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 (2014)<sup>1</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.

Ideally, the DEER 2020 prototypes should have incorporated the above findings. However, based on the review of the prototypes, it was found that the DEER 2020 prototypes partially addressed the leakage and re-entrainment issues discussed above.

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.

#### Baseline Modifications to eQUEST Keywords

eQUEST Keyword	DEER Value	Modified Baseline Value
SYSTEM:MIN-OUTSIDE-AIR	Varies	0.2
SYSTEM:MAX-OA-FRACTION	1.0	0.7
ZONE: OUTSIDE-AIR-FLOW	Varies	Set such that ZONE: OUTSIDE-AIR-FLOW is between: 1. 0.2 x Supply Air Flow Rate 2. 0.7 x Supply Air Flow Rate  This modification ensures the first two keywords are not overwritten.
DAY-SCHEDULE:VALUES[#]  Only in daily schedules being used for SYSTEM:MIN-AIR-SCH	0.001 for unoccupied periods, -999 for occupied periods	Modify 0.001 to 0.2 during unoccupied periods.  This modification ensures that unit operation during scheduled unoccupied periods will properly simulate damper leakage.
SYSTEM:OA-CONTROL	FIXED	OA-TEMP  Code Update and could not be created with default economizer baseline.

The SYSTEM modifications were applied to every direct expansion (DX) cooling HVAC system in the model except for packaged terminal air conditioners (PTACs) which are unlikely to have economizers and thus economizer damper leakage.

The ZONE modification was applied to each conditioned zone served by the effected HVAC systems.

The DAY-SCHEDULE modification was only applied to schedules being assigned to SYSTEM:MIN-AIR-SCH and avoids effecting PTAC units assigned to the same schedule by duplicating the DAY-SCHEDULE,

renaming and assigning them to the PTAC systems, and only modifying original applicable DAY-SCHEDULE values.

Hourly reports were verified to ensure that the keyword changes properly simulated the desired effects of damper leakage for both the occupied and unoccupied periods. The only three building types affected by the omission of PTACs were hospitals (Hsp), hotels (Htl), and universities (EUn).

### 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. The table below specifies the modeled and represented as-found changeover setting faults covered by this economizer repair measure. The non-functional economizer fault is modeled to include two scenarios: failed closed and failed partially open at the most commonly set damper position.

#### Modeled and Represented As-Found Conditions

Modeled Faults	Represented As-Found Conditions
Non-Functional Economizer, Dampers Failed Closed	Non-functional control module
	Stuck damper
	Frozen linkage
Non-Functional Economizer, Dampers Failed Partially Open	Non-functional damper motor

The model assumes a fixed outside air fraction of 20% for the failed closed scenario and a fixed outside air fraction of 30% for the failed partially open scenario. These assumptions are supported by WO32<sup>1</sup>, which provides outside air fractions (OAF) for the most common damper positions. The OAF of 30% for the failed partially open scenario is an average of the OAF for one or more fingers open.

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
Non-Functional Economizer, Dampers Failed Closed	SYSTEM:OA-CONTROL	OA-TEMP	FIXED
	SYSTEM:OA-CONTROL	OA-TEMP	FIXED
	SYSTEM:MIN-OUTSIDE-AIR	Damper Leakage Prototype, 0.2	0.3
Non-Functional Economizer, Dampers Failed Partially Open	ZONE: OUTSIDE-AIR-FLOW	Damper Leakage Prototype, Set such that ZONE: OUTSIDE-AIR-FLOW is between:	Set such that ZONE: OUTSIDE-AIR-FLOW is between:
		1. 0.2 x Supply Air Flow Rate	3. 0.3 x Supply Air Flow Rate
		2. 0.7 x Supply Air Flow Rate	4. 0.7 x Supply Air Flow Rate
			This modification ensures the first two keywords are not overwritten.

Modeled Faults	eQUEST Keyword	DEER Value	Modified Baseline Value
		This modification ensures the first two keywords are not overwritten.	
	DAY-SCHEDULE:VALUES[#]  Only in daily schedules being used for SYSTEM:MIN-AIR-SCH	Damper Leakage Prototype, 0.2 for unoccupied periods, -999 for occupied periods	Modify 0.2 to 0.3 during unoccupied periods.

The final Economizer Repair measure combines results from the modeled faults weighted by the corresponding frequency of that fault seen in the field. Based on WO32<sup>1</sup> findings, the damper failed closed scenario is weighted by 0.25 and the damper failed partially open scenario weighted by 0.75.

### Measure Case Energy Use Simulation

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

The table below specifies how the inputs for the for two base case eQUEST models were modified to develop the measure case. The Field and eQUEST Keyword columns list the keywords exactly how they are listed in the INP files for all cases. The example displayed in the table below belongs to the following offerings Economizer Repair (ADEC) on AC Unit with Gas Heat (HV3006) and Economizer Repair (Non-ADEC) on AC Unit with Gas Heat (HV302). It is important to note that on three out of the 5 changes are specific to one type, a day schedule and 2 specific zones.

#### eQUEST Keyword Comparison between the Base Cases and the Measure Case Example

Field	eQUEST Keyword	Base Case (Failed Closed)	Base Case (Failed Partially Open)	Measure Case
Day Schedules ("S1 Sys1 (PVVT) MinOA All" = DAY-SCHEDULE-PD TYPE = FRAC/DESIGN)	VALUES	( 0.2, &D, &D, &D, &D, &D, &D, &D, -999, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, 0.2 )	( 0.3, &D, &D, &D, &D, &D, &D, &D, -999, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, 0.3 )	( 0.2, &D, &D, &D, &D, &D, &D, &D, -999, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, &D, 0.2 )
HVAC Systems / Zones	MIN-OUTSIDE-AIR	0.2	0.3	0.2
	OA-CONTROL	FIXED	FIXED	OA-TEMP
HVAC Systems / Zones ("EL1 East Perim Zn (G.E4)" = ZONE)	OUTSIDE-AIR-FLOW	SET-DEFAULT FOR ZONE TYPE = CONDITIONED OUTSIDE-AIR-FLOW = ( {if (#L("OA-FLOW/AREA")*#LR("SPACE","AREA"))/#L("ASSIGNED-FLOW") < 0.2) then (#L("ASSIGNED-FLOW")*0.2) else if (#L("OA-FLOW/AREA")*#LR("SPACE","AREA"))/#L("ASSIGNED-FLOW") > 0.7) then (#L("ASSIGNED-FLOW")*0.7) else (#L("OA-FLOW/AREA")*#LR("SPACE","AREA")) endif endif } )..		

### Electric Unit Energy Savings Calculation

The electric unit energy savings (UES) is calculated as the difference between the baseline and measure UEC, then normalized by the system cooling capacity. Savings are calculated for a weighted average of the DEER 2020 vintages using utility-specific weightings.

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

$UES =$  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<sup>3</sup>

Fault Distribution	Fault Weight	Source
Non-functional economizer, dampers failed closed	.25	California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Non-Residential HVAC Rooftop Quality Maintenance." May 2. Page 14.
Non-functional economizer, dampers failed partially open	.75	

### 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 in the table 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

	Dampers Failed Closed	Dampers Failed Partially Open	Measure
Whole building energy use (kWh/yr)	75,595	75,597	71,823
System cooling capacity (Btu/h)	349,888	349,888	349,888

<sup>3</sup> from PGECOHC138 Nonresidential HVAC RTU Quality Maintenance

$$165.21 \left( \frac{kWh}{ton \times year} \right) = \frac{\left( 75,595 \left( \frac{kWh}{year} \right) \times 0.25 + 75,597 \left( \frac{kWh}{year} \right) \times 0.75 \right) - 71,823 \left( \frac{kWh}{year} \right)}{349,888 \left( \frac{Btu}{h} \right) / 12,000 \left( \left( \frac{Btu}{h} \right) / ton \right)}$$

### PEAK ELECTRIC DEMAND REDUCTION (kW)

Peak demand reduction was derived using the same methodology to derive electric unit energy savings. The peak demand reduction was estimated using energy modeling software, eQUEST version 3.65. The Database of Energy Efficient Resources (DEER) 2020 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 DEER peak period <sup>4</sup> from 4 pm to 9 pm during the three consecutive weekday period within the dates of June 1<sup>st</sup> through September 30<sup>th</sup>.

The following calculation determined the demand reduction per ton of cooling capacity.

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

*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

A sample calculation using a 2007 vintage small office (OfS) prototype located in climate zone 1 is provided. The table below provides demand 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 Use and Cooling Capacity Data

	Dampers Failed Closed	Dampers Failed Partially Open	Measure
9/16 4-5pm demand (kW)	24.06	24.06	22.41
9/16 5-6pm demand (kW)	17.89	17.89	16.03
9/16 6-7pm demand (kW)	7.00	7.00	7.00
9/16 7-8pm demand (kW)	3.85	3.85	3.85

<sup>4</sup> Resolution E-4952 Approval of the Database for Energy-Efficient Resources updates for 2020 and revised version 2019

9/16 8-9pm demand (kW)	3.40	3.40	3.40
9/17 4-5pm demand (kW)	22.91	22.91	20.94
9/17 5-6pm demand (kW)	17.01	17.01	15.06
9/17 6-7pm demand (kW)	7.00	7.00	7.00
9/17 7-8pm demand (kW)	3.85	3.85	3.85
9/17 8-9pm demand (kW)	3.40	3.40	3.40
9/18 4-5pm demand (kW)	27.54	27.54	27.62
9/18 5-6pm demand (kW)	21.92	21.92	21.97
9/18 6-7pm demand (kW)	7.21	7.21	7.21
9/18 7-8pm demand (kW)	3.85	3.85	3.85
9/18 8-9pm demand (kW)	3.40	3.40	3.40
<b>DEER Demand Average (kW)</b>	<b>11.62</b>	<b>11.62</b>	<b>11.13</b>
System cooling capacity (Btu/hr)	349,888	349,888	349,888

$$0.01667 \left( \frac{kW}{ton} \right) = \frac{(11.62(kW) \times 0.25 + 11.62(kW) \times 0.75) - 11.13(kW)}{349,888 \left( \frac{Btu}{h} \right) / 12,000 \left( \left( \frac{Btu}{h} \right) / ton \right)}$$

### GAS SAVINGS (THERMS)

The gas unit energy savings (UES) is calculated as the difference between the baseline and measure UEC, then 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

$UEC_{baseline\ wtd\ therms} =$  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

The weightings presented below are derived from PGECOHVC138 Nonresidential HVAC RTU Quality Maintenance. These factors weigh the type of equipment failure observed in the field.

### Weight Factors for Savings Calculations<sup>3</sup>

Fault Distribution	Fault Weight	Source
Non-functional economizer, dampers failed closed	.25	California Public Utilities Commission (CPUC), Energy Division. 2013. "Workpaper Disposition for Non-Residential HVAC Rooftop Quality Maintenance." May 2. Page 14.
Non-functional economizer, dampers failed partially open	.75	

## 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. 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 Natural Gas Energy Use and Cooling Capacity Data

	Dampers Failed Closed	Dampers Failed Partially Open	Measure
Whole building energy use (kWh/yr)	1,119.94	1,132.64	1,118.76
System cooling capacity (Btu/hr)	349,888	349,888	349,888

$$0.36715 \left( \frac{\text{Therms}}{\text{ton} \times \text{year}} \right) = \frac{\left( 1,119.94 \left( \frac{\text{Therms}}{\text{year}} \right) \times 0.25 + 1,132.64 \left( \frac{\text{Therms}}{\text{year}} \right) \times 0.75 \right) - 1,118.76 \left( \frac{\text{Therms}}{\text{year}} \right)}{349,888 \left( \frac{\text{Btu}}{\text{h}} \right) / 12,000 \left( \left( \frac{\text{Btu}}{\text{h}} \right) / \text{ton} \right)}$$

## Vintage Weighted Average

Baseline and measure simulations used the DEER building vintages (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

The final UES for each measure offering was calculated as the weighted average savings of all building vintages using the DEER impact weights.<sup>5</sup> The impact weights are expressed as percentages for each of the “eras” used for DEER weighted measures. The impact weights are used to weight savings values provided for specific building vintages of each era. The eras and their vintages that were used within the calculations for this workpaper are as follows: “Ex” - Existing/Median Vintage: 2003, 2007, 2011, and

<sup>5</sup> DEER 2020 Building Weights Tables.

2015. The impact weights were found by normalizing the DEER weight (“wt\_vint”) for each permutation of Building Type, Climate Zone, and Vintage by the total for its Building Type, Climate Zone, and Era.

## 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.”<sup>6</sup> This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.<sup>7</sup> 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.<sup>8</sup>

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	HVAC-RepEcono, DEER 2020 D20 v1
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)

Costs for these measures are not included in the 2010-2012 WO017 Ex Ante Measure Cost Study Final Report<sup>9</sup> by ITRON (Cost Study). The PG&E HVAC CQM Measure Costs document<sup>10</sup> is used to report estimated material and labor costs.

<sup>6</sup> California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

<sup>7</sup> KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

<sup>8</sup> California Public Utilities Commission (CPUC). 2016. Resolution E-4807. December 16. Page 13.

<sup>9</sup> Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

<sup>10</sup> PGE3PHVC152 attachment HVAC CQM Measure Costs document



**Economizer Repair (non-ADEC).** The material cost of the economizer repair non-ADEC measure offering is based on the equipment cost estimates were provided by CLEAResult field staff.

**Economizer Repair (ADEC).** The material cost of the economizer repair ADEC measure offering is based on a combination of manufacturer pricing and program invoicing.

Measure	Measure Detail	Equipment Cost (\$/ton)
Economizer Repair	Non-ADEC	\$ 21.99
	ADEC	\$ 69.61

### 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 PG&E HVAC CQM Measure Costs document<sup>10</sup> is used to report estimated material and labor costs.

**Economizer Repair (non-ADEC).** The installation labor cost of the economizer repair non-ADEC measure offering was obtained from contractor survey responses with 8 contractors.

**Economizer Repair (ADEC).** The installation labor cost of the economizer repair non-ADEC measure offering was obtained from contractor survey responses with 8 contractors.

Measure	Measure Detail	Labor Cost (\$/ton)
Economizer Repair	Non-ADEC	\$ 28.01
	ADEC	\$ 56.87

### 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 relevant NTG values for this measure are specified in below.

#### Net-to-Gross Ratios

Parameter	Value	Source
NTG – HVAC Maintenance: Refrigerant Charge Adjustment	0.45	Reference HVAC3, Table 7, Resolution E-4952 Approval of the Database for Energy-Efficient Resources updates for 2020 and revised version 2019

## 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 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 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	<b>Source:</b> Reference HVAC3, Table 7, Resolution E-4952 Approval of the Database for Energy-Efficient Resources updates for 2020 and revised version 2019. 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: READI v.2.5.1 DEER2020, D08 V2.05 . The value of 3 years is associated with EUL ID: <i>HVAC-RepEcono</i> .

## REVISION HISTORY

## Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	09/30/2018	Jennifer Holmes, Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: PGE3PHVC151, Revision 3 (November 2, 2017) Consensus reached among Cal TF members.
02	6/14/2019	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.