**Work Paper PGE3PHVC150**

**Enhanced Time Delay Relay**

**Revision # 1**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**California Climate Air Conditioner Upgrade –Enhanced Time Delay**

**Measure Codes H796**

***Cooling Optimizer Program***

# At-a-Glance Summary

|  |  |  |  |
| --- | --- | --- | --- |
| **Applicable Measure Codes:** | **H796** |  |  |
| **Measure Description:** | Western Cooling ControlTM (WCC) Enhanced Fan Time Delay for Dry Climate Air Conditioning – Retrofit - Residential | | |
| **Energy Impact Common Units:** | Per Air Conditioner | | |
| **Base Case Description:** | Existing central HVAC system with less than 2 minute fan off time delay during cooling | | |
| **Base Case Energy Consumption:** | Source: DEER 2008 HVAC annual end use adjusted to DEER 2014 base for appropriate climate zone and building type, PG&E existing vintage weighted | | |
| **Measure Energy Consumption:** | Source: Savings over DEER 2014 base end use, Building type, climate zone dependent | | |
| **Energy Savings**  **(Base Case – Measure):** | Source: Multiple. See section 1.4. Dependent on building type, climate zone, fan motor type | | |
| **Costs Common Units:** | Per Air Conditioning System | | |
| **Base Case Equipment Cost ($/unit):** | $0 | | |
| **Measure Equipment Cost ($/unit):** | Source: [Contractor Reported]  $48.50 Material Cost | | |
| **Gross Measure Cost ($/unit)** | $48.50 Material  $50 Labor for SFM and DMO  $30 Labor for MFM  $98.50 Total for SFM and DMO  $78.50 Total for MFM | | |
| **Measure Incremental Cost ($/unit):** | Source: [See section 1.4.1.2]  measure equipment plus labor including overhead and profit.  $98.50 SFM,DMO  $78.50 MFM | | |
| **Effective Useful Life (years):** | Source: [DEER2014] 10 | | |
| **Measure Application Type:** | Retrofit | | |
| **Net-to-Gross Ratios:** | Source: [DEER2014] 0.78  Actual is above 0.90 | | |
| **Important Comments:** |  | | |

At-A-Glance Measure List

Measure Units: per Air Conditioner

Selected measures are shown below. The complete measure list is provided in the attached spreadsheet: 

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  | **1st Baseline** | | | | | | | | **2nd Baseline** | | | | | | | |  |  |  |  |  |  |
| Measure Code | Version Source | Measure  Description | Measure Application Type | Building Type | Building Vintage | Climate Zone | Unit Definition | KW Peak Electric Demand Reduction | KWh Electric Savings | THM Gas Savings | (EUL) LIFE CYCLE | Base Case Cost ($/unit) | Measure Cost ($/unit) | Labor Cost ($/unit) | IMC Incremental  Measure Cost ($/unit) | KW Peak Electric Demand Reduction | KWh Electric Savings | THM Gas Savings | LIFE CYCLE | Base Case Cost ($/unit) | Measure Cost ($/unit) | Labor Cost ($/unit) | IMC Incremental  Measure Cost ($/unit) | GRR\_kW | GRR\_kWh | GRR\_thm | NTG | Implementation Method  [DI, DD, I] | ISR |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | SFM | ANY | Z11 | Air Conditioner | 0.325 | 243.3 | 0 | 10 | 0 | 98.5 | 50 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.325 | 243.3 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | SFM | ANY | Z12 | Air Conditioner | 0.307 | 149.8 | 0 | 10 | 0 | 98.5 | 50 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.307 | 149.8 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | SFM | ANY | Z13 | Air Conditioner | 0.314 | 280.2 | 0 | 10 | 0 | 98.5 | 50 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.314 | 280.2 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | MFM | ANY | Z11 | Air Conditioner | 0.203 | 152.4 | 0 | 10 | 0 | 78.5 | 30 | 78.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.203 | 152.4 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | MFM | ANY | Z12 | Air Conditioner | 0.185 | 90.2 | 0 | 10 | 0 | 78.5 | 30 | 78.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.185 | 90.2 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | MFM | ANY | Z13 | Air Conditioner | 0.203 | 181.4 | 0 | 10 | 0 | 78.5 | 30 | 78.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.203 | 181.4 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | DMO | ANY | Z11 | Air Conditioner | 0.323 | 553.8 | 0 | 10 | 0 | 98.5 | 50 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.323 | 553.8 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | DMO | ANY | Z12 | Air Conditioner | 0.323 | 408.4 | 0 | 10 | 0 | 98.5 | 50 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.323 | 408.4 | 0 | 0.78 | I | 1 |
| H796 | DEER2014 | Enhanced Time Delay Relay, PSC Fan Motor | RET | DMO | ANY | Z13 | Air Conditioner | 0.323 | 592.0 | 0 | 10 | 0 | 98.5 | 50 | 98.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.323 | 592.0 | 0 | 0.78 | I | 1 |

# Work Paper Approvals

|  |  |
| --- | --- |
|  |  |
| **Grant Brohard**  Manager, Technical Product Support | Date |
|  | Date |
|  | Date |
|  | Date |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| **Revision 0** | **6/22/2012** | **PGE3PHVC150 Enhanced Time Delay** | **Abram Conant (Proctor Engineering)** |
| **Revision 1** | **5/5/2014** | **Updated for DEER 2014 values** | **Abram Conant (Proctor Engineering)** |
| **Revision 1** | **5/5/2014** | **Updated to include calculation of savings when installed on a system with a high efficiency BPM/ECM fan motor. These calculations were previously in workpaper PGE3PMOT102 Enhanced Time Delay BPM Motor, which presented savings for BPM motor retrofit and Enhanced Time Delay control installed as a single measure.** | **Abram Conant (Proctor Engineering)** |
| **Revision 2** | **MM/DD/**  **YYYY** | **As needed: Work paper name here with description of revisions** | **See example above** |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description –***

H796 – Install enhanced fan time delay relay for dry climates into central HVAC system furnace/air handler with a standard PSC fan motor.

XXX – Install enhanced fan time delay relay for dry climates into central HVAC system furnace/air handler with a high efficiency BPM fan motor.

***Program Restrictions and Guidelines***

This measure applies to any unitary air conditioner that has a fan off time delay of less than 2 minutes. This measure applies to both standard efficiency and high efficiency models. When an air conditioner includes a high efficiency BPM fan motor, the savings are higher due to the lower watt draw of the fan motor during the time delay.

***Market Applicability:***

This measure is cross cutting for use the residential market sector and available for use in the small commercial sector.

This measure is targeted at the high cooling use region of climate zones 11, 12 and 13.

This measure installs into the furnace or air handler control system in existing central HVAC systems. The measure is installed by licensed and specially trained HVAC contractors. The rebate is downstream and is provided to the customer as an instant rebate at the time of installation. The participating HVAC contractors are reimbursed monthly for the instant rebates provided to their customers during the previous month.

## 1.2 Product Technical Description

The Western Cooling Control™ (WCC) enhanced fan time delay controls the indoor fan run time to improve air conditioner cooling performance in dry climate regions.

Air conditioners both reduce the temperature of and remove water from the air they are cooling. The amount of moisture removal needed varies by US climate region, but air conditioning equipment types do not. The same air conditioner models are sold and installed in the dry western US region as in the humid southeastern US region. As a result, air conditioners in the dry western region remove more water from the air than is necessary.

This excess water removal represents an opportunity to reduce the energy cost of cooling homes in dry climate regions such as the central valley of California. It has long been known that water can be evaporated to produce cooler air, as in an evaporative cooler. The WCC control is based on this concept but differs from traditional direct evaporative coolers in that no new moisture is added to the air. Rather, moisture that condensed on the indoor heat exchange coil when the air conditioner compressor was running is returned to the air to produce additional cooling following each compressor cycle.

The WCC continues to run the indoor fan after the compressor turns off, using the temperature and mass of the evaporator coil as well as the potential cooling energy stored as liquid water on the coil to deliver additional sensible cooling capacity to the building. In essence the indoor coil functions as an evaporative cooler under these conditions. The energy cost is low since the fan draws much less power than the compressor.

The major air conditioner manufacturers sometimes use the temperature and mass of the evaporator coil to increase the SEER of the air conditioner, but do not attempt to recover the energy stored as moisture. This is because the SEER cycling test is run with a completely dry evaporator coilRef 1, so there is no moisture to recover. However virtually all the time, even in California’s climates, the air conditioner is condensing moisture on the coil. This makes a tuned fan time delay potentially more effective than it is in the SEER cycling tests.

In field installations, the majority of units are not configured with even the short fixed length fan time delays the manufacturers specify on the SEER test. Of over 20,000 existing systems serviced under this program from 2006 – 2011, 86% had either no existing fan delay or a very short delay of 30 seconds or less.

Figure 1. SEER Cycling Test with TDR

WCC uses a proprietary algorithm to dynamically adjust the fan run time to maximize sensible efficiency of the cooling cycle. The fan-off time delay is recalculated during every air conditioner cycle as a function of the available cooling capacity remaining on the indoor coil.

Tests performed in certified psychrometric testing facilities have demonstrated potential energy savings greater than 30% resulting from the use of the WCC control.

Monitored field installations have demonstrated cooling energy use reductions averaging 14% for units with standard PSC fan motors, and exceeding 20% for units with high efficiency BPM fan motors.

## 1.3 Measure Application Type

The WCC is a retrofit measure.

The WCC control is installed into existing furnaces and air handlers. It is an additional control component, not a replacement of any existing component.

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

The DEER data do not contain the appropriate information for this measure. Baseline use information was taken from DEER2008 for the Use Category and Technology Group shown in Table 1 and adjusted to DEER2014 as described below.

Table 1: DEER Use and Technology Table

|  |  |  |  |
| --- | --- | --- | --- |
| **Use Category Description** | **Use Category** | **Use Sub Category Description** | **Use Sub Category** |
| HVAC | HVAC | Space Heating and Cooling | HVAC-HtCl |
| **Technology Groups Description** | **Technology Groups** | **Technology Types Descriptions** | **Technology Types** |
| dX AC Equipment | dxAC\_equip | SEER Rated Split System AC | spltSEER |

DEER does not have this measure. The DEER 2008 MISER tool provides baseline annual end use kWh and Therms for the HVAC end uses that are addressed by this measure. The baseline annual end use is not provided in the DEER 2014 READI v1.0.5. The DEER team stated in workshops during 2013 that the baseline annual end use values would be made available in future versions of the READI tool, but as of the writing of this workpaper they are still not available.

Therefore the baseline annual consumption values for air conditioners and furnaces were taken from the DEER 2008 Impact IDs listed in Table 2, and adjusted to DEER 2014 based on the ratio of DEER 2014 to DEER 2008 savings for residential SEER14 air conditioning units, as listed in Table 3. This calculation adjusts for the 2014 weather files as well as any changes in the customer average building models used in the DEER calculations.

Table 2: DEER 2008 Impact IDs and Baseline Annual Energy Use

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| DEER2008 Impact ID | Zone | Vintage | End Use  (kWh/air conditioner) | Tons of Cooling Capacity |
| SFM-w11-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 11 | PG&E Weighted | 1644 | 3.51 |
| SFM-w12-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 12 | PG&E Weighted | 1038 | 3.32 |
| SFM-w13-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 13 | PG&E Weighted | 1957 | 3.40 |
| SFM-wPGE-vEx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | PG&E Weighted | PG&E Weighted | 1159 | 3.27 |
| DMO-w11-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 11 | PG&E Weighted | 3948 | 3.50 |
| DMO-w12-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 12 | PG&E Weighted | 3218 | 3.50 |
| DMO-w13-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 13 | PG&E Weighted | 4737 | 3.50 |
| DMO-wPGE-vEx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | PG&E Weighted | PG&E Weighted | 3360 | 3.50 |

The calculation is:

This calculation assumes that the change in baseline annual energy use is proportional to the change in savings for the residential split SEER14 measure. This assumption is valid because the DEER update documentation does not indicate any substantive changes to the residential split system SEER 14 measure. The base use values adjusted to DEER 2014 are shown in Table 4. The calculations for every PG&E climate zone are provided in Appendix A.

Table 3: DEER 2008 to 2014 Adjustment

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| DEER2014 Impact ID | Zone | Vintage | Building Type | DEER 2008 savings, customer average base  (kWh/air conditioner) | DEER 2014 savings, customer average base  (kWh/air conditioner) | DEER 2014/2008 kWh Ratio | DEER 2008 Tons | DEER 2014 Tons | DEER 2014/2008 Tons Ratio |
| RE-HV-ResAC-14S | 11 | Ex | SFM | 471. 2 | 498.2 | 1.06 | 3.51 | 3.46 | 0.98 |
| RE-HV-ResAC-14S | 12 | Ex | SFM | 321.2 | 331.3 | 1.03 | 3.32 | 3.28 | 0.99 |
| RE-HV-ResAC-14S | 13 | Ex | SFM | 565.1 | 577.9 | 1.02 | 3.40 | 3.36 | 0.99 |
| RE-HV-ResAC-14S | PGE | Ex | SFM | 354.4 | 362.9 | 1.02 | 3.27 | 3.24 | 0.99 |
| RE-HV-ResAC-14S | 11 | Ex | DMO | 2071.5 | 2075.5 | 1.00 | 3.50 | 3.50 | 1.00 |
| RE-HV-ResAC-14S | 12 | Ex | DMO | 1667.8 | 1512.0 | 0.91 | 3.50 | 3.50 | 1.00 |
| RE-HV-ResAC-14S | 13 | Ex | DMO | 2521.0 | 2250.5 | 0.89 | 3.50 | 3.50 | 1.00 |
| RE-HV-ResAC-14S | PGE | Ex | DMO | 1777.0 | 1652.0 | 0.93 | 3.50 | 3.50 | 1.00 |

Table 4: DEER 2014 Impact IDs and Baseline Annual Energy Use

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| DEER2014 Impact ID | Building Type | Zone | Vintage | End Use  (kWh/air conditioner) | Tons of Cooling Capacity |
| RE-HV-ResAC-14S | SFM | 11 | PG&E Weighted | 1738 | 3.46 |
| RE-HV-ResAC-14S | SFM | 12 | PG&E Weighted | 1070 | 3.28 |
| RE-HV-ResAC-14S | SFM | 13 | PG&E Weighted | 2001 | 3.36 |
| RE-HV-ResAC-14S | SFM | PG&E Weighted | PG&E Weighted | 1187 | 3.24 |
| RE-HV-ResAC-14S | DMO | 11 | PG&E Weighted | 3955 | 3.50 |
| RE-HV-ResAC-14S | DMO | 12 | PG&E Weighted | 2917 | 3.50 |
| RE-HV-ResAC-14S | DMO | 13 | PG&E Weighted | 4229 | 3.50 |
| RE-HV-ResAC-14S | DMO | PG&E Weighted | PG&E Weighted | 3124 | 3.50 |

DEER 2008 does not include HVAC measures for multi-family (MFM) building types. This workpaper calculates the MFM baseline as a function of the single family (SFM) baseline and the average cooling capacity for MFM and SFM air conditioning units as follows:

BASELINEMFM = BASELINESFM x TONSMFM / TONSSFM

Where:

TONSMFM is the average air conditioner nominal tons in each climate zone for the more than 13,000 multi-family units served under the program through 2011.

TONSSFM is the DEER 2008 adjusted to DEER2014 baseline tonnage for single family units in each climate zone

BASELINESFM is the DEER2014 baseline energy use for single family units in each climate zone

In adopting the DEER baseline consumption, this analysis makes the conservative assumption that the base case air conditioners are not degraded in any way. The known degradation of existing units below their rated efficiency increases the base consumption and increases the savings (both kWh and kW) beyond the figures in this document.

#### 1.4.1.1 Measure electric and gas savings

The DEER 2014 adjusted energy savings are listed in the tables below. Savings for the three climate zones primarily targeted by the program are shown in the following tables. Savings calculations and detailed DEER information for all PG&E climate zones are included in Appendix A.

Table 5: Measure Electric Energy Savings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings (install on PSC fan motor) kWh/yr** | **Electric Savings (install on BPM fan motor) kWh/yr** | **Units** | **DEER Version** |
| SFM | PG&E Weighted | 11 | 243 | 313 | Per Air Conditioner | 2008 base adjusted to 2014 |
| SFM | PG&E Weighted | 12 | 150 | 193 | Per Air Conditioner | 2008 base adjusted to 2014 |
| SFM | PG&E Weighted | 13 | 280 | 360 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM | PG&E Weighted | 11 | 147 | 196 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM | PG&E Weighted | 12 | 96 | 116 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM | PG&E Weighted | 13 | 175 | 233 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO | PG&E Weighted | 11 | 510 | 712 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO | PG&E Weighted | 12 | 414 | 525 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO | PG&E Weighted | 13 | 613 | 761 | Per Air Conditioner | 2008 base adjusted to 2014 |

#### 1.4.1.2 Base Case Costs and Measure Case Costs

The base case cost is zero.

The measure case cost is $98.50 for SFM and DMO building types.

The measure case cost is $78.50 for MFM building type.

Typical hardware cost to the customer is $48.50.

Typical installation time is 15 minutes. The DEER2014 Costs and Values Summary documentation lists the base rate labor cost for residential HVAC at $67.88 per hour.

$67.88 \* 15/60 = $16.97.

The actual installation cost is higher than indicated by the installation time and DEER2014 base labor rate. Estimates provided by participating contractors indicate the cost is closer to $50 for building types where a single measure is installed per location, such as SFM and DMO building types. Contractor costs are lower when multiple measures are installed at the same location, such as for MFM building types. For MFM installations the participating contractors estimate $30 per measure.

Total cost for SFM and DMO building types is:

$48.50 + $50 = $98.50

Total cost for MFM building types is:

$48.50 + $30 = $78.50

#### 1.4.1.3 Net to Gross Assumption

A net to gross of 0.78 was used as specified by DEER2014 for HVAC maintenance measures. We believe that the actual net to gross for this hardwired installation is at least. 0.90. Since these retrofits are not implemented outside of the program the free ridership is 0%.

Table 6: Net to Gross Ratios

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NTGR\_ID | Description | Sector | NTGR | Documentation |
| Res-sAll-mHVAC-RCA | HVAC Maintenance: Refrigerant Charge Adjustment (RCA) | Res | 0.78 | 2014 DEER |

#### 1.4.1.4 Effective Useful Life / Remaining Useful Life

These measures are retrofit into existing furnaces and air handlers. The measure life is equal to the remaining life of the furnace/air handler.

The mean life of a residential central air conditioner is 20.5 years according to ASHRAE Transactions ResearchRef 2. As noted in that paper the average replacement age matches the mean life for a mature population.

The median age of air conditioners is 8 years according to the 2010 RASS survey. On average then, the average air conditioner will be in place for another 12.5 years. What is more, a large percentage of the air conditioner replacements do not include replacement of the furnace (which is the AC indoor air handler where the measures addressed by this workpaper are installed).

However we have used a more conservative measure life of 10 years derived from the DEER 2014:

* EUL\_ID HV-RefChrg: is "Typical Refrigerant Charge Adjustment".

Since the WCC enhanced time delay is a hardwired modification as opposed to an adjustment, it is more durable than HV-RefChrg. To be conservative, the 10 year Effective Useful Life value was obtained directly from DEER2014 without alteration.

This is conservative compared to the DEER EUL values for other HVAC component measures such as HVAC fan motors (15 years) and other HVAC controls such as thermostats (11 years).

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

The in-service/first year installation rate is 100%. These measures are reported to the program from the jobsite, at the time of installation.

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

***Title 20:*** These measures do not fall under Title 20 of the California Energy Regulations.

***Title 24:*** These measures do not fall under Title 24 of the California Energy Regulations.

***Federal Standards:*** These measures do not fall under Federal DOE or EPA Energy Regulations.

There is no code or standard addressing the residential furnace/AC air handler fan time delay.

The measure is a potential retrofit to any unit with standard 24V controls that does not operate the indoor fan continuously.

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

The savings for this measure are derived from the DEER2008 adjusted to DEER2014 baseline annual end use for cooling and assumed savings of:

|  |  |
| --- | --- |
| Table 7: Enhanced Time Delay Annual Savings | |
| Average cooling savings for units with standard PSC fan motor | 14% |
| Average cooling savings for units with high efficiency BPM fan motor | 18% |

Studies and data supporting these savings levels are presented in sections 1.4.3 - 1.4.4 and in the calculations section of this workpaper.

#### 1.4.3.1 Study #1, California Energy Commission EISG PIER Independent Assessment Report “Proportional Time Delay Relay for Air Conditioner Latent Capacity Recovery”

This section presents the measured energy savings resulting from installing the WCC enhanced fan time delay in California homes within the climate zones served by this program.

This studyRef 3 installed enhanced fan time delay devices into 10 homes in the central valley of California and monitored the pre/post installation cooling energy consumption. Seven of the homes received a device with control characteristics identical to the WCC device that is installed under this program. The results from these 7 sites are tabulated below:

Table 8: Field Monitored Energy Savings

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Site | Lemoore | Fresno #1 | Stockton #1 | Tracy | Clovis #1 | Clovis #2 | Bakersfield |
| Rated Capacity (Btu/h) | 36,000 | 36,000 | 60,000 | 36,000 | 42,000 | 48,000 | 48,000 |
| Nominal Tons of Cooling Capacity | 3 | 3 | 5 | 3 | 3.5 | 4 | 4 |
| Refrigerant | R-22 | R-22 | R-22 | R-410A | R-22 | R-22 | R-22 |
| A/C Vintage | 1980 | 1990 | 1992 | 2009 | 2000 | 2001 | 2001 |
| A/C Type | Package | Package | Split | Split | Split | Package | Split |
| Fan Motor Type | PSC | PSC | PSC | PSC | PSC | BPM | PSC |
| Existing Fan Delay Time (min) | 0 | 1.2 | 0 | 1.5 | 0 | 1.5 | 1 |
| Air Flow (CFM) | 690 | 1013 | 1417 | 815 | 1270 | 1178 | 1425 |
| Air Handler Location | Rooftop | Rooftop | Garage | Garage | Attic | Rooftop | Attic |
| Duct Leakage (CFM @ 25Pa) | 249 | 175 | 868 | 179 | 148 | 230 | 73 |
| **% Cooling Energy Use Reduction** | **14%** | **14%** | **14%** | **18%** | **9%** | **25%** | **N/A\*** |

\* Insufficient data available to compare energy use at this site

The study included a variety of HVAC equipment types, ages, and performance characteristics.

The study included 3 sites with no pre-existing fan time delay, and 4 sites with an existing time delay of 1.2 to 1.5 minutes.

The average reduction in cooling energy use across all sites was 16%.

The average reduction in cooling energy use for sites with a PSC indoor fan motor was 14%.

One site had a BPM indoor fan motor and experienced a cooling energy use reduction of 25%.

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings** | **Study units** | **Specific study reference** |
| Residential | All | 12, 13 | 16% average | HVAC System | Ref 3 |
| Residential | All | 12, 13 | 14% for sites with PSC indoor fan motor | HVAC System | Ref 3 |
| Residential | All | 12, 13 | 25% for site with BPM indoor fan motor | HVAC System | Ref 3 |

#### 1.4.3.2 Study #2, 2013 California Building Energy Efficiency Standards Case Report

This section presents laboratory measured data documenting the effect on sensible efficiency of indoor fan time delay controls such as the WCC enhanced fan time delay.

As part of research for the 2013 Title 24 standards, air conditioner testing was performed in a psychrometric facility certified for SEER rating performance testingRef 4. The tests included a cycling test following the SEER test sequence, but at indoor and outdoor conditions typical for California homes. These cycling tests included a variety of fan delay lengths and airflows during the fan delay.

The typical existing HVAC system in California has a Permanent Split Capacitor (PSC) indoor fan motor and 350 cfm of airflow per nominal ton of cooling capacity. The laboratory cycling test results for this scenario are shown in Figure 2 and Table 9. Shown are results measured at the unit and the corresponding result if duct losses equivalent to 20% of capacity when the system is operating at full capacity are assumed. Duct losses limit the maximum length of the fan time delay, but do not diminish the energy savings percentage at moderate time delay lengths as are provided by WCC because the losses that occur during the fan time delay also occur during the compressor cycle.

Figure 2: Laboratory Cycling Test Results, 350 CFM/ton, PSC Fan Motor



Table 9: Laboratory Cycling Test Results, 350 CFM/ton, PSC Fan Motor

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cycle** | **Condition** | **Max Sensible EER** | **Time Delay at Max Sensible EER (sec)** | **% Energy Savings over No Delay** |
| No fan delay | At Unit | 4.51 | 0 | - |
| With Duct Losses | 2.52 | 0 | - |
| 105 sec fan delay | At Unit | 6.01 | 100 | 25% |
| With Duct Losses | 3.59 | 100 | 30% |
| 200 sec fan delay | At Unit | 6.26 | 195 | 28% |
| With Duct Losses | 3.7 | 195 | 32% |
| 300 sec fan delay | At Unit | 6.98 | 300 | 35% |
| With Duct Losses | 3.89 | 300 | 35% |
| 610 sec fan delay | At Unit | 7.3 | 610 | 38% |
| With Duct Losses | 3.75 | 360 | 33% |

The research also included evaluation with different motor types. Figures 3 and 4 show the results of these tests for PSC and BPM fan motors, with and without duct losses. Points to the left of the vertical line occur during the compressor portion of the cycle, while points to the right of the line occur during the fan delay.

Figure 3: Sensible EER for 350CFM/ton Compressor Cycle and 350 CFM/ton Fan Delay

|  |  |
| --- | --- |
| **Sensible EER at Unit** | **Sensible EER with Duct Losses** |
|  |  |

Figure 4: Sensible EER for 350CFM/ton Compressor Cycle and 216 CFM/ton Fan Delay

|  |  |
| --- | --- |
| **Sensible EER at Unit** | **Sensible EER with Duct Losses** |
|  |  |

Table 10 shows the cycle average sensible EER with the BPM fan motor and a variety of fan delays, as well as the percent energy savings over the PSC/no fan delay cycle. The savings measured at the unit range from 22% for short delays at reduced speed to over 40% for longer delays.

Table 10: Laboratory Cycling Test Results, BPM Fan Motor

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **BPM Motor @ 350 CFM/ton** | | **BPM Motor @ 350 CFM/ton - 216 CFM/ton** | |
| **Cycle** | **Condition** | **Cycle Average Sensible EER** | **% Energy Savings over No Delay** | **Cycle Average Sensible EER** | **% Energy Savings over No Delay** |
| No fan delay | At Unit | 5.35 | - | 5.35 | - |
| With Duct Loss | 3.15 | - | 3.15 | - |
| 200 sec fan delay | At Unit | 7.63 | 30% | 6.9 | 22% |
| With Duct Loss | 4.71 | 33% | 3.62 | 13% |
| 300 sec fan delay | At Unit | 8.85 | 40% | 7.84 | 32% |
| With Duct Loss | 5.21 | 40% | 3.94 | 20% |
| 600 sec fan delay | At Unit | Not Tested | - | 9.59 | 44% |
| With Duct Loss | Not Tested | - | 4.24 | 26% |

**Study Findings:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Fan Motor Type** | **Cooling Savings (%)** | **Study units** | **Specific study reference** |
| N/A | N/A | N/A | PSC | 25% - 38% at unit  30% - 35% with duct losses | HVAC System | Ref 4 |
| N/A | N/A | N/A | BPM | 22% - 44% at unit  13% - 40% with duct losses | HVAC System | Ref 4 |

#### 1.4.3.3 Study #3 CEC PIER Study “Energy Performance of Hot Dry Optimized Air Conditioning Systems”

This section presents laboratory measured data documenting the effect on sensible efficiency of indoor fan time delay controls such as the WCC enhanced fan time delay.

Previous dry climate air conditioning research for the California Energy CommissionRef 5 included laboratory testing of indoor fan delays following compressor cycles of various lengths.

Figure 5 and Table 11 show Southern California Edison test data contained in the embedded Excel workbookRef 5  in tab "SCE Lab Data", Column O is Sensible EER. For a five-minute time delay, the energy savings range from 29% for a 5-minute cycle to 15% for a 15-minute compressor cycle. This illustrates the relationship between compressor cycle length, fan cycle length, and latent recovery savings opportunity.

Figure 5: Sensible EER in enhanced time delay tests at Southern California Edison



Sensible EER through 5 minute delay

Sensible EER through 10 minute delay

The calculation to derive Sensible EER is:

Sensible EER =  / *Average Watt Draw* 

Where: *SensibleCapacityRate* is in Btus per hour

*x* is the number of 1 minute time intervals from compressor on

Table 11: Laboratory Results (Southern California Edison)

|  |  |  |  |
| --- | --- | --- | --- |
| Compressor Cycle Length | End of Compressor Cycle Sensible EER | Sensible EER after 5 minute fan delay | Savings |
| 5 minutes | 6.0 | 8.5 | 29% |
| 10 minutes | 6.3 | 8.0 | 21% |
| 15 minutes | 6.6 | 7.75 | 15% |

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Cooling Energy Savings (%)** | **Study units** | **Specific study reference** |
| N/A | N/A | N/A | 15% - 29% | HVAC System | Ref 5 |

#### 1.4.3.4 Study #4 FSEC Report “Understanding the Dehumidification Performance of Air-Conditioner Equipment at Part-Load Conditions”

This section presents data reported by the Florida Solar Energy Center dealing with the re-evaporation of air conditioner condensate when the indoor fan continues running after the compressor cycle, and the resulting sensible efficiencies.

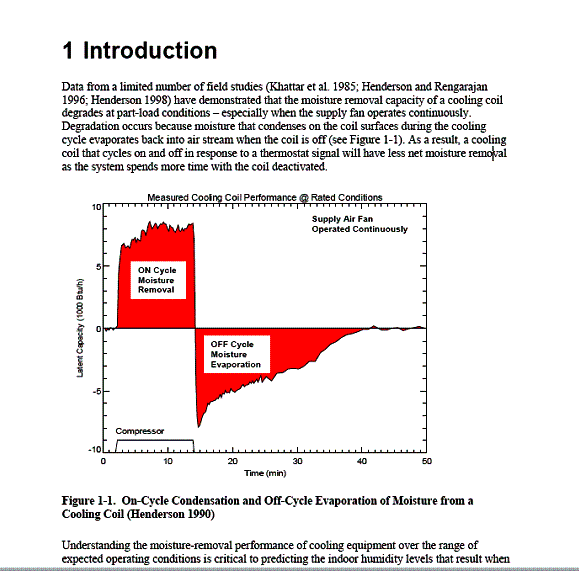
****A published report by Henderson et al. Ref 6 details the effect of continuing the airflow through the evaporator after the compressor ends its cycle. A portion of this report is embedded in the Reference Section. Figure 6 (Figure 1-1 on page 1-1 of that study) shows the stored latent capacity during the 12 minutes the compressor is on. When the compressor ends its cycle at 14 minutes on the time scale below the stored capacity is delivered through evaporation as the fan continues to run.

Figure 6: Stored Latent Capacity and Delivered Sensible Capacity in Fan only Mode (tail) in tests at Florida Solar Energy Center

As shown in Figure 6, the moisture stored on the coil can almost completely be recovered as sensible capacity when the fan is run at an appropriate speed and for an appropriate time. This report details many of the experiments in Florida that identify the measured effect of latent storage and latent recovery. One example is the test by Khattar Ref 7 detailed in Appendix D of the Henderson report. In that test of a three ton unit, the Sensible EER with the compressor on for ten minutes was 5.417. This was followed by a continuing fan run that averaged a Sensible EER of 9.17 over the next five minutes. Combining the compressor on time period and the fan only time period, the Sensible EER averaged 6.67 for a savings of 18.8% with a permanent split capacitor (PSC) motor.

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Cooling Energy Savings (%)** | **Study units** | **Specific study reference** |
| N/A | N/A | N/A | 18% | HVAC System | Ref 6 and 7 |

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

#### 1.4.4.1 Calculations from Laboratory Measured Data

This section presents calculations based the laboratory results documented in section 1.4.3.2 to forecast the savings that occur when more efficient and variable speed indoor fan motors are used during the fan delay.

The laboratory data from the California Title 24 research shows the following sensible capacity characteristics during the air conditioner compressor cycle and subsequent fan cycle:

Figure 7: Gross Sensible Cooling Capacity through Complete Cycle



Compressor Cycle

Fan Cycle

Maximum compressor cycle gross sensible capacity

Two data sets are shown in Figure 7. In one (red O), the indoor fan is operating at 350 CFM/ton during the fan delay as would be the case for a standard PSC fan motor. In the other (blue triangle), the indoor fan is operating at 216 CFM/ton during the indoor fan delay as would be the case for a variable speed BPM motor which runs at low speed when only the fan is on. The high speed delay runs for 5 minutes, while the low speed delay runs for 10 minutes.

Normalizing both data sets against the maximum gross sensible capacity measured during the compressor portion of the cycle as shown by the arrow in Figure 7 yields the following characterization of fan cycle sensible capacity relative to the sensible capacity delivered by the compressor:

Figure 8: Fan Cycle Sensible Capacity vs. Fan Run Time



From related workpaper PGE3PMOT102 section 1.4.4.2 and 1.4.3.2, PSC and BPM fan motors in a typical central HVAC system in CA can be characterized as follows:

* PSC motor watt draw during cooling and fan delay = 632W
* BPM motor watt draw during cooling and high speed fan delay = 348W
* BPM motor watt draw during low speed fan delay = 100W

The embedded Excel workbook in Ref 4 shows calculations applying the above fan power characteristics and the fan delay capacity curves in figure 8 to an air conditioning system with the following characteristics:

* 3 tons of cooling capacity
* 350 cfm of airflow per ton of cooling capacity
* Compressor cycle operating EER of 10.0
* Sensible heat ratio (sensible capacity / total capacity) of 0.80
* Compressor cycle duration of 10 minutes

These calculations are conservative for the following reasons:

1. Henderson et al. Ref 6 measured the time from the beginning of the compressor cycle to the advent of condensate draining from the pan. The time ranged from 11.5 minutes to 34 minutes (Page 3.14, Table 3-7). This is the time it takes for the coil to be fully saturated with water. Since the compressor cycles preceding the fan delays in Figure 8 were 6 minutes long, the evaporator coil probably has not reached its maximum water storage capacity. The capacity available to be recovered as sensible cooling during the fan delay increases as the coil becomes more saturated with water.
2. The calculations below use the conservative assumption that the compressor cycle sensible capacity is a constant. Since the sensible capacity ramps up from near zero at the beginning of the cycle, the average sensible capacity across the compressor cycle is actually lower. With a lower average compressor cycle sensible capacity the fan cycle sensible capacity would represent a larger portion of the total, resulting in higher percentage energy savings.
3. These calculations are based on an actual EER of 10. The average air conditioner in the field actually performs below its rated efficiency. Lower sensible efficiency during the compressor cycle would result in the very high sensible efficiency fan cycle having a larger impact on cycle average sensible efficiency.

The calculations are as follows:

*Compressor Cycle Power = Total Capacity / EER*

*= 36,000 BTU/h / 10.0 BTU/W\*h*

*=* ***3600 W***

*Gross Capacity = Total Capacity + Nominal Fan Motor Heat*

*= 36,000 BTU/h + 1250 BTU/h per 1000 CFM x 1050/1000 CFM*

*=* ***37,312 BTU/h***

*Sensible Capacity = Total Capacity x Sensible Heat Ratio*

*= 36,000 BTU/h x 0.80*

*=* ***28,800 BTU/h***

*Gross Sensible Capacity = Gross Capacity \* Sensible Heat Ratio*

*= 37,312 BTU/h x 0.80*

*=* ***29,850 BTU/h***

*Fan Cycle Gross Sensible Capacityi = Gross Sensible Capacity x Fi x i*

*Where*

*Fi is the Normalized fan cycle gross sensible capacity at time i shown in Figure 8*

*i is the time interval in hours*

*Fan Cycle Sensible Capacityi = Fan Cycle Gross Sensible Capacityi – Fan Heat*

*Where*

*Fan Heat = Fan W x 3.412 BTU/W\*h x (5/60/60) hours*

*= 632 W x 3.412 BTU/W\*h x (5/60/60) hours*

*=* ***2.995 BTU per 5 second interval for the PSC motor***

*= 348 W x 3.412 BTU/W\*h x (5/60/60) hours*

*=* ***1.647 BTU per 5 second interval for the high speed BPM motor***

*= 100 W x 3.412 BTU/W\*h x (5/60/60) hours*

*=* ***0.474 BTU per 5 second interval for the low speed BPM motor***

*Fan Cycle Sensible Capacity = *

*Where*

*tmax = the length of the fan time delay*

*=* ***1547 BTU for the 5 minute PSC motor fan delay***

*=* ***1626 BTU for the 5 minute high speed BPM fan delay***

*=* ***1923 BTU for the 10 minute low speed BPM fan delay***

*Fan Cycle Energyi = Fan Power x i*

*Where*

*i is the time interval in hours*

*= 632 W x (5/60/60) hours*

*=* ***0.878 W\*h per 5 second interval for the PSC motor***

*= 348 W x (5/60/60) hours*

*=* ***0.483 W\*h per 5 second interval for the high speed BPM motor***

*= 100 W x (5/60/60) hours*

*=* ***0.139 W\*h per 5 second interval for the low speed BPM motor***

*Fan Cycle Energy = *

*Where*

*tmax = the length of the fan time delay*

*=* ***51.8 W\*h for the 5 minute PSC motor fan delay***

*=* ***28.5 W\*h for the 5 minute high speed BPM fan delay***

*=* ***16.5 W\*h for the 10 minute low speed BPM fan delay***

*Compressor Cycle Sensible Capacity = Sensible Capacity x Cycle Duration*

*= 28,800 BTU/h x (10/60)hours*

*=* ***4800 BTU*** *for a 10 minute compressor cycle*

*Compressor Cycle Energy = Compressor Cycle Power x Cycle Duration*

*= 3600 W x (10/60)hours*

*=* ***600 W\*h*** *for a 10 minute compressor cycle*

*Full Cycle Sensible Capacity = Compressor Cycle Sensible Capacity + Fan Cycle Sensible Capacity*

*= 4800 BTU + 1547 BTU*

*=* ***6347 BTU for the full cycle with 5 minute PSC fan delay***

*= 4800 BTU = 1626 BTU*

*=* ***6424 BTU for the full cycle with 5 minute high speed BPM fan delay***

*= 4800 BTU + 1923 BTU*

*=* ***6723 BTU for the full cycle with 10 minute low speed BPM fan delay***

*Full Cycle Energy = Compressor Cycle Energy + Fan Cycle Energy*

*= 600 W\*h + 51.8 W\*h*

*=* ***651.8 W\*h for the full cycle with 5 minute PSC fan delay***

*= 600 W\*h + 28.5 W\*h*

*=* ***628.5 W\*h for the full cycle with 5 minute high speed BPM fan delay***

*= 600 W\*h + 16.5 W\*h*

*=* ***616.5 W\*h for the full cycle with 10 minute low speed BPM fan delay***

*Full Cycle Net Sensible EER = Full Cycle Sensible Capacity / Full Cycle Energy*

*= 4800 BTU / 600 W\*h*

*=* ***8.00 BTU/W\*h for the compressor cycle with no fan delay***

*= 6347 BTU / 651.8 W\*h*

*=* ***9.74 BTU/W\*h for the full cycle with 5 minute PSC fan delay***

*= 6424 BTU / 628.5 W\*h*

*=* ***10.23 BTU/W\*h for the full cycle with 5 minute high speed BPM fan delay***

*= 6723 BTU / 616.5 W\*h*

*=* ***10.90 BTU/W\*h for the full cycle with 10 minute low speed BPM fan delay***

*Energy Savings Percentage = *

*where:*

*subscript 1 = initial condition*

*subscript 2 = final condition*

*= (9.74 – 8.00) / 9.74 =****18% savings for the 5 minute PSC fan delay***

*= (10.23 – 8.00) / 10.23 =****22% savings for the 5 minute high speed BPM fan delay***

*= (10.90 – 8.00) / 10.90 =****27% savings for the 10 minute low speed BPM fan delay***

Table 12: Calculated Savings by Fan Motor and Delay Type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | No  fan delay | PSC  5 min delay | BPM hi spd  5 min delay | BPM lo spd 10 min delay |
| Fan Cycle Net Sensible Capacity (BTU) | 0 | 1547 | 1626 | 1923 |
| Full Cycle Net Sensible Capacity (BTU) | 4800 | 6347 | 6426 | 6723 |
| Fan Cycle W\*h | 0 | 51.8 | 28.5 | 16.5 |
| Full Cycle W\*h | 600 | 651.8 | 628.5 | 616.5 |
| Fan Cycle Net Sensible EER (BTU/W\*h) | - | 29.9 | 57.1 | 116.3 |
| Full Cycle Net Sensible EER (BTU/W\*h) | 8 | 9.74 | 10.23 | 10.90 |
| **Cooling Energy Savings** | **-** | **18%** | **22%** | **27%** |

**Calculated Energy Savings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Cooling Energy Savings (%)** | **Study units** | **Specific study reference** |
| N/A | N/A | N/A | PSC: 18%  BPM: 22% - 27% | HVAC System | Ref 4 |

#### 1.4.4.2 Air Conditioning Peak Population Characteristics

Within the residential population there are three significant modes of air conditioner peak

demand as follows:

* Residences where the air conditioners run continuously for some or all of the peak hours. The continuously running AC group consists of air conditioners that cannot meet the load either because they are small or the load is excessive (such as is caused by a thermostat adjustment to a lower temperature).
  + The BPM measure peak demand reduction for these units is the reduction in fan motor watt draw.
* Residences that have air conditioners that are cycling during these hours.
  + The BPM measure peak demand reduction for these units is a function of the cooling efficiency improvement resulting from the higher efficiency BPM motor and dry climate fan control.
* Residences where the air conditioners are off during the peak hours.

Research performed by Proctor Engineering for PG&E Contract #4400000873 included a compilation of air conditioning peak operation characteristics from studies in five cities. (ref 9).

Among the cities studied, the Fresno, CA population found the lowest fraction of operating units cycling at peak. Of all units in the Fresno study, 36% were running continuously at peak. Of the Fresno units that were operating at peak, 55% were cycling.

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

We are required by CPUC decision 06-06-063 dated June 29, 2006 to apply time-of-use (TOU) adjustment factors on residential A/C and commercial A/C (packaged and split-system direct-expansion cooling) measures only. This measure has a DEER2014 load shape, i.e. the load shape starts with “DEER:” the TOU adjustment factor assigned to that measure should be zero.

If a non-DEER load shape is used, the applicable TOU correction factor is calculated as:



where

*kWAC*is the kW savings associated with the A/C unit, and

*kWTotal* is the total kW savings for the sum of kW measures.

100% of the savings for this measure are associated with the A/C unit.

The TOU factor is 100%.

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

For the general population of units served by this program, it is assumed that the majority of units are equipped with standard efficiency PSC fan motors. For these PSC units:

* Section 1.4.3.1 found 14% average savings in the field
* Section 1.4.3.2 found lab measured savings exceeding 25%, even with assumed duct losses
* Section 1.4.3.4 found 18% savings
* Section 1.4.4.1 shows 18% savings

The PSC savings are estimated at 14%, which is taken directly from the independent assessment in section 1.4.3.1.

Associated workpaper PGE3PMOT102 addresses measures which retrofit high efficiency BPM fan motors into PSC furnaces and air handlers. For these BPM units:

* Section 1.4.3.1 found measured savings of 25% in the field
* Section 1.4.3.2 found laboratory measured savings of 20% to 40% for moderate delay lengths
* Section 1.4.3.3 found savings of 15% to 29% depending on compressor cycle length
* Section 1.4.4.1 shows savings of 22% to 27% for a 10 minute compressor cycle
* Workpaper PGE3PMOT102 shows BPM motor changeout savings of 9%

The BPM savings are estimated at 20%, which is conservative relative to the field measured savings from the independent assessment in section 1.4.3.1. This workpaper makes the conservative assumption that all units with BPM fan motors had the motor installed and savings claimed under an energy efficiency program. The savings for Enhanced Time Delay installation on a BPM motor are therefore reduced to account for remaining use after the BPM changeout:

20% X (1-9%) = 18% savings for installation on a system with a BPM fan motor

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

Table 13: References for Calculation Inputs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Input Variable** | **Variations** | **Base Case 1** | **Base Case 2** | **Measure Case Value** | **Reference Section** |
| **Electric Savings** | CZ, BT | DEER2014 Existing |  | *14% cooling energy use reduction* | *Section 1.4.3.1* |
| **Electric Savings BPM** | CZ, BT | DEER2014 Existing |  | *18% cooling energy use reduction* | *Section 1.4.3.1*  *Section 1.4.3.2*  *Section 1.4.4.1* |
|  |  |  |  |  |  |
| **Hours of operation** | CZ, BT | DEER2014 Existing |  |  |  |
| **Full Cost** | ER |  |  | $100 | Section 1.4.1.2 |
| **Incremental Cost** | ER |  |  | $100 | Section 1.4.1.2 |
| **EUL /RUL** | ER |  |  | 10 | Section 1.4.1.4 |
| **NTG** | .78 |  |  |  | Section 1.4.1.3 |
| **ISR** | Applies -- Yes / No |  |  |  |  |
| **TOU Factor** | *A/C projects only* |  |  |  | *Section 1.4.5* |

# Section 2. Calculation Methods

## 2.1 Electric Energy Savings Estimation Methodologies

The Annual Energy Savings and Peak Reductions were calculated in the embedded workbook in Appendix A using the following calculations:



*where,*

 *is the Baseline Annual Energy Consumption from:  
Technology ID D08-RE-HV-ResAC-14S for Residential Installation weighted by vintage and climate zone for PG&E, adjusted to DEER 2014 as described in section 1.4.1. The DEER2008 Run IDs and DEER2014 adjustments are listed in Tables 2, 3, and 4.*

 *is 14% Energy Savings for PSC fan motors (Section 1.5).*

*or 18% Energy Savings for BPM fan motors (Section 1.5).*

## 2.2. Demand Reduction Estimation Methodologies

The Demand Reduction values were calculated as:



*where,*

 = 

 *is the Baseline Average Tonnage from: Technology ID D08-RE-HV-ResAC-14S for Residential Installation weighted by vintage and climate zone for PG&E, adjusted to DEER 2014 as described in section 1.4.1. The DEER2008 Run IDs and DEER2014 adjustments are listed in Tables 2, 3, and 4.*

 *is the Peak EER of 7*

 *is the Percentage Energy Savings from Table 13*

 *is 55% is the percentage of units assumed to be cycling at peak (section 1.4.4.2)*

## 2.3. Gas Energy Savings Estimation Methodologies

This measure does not produce gas savings or interact with the HVAC system during heating operation.

# *Section 3. Load Shapes*

## 3.1 Base Case Load Shapes

The base case load shape would be expected to follow a typical residential HVAC end use load shape for a particular building type (single family, multi-family, mobile home). The appropriate base case load shape would represent existing HVAC equipment types and performance levels.

Load shapes that represent code base HVAC performance are not appropriate for this measure because the program addresses existing systems with the performance degradations that are typical to existing HVAC systems in California.

## 3.2 Measure Load Shapes

The closest load shape chosen for this measure is the DEER:HVAC\_Refrig\_Charge load shape. The DEER:HVAC\_Refrig\_Charge load shape was selected because it represents existing air conditioning systems.

Alternatively, this measure is represented by non-DEER load shape 26 = Res. Central Air Conditioning. If load shape 26 is use, the applicable TOU factor is 100%.

Table 14: Base Case Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **E3 Alt. Building Type** | **Load Shape** |
| SFM | RES | DEER:HVAC\_Refrig\_Charge |
| MFM | RES | DEER:HVAC\_Refrig\_Charge |
| DMO | RES | DEER:HVAC\_Refrig\_Charge |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case(s) Costs

The base case cost is zero.

## 4.2 Measure Case Costs

The Measure Case Costs are:

Table 15: Measure Case Costs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Measure Case Cost** |
| H796 – SFM, DMO | RET | Existing | $48.50 | $50 | $0 | $98.50 |
| H796 - MFM | RET | Existing | $48.50 | $30 | $0 | $78.50 |

*All costs are noted as $ per measure unit*

Measure costs were calculated as described in section 1.4.1.2.

## 4.3 Incremental & Full Measure Costs

Typical hardware cost to the customer is $48.50.

Typical installation time is 15 minutes. The DEER2014 Costs and Values Summary documentation lists the base rate labor cost for residential HVAC at $67.88 per hour.

$67.88 \* 15/60 = $16.97.

The actual installation cost is higher than indicated by the installation time and DEER2014 base labor rate. Estimates provided by participating contractors indicate the cost is closer to $50 for building types where a single measure is installed per location, such as SFM and DMO building types. Contractor costs are lower when multiple measures are installed at the same location, such as for MFM building types. For MFM installations the participating contractors estimate $30 per measure.

Total cost for SFM and DMO building types is:

$48.50 + $50 = $98.50

Total cost for MFM building types is:

$48.50 + $30 = $78.50

Table 16: Total Measure Cost

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Description** | **Labor** | **Material** | **Total Unit Cost** |
| **HVAC** Install Enhanced Time Delay, Building Types SFM, DMO | $50 | $48.50 | $98.50 |
| **HVAC** Install Enhanced Time Delay, Building Types MFM | $30 | $48.50 | $78.50 |

### 4.3.1 Gross Measure Cost

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

This measure Measure Application Type(s) is(are) **Retrofit** so the Gross Measure Cost (GMC) is represented by the equation below:

GMC = Measure Equipment Cost + Measure Labor Cost

*GMC = $48.50 per (unit) + $50 per (unit) = $98.50 per(unit) for SFM, DMO*

*GMC = $48.50 per (unit) + $30 per (unit) = $78.50 per(unit) for MFM*

### 4.3.2 Incremental Measure Costs

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

This Measure Application Types is **Retrofit**, so the Incremental Measure Cost (IMC) is represented by the equation below:

IMC = Measure Equipment Cost + Measure Labor Cost

*IMC = $48.50 per (unit) + $50 per (unit) = $98.50 per(unit) for SFM, DMO*

*IMC = $48.50 per (unit) + $30 per (unit) = $78.50 per(unit) for MFM*

Table 17: Measure Total and Incremental Costs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure ID** | **Measure Application Types** | **Base Case Total Cost** | **Measure Case Total Cost** | **Gross Measure Case Cost** | **Incremental Measure Cost** |
| H796 –  SFM, DMO | RET | 0 | 98.50 | 98.50 | 98.50 |
| H796 –  MFM | RET | 0 | 78.50 | 78.50 | 78.50 |

# 

# Input Appendices

## A. (1.4.1) DEER Base Case and Measure Case Information

The DEER2008 and 2014 baseline records and savings calculations are provided in the embedded spreadsheet:



# References

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1. Henderson, H., D. Shirey, and R. Raustad. 2006. *Understanding The Dehumidification Performance of Air-Conditioner Equipment at Part-Load Conditions*. Final Report FSEC-CR-1537-05. Cocoa, FL. Florida Solar Energy Center. Figure 1-1, page 1-1 and   
   Appendix D. This report is too large (over 600 pages and 13 megabytes) to imbed or to copy. It is available on the FSEC website http://securedb.fsec.ucf.edu/pub/pub\_search. We have imbedded a screen print of the first page of the introduction.   
   (Word Document: FSEC Dehumidification Study.doc)



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