Work Paper PGE3PHVC151

**Revision 4**

**Pacific Gas & Electric**

**Economizer Repair**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | HV307, HV306, HV308, HV309, HV303, HV302, HV304, HV305 |
| **Measure Description** | Restore economizer functionality through repairs |
| **Base Case Description** | Existing HVAC equipment with non-functional economizer |
| **Units** | Per ton cooling capacity, Cap-Tons. |
| **Energy Savings** | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Economizer Repair (Non-ADEC): $39.42/Ton |
| Economizer Repair (ADEC): $136.78/Ton |
| **Incremental Measure Cost ($/unit)** | N/A |
| **Effective Useful Life** | 3 years (DEER EUL ID: HVAC-RepEcono) |
| **Measure Installation Type** | Retro-Commissioning (RC), (RC, previously known as Retrofit Add-on (REA)) |
| **Net-to-Gross Ratio** | 0.73 (DEER NTGR ID: NonRes-sAll-mHVAC-RCA) |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| Revision 0 | 6/25/2012 | Janice Peterson, PECI | • Original work paper for 2013-2014 |
| Revision 0 | 8/28/2012 | Tai Voong (PG&E) | • At-A-Glance Measure List:Changed Building Vintage from “AV” to “Any” and Unit Definition from “Ton” to “Cap-Tons”. |
| Revision 1 | 6/18/2013 | Tai Voong (PG&E) | •Revised savings, NTG, and ISR to comply with ED’s Disposition on the HVAC Quality Maintenance/AirCare Plus Workpapers dated on the March 2, 2013 and May 16, 2013 disposition.  •Only the PG&E executive summary savings template was updated. Work paper language will be updated later.  •For updated Savings values, see file PGE3PHVC151 R1\_EconomizerRepair(chl7v2).xlsx |
| Revision 2 | 10-8-15 | Matt Tyler (CLEAResult), Sherry Hu (PG&E) | •Work paper was updated according to Workpaper Disposition for Nonresidential HVAC Rooftop Quality Maintenance3 and WO3210.  •Removed one measure code C102, and added eight new ones. |
| Revision 3 | 11-2-17 | Henry Liu (PG&E) | •Add the delivery method downstream |
| Revision 4 | 11/30/18 | Tai Voong (PG&E) | • Retroactive updates to EUL for BRO measures per Resolution E-4952 and E-4818. Retroactive to 1/1/2018. |

# Commission Staff and Cal TF Comments

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

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This statewide work paper details repairing non-functional economizers on existing nonresidential split-system and unitary HVAC equipment. This is one of eight that cover specific HVAC Quality Maintenance (QM) treatments formerly combined into the measures described in the Revision 0 version of the June 26, 2012 Work Paper PGECOHVC138 Nonresidential HVAC RTU Quality Maintenance[[1]](#endnote-2) and the Revision 3 version of the December 26, 2014 Work Paper SCE13HC037 Comprehensive Commercial HVAC Rooftop Unit Quality Maintenance[[2]](#endnote-3). All HVAC Quality Maintenance treatments are now covered by the following work papers:

* Airflow Adjustment (To be completed in 2016)
* Condenser Coil Cleaning (PGE3PHVC156R2)
* Economizer Controls (PGE3PHVC152R3)
* Economizer Repair (PGE3PHVC151R2)
* Evaporator Coil Cleaning (PGE3PHVC158R2)
* Refrigerant Charge Adjustment (PGE3PHVC160R2)
* Unoccupied Fan Control (PGE3PHVC157R2)
* Programmable Thermostat (PGE3PHVC153R3)

Separation of this HVAC QM treatment into a statewide set of measures in this work paper was performed using guidance from the document WORKPAPER DISPOSITION FOR Non-Residential HVAC Rooftop Quality Maintenance[[3]](#endnote-4) and supplementary spreadsheet: 20132014-CommercialHVACMaintenance-SavingsValues-April2013-v1-2.xlsx[[4]](#endnote-5). Both are referenced in more detail later in this document.

Table 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 | N/A |
| Industry Standard Practice | Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems[[5]](#endnote-6) |

Table Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  |  | HV307 | Economizer Repair (ADEC) on AC Only Units |
|  |  |  | HV306 | Economizer Repair (ADEC) on AC Unit with Gas Heat |
|  |  |  | HV308 | Economizer Repair (ADEC) on Heat Pump |
|  |  |  | HV309 | Economizer Repair (ADEC) on Variable Volume AC Unit with Gas Heat |
|  |  |  | HV303 | Economizer Repair (Non-ADEC) on AC Only Units |
|  |  |  | HV302 | Economizer Repair (Non-ADEC) on AC Unit with Gas Heat |
|  |  |  | HV304 | Economizer Repair (Non-ADEC) on Heat Pump |
|  |  |  | HV305 | Economizer Repair (Non-ADEC) on Variable Volume AC Unit with Gas Heat |

This statewide work paper supports HVAC QM programs as well as HVAC tune-up programs in multiple programs and service territories. Refer to programs that offer the measure for specific restrictions and guidelines in addition to those described herein.

The target market for this measure is nonresidential buildings served by unitary DX and split systems with economizers that do not serve process or refrigeration loads. The measure is defined for all nonresidential building types and all 16 California climate zones are covered. Savings are calculated for a weighted average of seven Database for Energy Efficient Resources (DEER15[[6]](#endnote-7)) vintages using utility-specific weightings.

Participating contractors must ensure the customer facility is physically located within the service territory of the Investor Owned Utility (IOU) administering the program, and that the customer receives electric services from that IOU. Other terms and conditions are set by individual programs.

This measure requires field documentation of the existing conditions that verify the measure was necessary and that the measure was successfully applied. This measure does not apply if the HVAC system has a fully functional economizer.

## 1.2 Technical Description

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 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. 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).

## 1.3 Installation Types and Delivery Mechanisms

The installation type describes the program scenario in which the measure is applied, thus guiding energy savings and measure cost methodology. The installation type is retrocommissioning and operational programs in commercial settings (RC, previously known as REA in the table below, but terminology updated per CPUC Resolution E-4818 ) since the baseline is the existing unit. These are summarized below in Table 3.

Table Installation Type Descriptions

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

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings. See Table 4 and Table 5 below for descriptions of available delivery methods and incentive methods, respectively.

**SCE Delivery Mechanism:** Financial Supportpaired withDirect Install, Down-Stream Incentive – Deemed, or Mid-Stream Incentive

**PG&E Delivery Mechanism:** Financial Support paired with Direct Install, Down-Stream Incentive – Deemed, or Mid-Stream Incentive

Table Delivery Method Descriptions

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

Table Incentive Method Descriptions

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

## 1.4 Measure Parameters

### 1.4.1 DEER Data

The Database for Energy Efficient Resources (DEER) was referenced on November 19, 2015 for any 2016 updates that would impact this measure. No relevant updates were noted and a full Code Update for 2016 has not yet been presented on deeresources.com.The Database for Energy Efficient Resources (DEER15[[7]](#endnote-8)) includes a measure for Economizer Maintenance under D03-060 but it is not applied to all necessary nonresidential buildings and does not include additional baseline assumptions discussed in §2.

Table DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Work Paper?** |
| 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; see §2 |
| DEER Version | DEER 2015, READI v2.2.0 |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTGR values were obtained using the DEER READI tool[[8]](#endnote-9). The relevant NTGR values for the measures in this work paper are shown in **Table 7**.

Table Measure Net-to-Gross Ratios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| NonRes-sAll-mHVAC-RCA | HVAC Maintenance: Refrigerant Charge Adjustment (RCA) | Com | Any | DirInstall, PreRebDown, NonUpStrm | 0.73 |

**Spillage Rate**

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

**Installation Rate**

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in **Table 8** below.

Table Installation Rates

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

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for a RC measure with an applicable code baseline. Per Resolution E-4818, measures resulting in performance that does not exceed the nominal efficiency of the pre-existing equipment have an effective useful life not to exceed three years, and for this reason the EUL of this measure is capped at three years. The relevant EUL and RUL values for the measures in this work paper are shown in **Table 9** below.

Table 9 EUL and RUL

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| NonRes-RCx-Operational | Repair Economizer | Com | HVAC | 3 | 1 |

### 1.4.2 Codes and Standards Analysis

These maintenance measures are not governed by either state or federal codes and standards. The document Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems[[9]](#endnote-10) may be used by QM programs as a guide for measure implementation. Only licensed California contractors will participate in the program. As required by the California State Licensing Board, contractors will be responsible for meeting all applicable codes. In general, maintenance and repairs do not require permits. California’s Title 24 Building Energy Efficiency Standards provide operating requirements for air economizers, which are referenced in the table below. While these requirements are relevant, compliance is not required as these are maintenance measures.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2013) | Section 140.4(e) Economizers | July 1, 2014 |

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

### Two studies of significant importance to the measure development in this work paper are described in the following section. Per Resolution E-4818 the default measure-level baseline shall be existing conditions for behavioral, retrocommissioning, and operational (BRO) measure installation types, which encompasses the measures in this work paper.

### 1.5.1 WORKPAPER DISPOSITION FOR Non-Residential HVAC Rooftop Quality Maintenance3

Completion date: 5-2-2013

Author: California Public Utilities Commission, Energy Division

This document (Disposition) outlines revision requirements to the existing work papers that cover discrete RTU QM service tasks and suites of service tasks for nonresidential QM programs for packaged RTUs. Three general directives are outlined in the Disposition:

1. Revise ex ante claims process to be based on actual service tasks completed as part of the QM process,
2. Revise All UES values to use staff recommended values, and
3. All IOUs should establish consistent savings estimate approach, preferably using eQUEST.

Additional, more detailed guidance is provided in the Disposition for each of the recognized service tasks. The Disposition addressed the Economizer Control through interim UES savings values and recommended that future energy savings methodologies be based on those outlined in PGECOHVC138 Nonresidential HVAC RTU Quality Maintenance1.

### 1.5.2 *HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report*[[10]](#endnote-11)

Completion date: 1-28-2014

Author: California Public Utilities Commission, Energy Division

This document (WO32) is a study of statewide, third-party, and local programs targeting unitary HVAC systems during the 2010-2012 program cycle, including Commercial Quality Maintenance (CQM). 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 quality maintenance 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 are generally allowing 15% outdoor airflow with closed dampers, 20% outdoor airflow with the commonly applied “finger open” methodology for minimum ventilation, and 62% outdoor airflow with dampers completely open. The damper leakage findings can greatly vary energy savings results and have been incorporated into building energy modeling methodology as described in §2.1.

Additional WO32 findings include as-found non-functional economizer conditions where, “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 as described in §2.2 and §2.4.

## 1.6 Data Quality and Future Data Needs

While WO32 is useful in quantifying outdoor airflow and characterizing non-functional economizer conditions, additional data would be helpful in corroborating and further characterizing the findings. For example, the laboratory testing referenced in WO32 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 airflow 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).

# Section 2. Calculation Methodology

Energy savings and demand reduction for non-refrigeration models were estimated using eQUEST version 3.64.7130 energy modeling software and DOE-2.2R version 52h energy modeling simulation engine for refrigeration models. The DEER 2014 and DEER 2015 prototypes for the customer average (CAv) case of the Tech IDs shown in **Table 10** were used with some modification (as described in §2.1) to develop base and measure case energy use and demand estimates.

DEER prototypes were generated using MASControl v3.00.27[[11]](#endnote-12) for all prototypes applicable to the DEER 2015 Code Update and MASControl v3.00.20[[12]](#endnote-13) for the remaining DEER 2014 Code Update prototypes. All modeling was performed using default DEER hours and the CZ2010 weather files[[13]](#endnote-14).

Table 10 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 | **Non-Motel:** D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p5eer  MASControl v3.00.27 |
| **Motel:** D08-NE-ILtg-Power-Exit-60pct  MASControl v3.00.20 |
| Economizer Repair (Non-ADEC) on AC Only Unit  Economizer Repair (ADEC) on AC Only Unit | **Non-Motel:** D08-NE-HVAC-airAC-SpltPkg-110to134kBtuh-11p5eer  MASControl v3.00.27 |
| **Motel:** D08-NE-ILtg-Power-Exit-60pct  MASControl v3.00.20 |
| Economizer Repair (Non-ADEC) on Heat Pump  Economizer Repair (ADEC) on Heat Pump | **Non-Education Relocatable Classroom:**  D08-NE-HVAC-airHP-SpltPkg-110to134kBtuh-11p5eer-3p4cop  MASControl v3.00.20 |
| **Education Relocatable Classroom:**  D08-NE-HVAC-airHP-PkgEcono-55to64kBtuh-15p0seer-8p2hspf  MASControl v3.00.27 |
| Economizer Repair (Non-ADEC) on Variable Volume AC Unit with Gas Heat  Economizer Repair (ADEC) on Variable Volume AC Unit with Gas Heat | **All:** D08-NE-HVAC-airAC-PVAV-240to759kBtuh-10p8eer  MASControl v3.00.27 |

With the exception of motel building type and education relocatable classroom building type with heat pumps, DEER prototypes for AC and Heat Pump measures were created using the “110to134kBtuh” 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 Volume AC units were not available in the “110to134kBtuh” range and were created using “240to759kBtuh”.

## 2.1 DEER Prototype Modifications: Damper Leakage

Modifications were made to the DEER prototypes to simulate outside air damper leakage and return air damper leakage and exhaust re-entrainment. These modified DEER prototypes were then used to develop the Base and Measure case eQUEST models as described in §2.2 and §2.3 below. Rationale for the damper leakage modifications is described below.

In the course of developing *Demand Controlled Ventilation for Single Zone Packaged HVAC*[[14]](#endnote-15)*,* work paper authors met with a consultant (Kevin Madison) from the Energy Division Ex-Ante Review Team to develop appropriate baseline assumptions and resulting modifications to the DEER prototypes. The following modifications were agreed upon.

1. A minimum outside air fraction of 20% was used instead of 0% due to emerging research (not yet published at the time of the meeting) 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) 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.

Review of WO3210 confirmed that these outside air assumptions are consistent with the best available laboratory data, and were therefore used to adjust baseline assumptions for this work paper as well. To implement these modifications to the DEER prototypes the specific modifications to eQUEST keywords shown in **Table 11** were performed.

**Table 11 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:OA/FLOW-PER | Varies | Set such that ZONE:OA-FLOW/PER x Peak Occupancy # of People  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  Only in “v75” prototypes where some systems were not affected by DEER 2015 Code Update and could not be created with default economizer baseline. |

The SYSTEM modifications were applied to every 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 affected HVAC systems. The DAY-SCHEDULE modification was only applied to schedules being assigned to SYSTEM:MIN-AIR-SCH and avoids affecting 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).

These modified DEER prototype models are referred to as the “Damper Leakage” prototypes in the remainder of this Work Paper.

## 2.2 Base Case

The base case methodology begins with Damper Leakage prototypes and alters the models to simulate faults representing HVAC units in an as-found condition. **Table 12** describes the modeled and represented as-found changeover setting faults covered by the 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.

Table Modeled and Represented As-Found Conditions

|  |  |
| --- | --- |
| **Modeled Faults** | **Represented As-Found Conditions** |
| Non-Functional Economizer,  Dampers Failed Closed  Non-Functional Economizer,  Dampers Failed Partially Open | Non-functional control module |
| Stuck damper |
| Frozen linkage |
| 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, 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 shown in **Table 13** were performed on all non-PTAC system types.

**Table 13 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 |
| Non-Functional Economizer,  Dampers Failed Partially Open | SYSTEM:OA-CONTROL | OA-TEMP | FIXED |
| SYSTEM:MIN-OUTSIDE-AIR | Damper Leakage Prototype, 0.2 | 0.3 |
| ZONE:OA/FLOW-PER | Damper Leakage Prototype, Set such that ZONE:OA-FLOW/PER x Peak Occupancy # of People  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. | Set such that ZONE:OA-FLOW/PER x Peak Occupancy # of People  is between:   1. 0.3 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 | 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 findings discussed in §1.5.2, the damper failed closed scenario is weighted by 0.25 and the damper failed partially open scenario weighted by 0.75. See §2.4 for the weighted savings calculations.

## 2.3 Measure Case

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

## 2.4 Electric Energy Savings Estimation Methodologies

As a Retrocommissioning measure only a single baseline calculation is required. The electric energy savings from the first baseline are represented in the calculations below.

**Equation 1: Annual Energy Savings**

Where:

kWh per ton savings = annual unit energy savings

weighted baseline kWh = annual building energy consumption from each modeled fault weighted by the frequency distribution the corresponding as-found condition, see **Table 14**

measure kWh = annual building energy consumption of measure

cooling tons = design cooling capacity of base case non-PTAC systems

Table Weightings for Savings Calculations

|  |  |
| --- | --- |
| **Fault Distribution** | **Fault Weight** |
| Non-Functional Economizer,  Dampers Failed Closed | 0.25 |
| Non-Functional Economizer,  Dampers Failed Partially Open | 0.75 |

A sample calculation using a 1996 vintage small office (OfS) prototype with AC and Gas Heat located in climate zone 1 is provided. **Table 15** 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.

**Table 15 OfS-w01-v96-airAC Prototype Electric Energy Use and Cooling Capacity Data**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Dampers Failed Closed** | **Dampers Failed Partially Open** | **Measure** |
| Whole building energy use (kWh/yr) | 109,915 | 108,368 | 105,149 |
| System cooling capacity (Btu/h) | 261,909 | 261,909 | 261,909 |

## Demand Reduction Estimation Methodologies

Demand reduction estimates must consider the DEER peak demand period. The peak period is defined as 2:00 PM to 5:00 PM on three specific weekdays and varies by climate zone as shown in the following table[[15]](#endnote-16):

Table DEER Peak Demand Periods

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

Demand reduction is calculated similarly to electric energy savings, however DEER demand reduction estimation protocol requires using the average hourly peak demand for the 9-hours of the DEER peak period. The following equation is then used to determine demand reduction per ton of cooling capacity.

Where:

kW per ton savings = annual unit demand reduction

weighted baseline kW = average demand for DEER peak period of customer average from each modeled fault weighted by the frequency distribution the corresponding as-found condition, see **Table 14**

measure kW = average demand for DEER peak period of measure

cooling tons = design cooling capacity of base case non-PTAC systems

A sample calculation using a 1996 vintage small office (OfS) prototype located in climate zone 1 is provided. **Table 17** provides electric energy use and cooling capacity data for the baseline and measure case on the Asm prototype approximating a building constructed in 1986 in climate zone 11.

**Table 17 OfS-w01-v96-airAC Prototype Electric Demand Use and Cooling Capacity Data**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Dampers Failed**  **Closed** | **Dampers Failed Partially Open** | **Measure** |
| 9/16 2-3pm demand (kW) | 33.88 | 33.42 | 31.43 |
| 9/16 3-4pm demand (kW) | 33.14 | 32.72 | 30.90 |
| 9/16 4-5pm demand (kW) | 26.93 | 26.51 | 24.29 |
| 9/17 2-3pm demand (kW) | 32.96 | 32.56 | 30.30 |
| 9/17 3-4pm demand (kW) | 32.59 | 32.25 | 30.02 |
| 9/17 4-5pm demand (kW) | 26.59 | 26.26 | 23.76 |
| 9/18 2-3pm demand (kW) | 38.52 | 38.73 | 38.50 |
| 9/18 3-4pm demand (kW) | 37.15 | 37.17 | 37.14 |
| 9/18 4-5pm demand (kW) | 31.29 | 31.39 | 31.28 |
| **DEER Demand Average (kW)** | **32.56** | **32.33** | **30.85** |
| System cooling capacity (Btu/h) | 261,909 | 261,909 | 261,909 |

## Gas Energy Savings Estimation Methodologies

As a Retrocommissioning measure, the incremental cost is equal to the gross measure cost and only a single baseline calculation is required. The electric energy savings from the first baseline are represented in the calculations below.

**Equation 2: Annual Energy Savings**

Where:

Therms per ton savings = annual unit energy savings

weighted baseline Therms = annual building energy consumption from each modeled fault weighted by the frequency distribution the corresponding as-found condition, see **Table 14**

measure Therms = annual building energy consumption of measure

cooling tons = cooling capacity of base case non-PTAC systems

A sample calculation using a 1996 vintage small office (OfS) prototype with AC and Gas Heat located in climate zone 1 is provided. **Table 18** 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.

**Table 18 OfS-w01-v96-airAC Prototype Natural Gas Energy Use and Cooling Capacity Data**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Dampers Failed**  **Closed** | **Dampers Failed Partially Open** | **Measure** |
| Whole building energy use (Therms/yr) | 1,006.84 | 1,269.09 | 1,007.32 |
| System cooling capacity (Btu/h) | 261,909 | 261,909 | 261,909 |

## Vintage Weighted Average

Baseline and measure simulations used the 7 DEER building vintages[[16]](#endnote-17) described in **Table 19** for both customer average and code prototypes.

**Table 19 DEER Building Vintage Codes and Descriptions**

|  |  |
| --- | --- |
| **DEER Vintage Code** | **Description** |
| v75 | Before 1978 |
| v85 | 1978 - 1992 |
| v96 | 1993 - 2001 |
| v03 | 2002 - 2005 |
| v07 | 2006 - 2009 |
| v11 | 2010 - 2013 |
| v14 | 2014 - 2015 |

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.

Where:

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=energy savings value for a given vintage (kWh/ton, kW/ton, or therms/ton)

**Table 20** contains sample measure savings for a customer average small office building in climate zone 4 and PG&E territory. The sample measure savings are shown by vintage and the resulting final weighted savings values after applying the DEER 2014 weighting methodology.

**Table 20 Vintage Weighting Sample for PG&E OfS CZ01**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WtSet** | **Vintage** | **DEER Weight** | **Savings**  **kWh/Ton** | **Demand Reduction**  **kW/Ton** | **Savings**  **Therms/Ton** |
| PGEOfSCZ01 | v75 | 0.5092 | 81.27 | 0.0416 | 5.31 |
| PGEOfSCZ01 | v85 | 0.2020 | 42.59 | 0.0151 | 1.65 |
| PGEOfSCZ01 | v96 | 0.1493 | 24.66 | 0.0106 | 1.34 |
| PGEOfSCZ01 | v03 | 0.0597 | 12.87 | 0.0040 | 0.42 |
| PGEOfSCZ01 | v07 | 0.0319 | 6.21 | 0.0022 | 0.25 |
| PGEOfSCZ01 | v11 | 0.0319 | 5.67 | 0.0020 | 0.25 |
| PGEOfSCZ01 | v14 | 0.0160 | 1.55 | 0.0006 | 0.13 |
| **Final Weighted Savings** | **Existing** |  | **174.82** | **0.0760** | **9.36** |

# Section 3. Load Shapes

Load shapes are used for portfolio lifecycle cost analysis. A load shape indicates the distribution of a measure’s energy savings over one year. A load shape is a set of fractions summing to unity, with one fraction per hour (or other time period). Multiplying a savings value by the load shape value for any particular hour yields the energy savings for that particular hour.

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in **Table 21** below.

Table Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Assembly | DEER:HVAC\_Split-Package\_AC, DEER:HVAC\_Split-Package\_HP | NON\_RES |
| Education - Primary School |
| Education - Secondary School |
| Education - Relocatable Classroom |
| Education - Community College |
| Education - University |
| Grocery |
| Health/Medical - Nursing Home |
| Health/Medical - Hospital |
| Lodging – Hotel |
| Lodging - Motel |
| Manufacturing – Bio/Tech |
| Manufacturing – Light Industrial |
|  |
| Office - Large |
| Office - Small |
| Restaurant - Fast-Food |
| Restaurant - Sit-Down |
| Retail - Multistory Large |
| Retail - Single-Story Large |
| Retail - Small |
| Storage - Conditioned |
| Warehouse - Refrigerated |

# Section 4. Costs

Costs for Economizer Repair (Non-ADEC) is included in the 2010-2012 WO017 Ex Ante Measure Cost Study Final Report [[17]](#endnote-18) by ITRON (Cost Study). Other costing methods are used for a portion of the Economizer Repair (ADEC) determination and are described in the following sections. The DEER Measure Cost Data Users Guide[[18]](#endnote-19) was also referenced. As a Retrocommissioning measure, the incremental cost for Economizer Repair is equal to the gross measure cost.

## 4.1 Base Case Cost

The base case is the customer’s existing equipment; therefore the base case cost is $0.00.

## 4.2 Measure Case Cost

For economizer repair without installation of ADEC, the 2010-2012 WO17 Ex Ante Measure Cost Study provides costs per-ton cooling of $19.64 for material and $19.78 for labor.

Cost data *PGECOHVC143 Revision 1 VFD and Enhanced Ventilation for Packaged HVAC units with Gas Heating and Packaged Heat Pumps[[19]](#endnote-20)* was used to determine costs for ADEC installation. Table 13 of that document provides per ton equipment and labor costs for VFD installation with and without ADEC installation. The difference of those costs is used here as an estimate for ADEC equipment and labor installation costs ($65.14 and $32.22, respectively). These costs are then summed with the Economizer Repair (Non-ADEC) costs to arrive at final costs for the measure.

## 4.3 Full and Incremental Measure Cost

Table Full and Incremental Measure Cost Equations

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

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

Table Full and Incremental Costs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| Economizer Repair (Non-ADEC) | RC | $19.64 +$19.78 = $39.42 | $19.64 +$19.78 = $39.42 | N/A |
| Economizer Repair (ADEC) | RC | $84.78 + $52.00 = $136.78 | $84.78 + $52.00 = $136.78 | N/A |

# Attachments

# References

1. Judith Jennings, et al, Pacific Gas and Electric Company (2012,06,26). Work Paper PGECOHVC138 Nonresidential HVAC RTU Quality Maintenance,. [↑](#endnote-ref-2)
2. Andres Fergadiotti, Southern California Edison (2014,12,26). Work Paper SCE13HC037 Comprehensive Commercial HVAC Rooftop Unit Quality Maintenance [↑](#endnote-ref-3)
3. California Public Utilities Commission, Energy Division, WORKPAPER DISPOSITION FOR Non-Residential HVAC Rooftop Quality Maintenance, 5-2-2013. [↑](#endnote-ref-4)
4. California Public Utilities Commission, Energy Division, Spreadsheet: *20132014-CommercialHVACMaintenance-SavingsValues-April2013-v1-2.xlsx,*submitted as addendum to WORKPAPER DISPOSITION FOR Non-Residential HVAC Rooftop Quality Maintenance. [↑](#endnote-ref-5)
5. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. and Air Conditioning Contractors of America. (© ASHRAE and ACCA, 2008). Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems. [↑](#endnote-ref-6)
6. James J. Hirsch & Associates. (2014, October 17). DEER2015 – Codes and Stardards Update.

   Retrieved from deeresources.com:

   http://www.deeresources.com/index.php/deer-versions/deer2015-code-update [↑](#endnote-ref-7)
7. James J. Hirsch & Associates. (2014, October 17). DEER2015 – Codes and Stardards Update.

   Retrieved from deeresources.com:

   http://www.deeresources.com/index.php/deer-versions/deer2015-code-update [↑](#endnote-ref-8)
8. James J. Hirsch & Associates. READi tool, V2.0.2. Developed for California Energy Commission. [↑](#endnote-ref-9)
9. ANSI, ASHRAE, and ACCA. *Standard 180-2008, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*. [↑](#endnote-ref-10)
10. DNV GL, HVAC Impact Evaluation FINAL Report WO32 HVAC – Volume 1: Report, Prepared for California Public Utilities Commission, Energy Division, 1-28-2014 [↑](#endnote-ref-11)
11. James J. Hirsch & Associates. (2014, October 31). *MASControl 3.00.27.* Retrieved from deeresources.com: http://www.deeresources.com/files/DEER2015/download/SetupMASControlX32\_3\_00\_27.msi [↑](#endnote-ref-12)
12. James J. Hirsch & Associates. (2013, September 9). *MASControl 3.00.20*. Retrieved from deeresources.com: http://www.deeresources.com/files/DEER2013codeUpdate/download/SetupMASControlX32\_3\_00\_20.msi [↑](#endnote-ref-13)
13. White Box Technologies, Inc. *CZ2010 Weather Data.* Developed for California Energy Commission. http://weather.whiteboxtechnologies.com/wd-CZ2010 [↑](#endnote-ref-14)
14. Sherry Hu et al, Work Paper PGECOHVC168 Demand Controlled Ventilation for Single Zone Packaged HVAC, Pacific Gas and Electric Company, 04/09/2014. [↑](#endnote-ref-15)
15. James J. Hirsch & Associates. (2014, February 11). DEER2014 — Codes and Standards Update. Retrieved from deeresources.com: http://deeresources.com/files/DEER2013codeUpdate/download/DEER2014UpdateDocumentation\_2-12-2014.pdf. [↑](#endnote-ref-16)
16. James J. Hirsch & Associates. (2014, March 18). DEER2014 Energy Impact Weights Tables v2. Retrieved from deeresources.com: http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EnergyImpact-Weights-Tables-v2.xlsx [↑](#endnote-ref-17)
17. Itron. 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. San Francisco, CA (2014, May 27). Retrieved 8/26/2015 at http://www.energydataweb.com/cpucFiles/pdaDocs/1100/2010-2012%20WO017%20Ex%20Ante%20Measure%20Cost%20Study%20-%20Final%20Report.pdf. [↑](#endnote-ref-18)
18. DEER Measure Cost Data Users Guide found on www.deeresources.com under DEER2011 Database Format hyperlink, DEER2011 for 13-14, spreadsheet SPTdata\_format-V0.97.xls. [↑](#endnote-ref-19)
19. Pacific Gas & Electric Company. PGECOHVC143 Revision 1 VFD and Enhanced Ventilation for Packaged HVAC Units with Gas Heating and Packaged Heat Pumps, 5-30-2014 [↑](#endnote-ref-20)