**Work Paper PGE3PMOT102**

**Enhanced Time Delay BPM Motor**

**Revision # 2**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**California Climate Air Conditioner Upgrade – Brushless Fan Motor with Enhanced Time Delay**

**Measure Codes H797, H798**

***Cooling Optimizer Program***

# At-a-Glance Summary

|  |  |  |
| --- | --- | --- |
| **Applicable Measure Codes:** | **H797** | **H798** |
| **Measure Description:** | Install a high efficiency Brushless Permanent Magnet indoor fan motor with enhanced fan delay controls for dry climates into a central HVAC system with thermostat fan control set to Auto. | Install a high efficiency Brushless Permanent Magnet indoor fan motor into a central HVAC system with thermostat fan control set to Continuous Fan. |
| **Energy Impact Common Units:** | each | |
| **Base Case Description:** | Existing central HVAC system with Permanent Split Capacity (PSC) indoor fan motor | |
| **Base Case Energy Consumption:** | Source: DEER 2008 adjusted to DEER 2014 HVAC end use 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, fan usage dependent | |
| **Energy Savings**  **(Base Case – Measure):** | Source: [Multiple. See section 1.4] Building type, climate zone, fan usage dependent | |
| **Costs Common Units:** | each | |
| **Base Case Equipment Cost ($/unit):** | Source: 2010-2012 Ex Ante Measure Cost Study  $261.74 | |
| **Measure Equipment Cost ($/unit):** | Source: 2010-2012 Ex Ante Measure Cost Study  $380.92 | |
| **Gross Measure Cost ($/unit)** | $119.18 | |
| **Incremental Measure Cost ($/unit):** | $119.18 | |
| **Effective Useful Life (years):** | Source: [DEER2014] 15 | |
| **Measure Application Type:** | Replace on Burnout (ROB) measure, Direct Install delivery channel. | |
| **Net-to-Gross Ratios:** | Source: [DEER2014] 0.55 | |
| **Important Comments:** | Enhanced Time Delay Savings are documented in associated Workpaper PGE3PHVC150 | |

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# Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |
| --- |
| **Carolyn Weiner**  Manager, CES Products and Programs |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| **Revision 0** | **6/22/2012** | **PGE3PMOT102 Enhanced Time Delay BPM Motor** | **Abram Conant (Proctor Engineering)** |
| **Revision 1** | **6/19/2014** | **Updated for DEER 2014, incremental costs to reflect cost of currently available BPM models, & section 1.4.4.1 with current data.** | **Abram Conant (Proctor Engineering)**  **Tai Voong (PG&E)** |
| **Revision 2** | **3/2/2016** | **Updated cost data using 2010-12 Ex Ante Measure Cost Study. Updated to latest ex ante template.** | **Jia Huang (PG&E)** |

# Table of Contents

[At-a-Glance Summary i](#_Toc390952867)

[Work Paper Approvals ii](#_Toc390952868)

[Document Revision History iii](#_Toc390952869)

[Table of Contents iv](#_Toc390952870)

[List of Tables v](#_Toc390952871)

[List of Figures v](#_Toc390952872)

[Section 1. General Measure & Baseline Data 1](#_Toc390952873)

[1.1 Product Measure Description & Background 1](#_Toc390952874)

[1.2 Product Technical Description 1](#_Toc390952875)

[1.3 Measure Application Type 2](#_Toc390952876)

[1.4 Product Base Case and Measure Case Data 3](#_Toc390952877)

[1.4.1 DEER Base Case and Measure Case Information 3](#_Toc390952878)

[1.4.1.1 Measure electric and gas savings 6](#_Toc390952879)

[1.4.1.3 Net to Gross Assumption 7](#_Toc390952880)

[1.4.1.4 Effective Useful Life / Remaining Useful Life 7](#_Toc390952881)

[1.4.1.5 In-service rate / first year installation rate 7](#_Toc390952882)

[1.4.2 Codes & Standards Requirements Base Case and Measure Information 7](#_Toc390952883)

[1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information 8](#_Toc390952884)

[1.4.3.1 Study #1, ACEEE Report “The Efficiency Boom: Cashing In on the Savings from Appliance Standards” 8](#_Toc390952885)

[1.4.3.2 Study #2, CEC Study “Furnace Fan Watt Draw and Air Flow in Cooling and Air Distribution Modes” 9](#_Toc390952886)

[1.4.3.3 Study #3 Electricity Use by New Furnaces - A Wisconsin Field Study 10](#_Toc390952887)

[1.4.3.4 Study #5 2013 California Building Energy Efficiency Standards Case Report 10](#_Toc390952888)

[1.4.3.5 Study #4 US Department of Energy Residential Furnace Fans Standards Rulemaking Documents 12](#_Toc390952889)

[1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases 13](#_Toc390952890)

[1.4.4.1 Field Measured Data 13](#_Toc390952891)

[1.4.4.2 Laboratory Measured Data 16](#_Toc390952892)

[1.4.4.3 Cooling Compressor Cycle Energy Savings – Engineering Calculation 17](#_Toc390952893)

[1.4.4.4 Cooling Compressor Cycle Energy Savings – Modeled Performance 19](#_Toc390952894)

[1.4.4.5 Cooling Fan Cycle Energy Savings 20](#_Toc390952895)

[1.4.4.6 Air Conditioning Peak Population Characteristics 20](#_Toc390952896)

[Section 2. Calculation Methods 22](#_Toc390952897)

[2.1 Electric Energy Savings Estimation Methodologies 22](#_Toc390952898)

[2.2. Demand Reduction Estimation Methodologies 23](#_Toc390952899)

[2.2.1 Summer Demand Reduction for Units with Auto Fan 23](#_Toc390952900)

[2.2.2 Summer Demand Reduction for Units with Continuous Fan 24](#_Toc390952901)

[2.3. Gas Energy Savings Estimation Methodologies 24](#_Toc390952902)

[*Section 3. Load Shapes* 24](#_Toc390952903)

[3.1 Base Case Load Shapes 24](#_Toc390952904)

[3.2 Measure Load Shapes 25](#_Toc390952905)

[Section 4. Base Case & Measure Costs 25](#_Toc390952906)

[4.1 Base Case(s) Costs 25](#_Toc390952907)

[4.2 Measure Case Costs 25](#_Toc390952908)

[4.3 Incremental & Full Measure Costs 26](#_Toc390952909)

[*4.3.1 Full Measure Cost* 26](#_Toc390952910)

[*4.3.2 Incremental Measure Costs* 26](#_Toc390952911)

[References 28](#_Toc390952912)

# 

# List of Tables

[Table 1: DEER Use and Technology Table 3](#_Toc389659802)

[Table 2: DEER 2008 Impact IDs and Baseline Annual Energy Use 4](#_Toc389659803)

[Table 3: DEER 2008 to 2014 Adjustment, Cooling kWh 4](#_Toc389659804)

[Table 4: DEER 2008 to 2014 Adjustment, Heating Therms 5](#_Toc389659805)

[Table 5: DEER 2014 Impact IDs and Baseline Annual Energy Use 5](#_Toc389659806)

[Table 6: Measure Electric and Gas Energy Savings 6](#_Toc389659807)

[Table 7: Net to Gross Ratios 7](#_Toc389659808)

[Table 8: Motor Replacement Annual Savings 8](#_Toc389659809)

[Table 9: BPM motor and Fan Delay Savings over PSC motor without Fan Delay 12](#_Toc389659810)

[Table 10: Average Fan Watt Draw for Units with 3 Tons of Cooling Capacity 15](#_Toc389659811)

[Table 11: Motor Replacement Compressor Cycle Savings 19](#_Toc389659812)

[Table 12: Modeled Compressor Cycle Cooling Savings 19](#_Toc389659813)

[Table 13: References for Calculation Inputs 21](#_Toc389659814)

[Table 14: Base Case Building Types and Load Shapes 25](#_Toc389659815)

[Table 15: Measure Case Costs 25](#_Toc389659816)

# 

# List of Figures

[Figure 1: Fan Watt Draw 10](#_Toc389646593)

[Figure 2: Typical Cooling Airflow 10](#_Toc389646594)

[Figure 3: Sensible EER for 350CFM/ton Compressor Cycle and 350 CFM/ton Fan Delay 12](#_Toc389646595)

[Figure 4: Sensible EER for 350CFM/ton Compressor Cycle and 216 CFM/ton Fan Delay 12](#_Toc389646596)

[Figure 5: Fan Input Power Reduction in Cooling Mode 15](#_Toc389646597)

[Figure 6: Field Measured Fan Power Pre and Post BPM Retrofit 15](#_Toc389646598)

[Figure 7: Pre and Post Retrofit Watts for Various Air Conditioner Sizes 16](#_Toc389646599)

[Figure 8: BPM Motor Performance 17](#_Toc389646600)

# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description –***

H797 – Install a high efficiency Brushless Permanent Magnet indoor fan motor with enhanced fan delay controls for dry climates into a central HVAC system with thermostat fan control set to Auto.

H798 - Install a high efficiency Brushless Permanent Magnet indoor fan motor into a central HVAC system with thermostat fan control set to Continuous Fan.

***Program Restrictions and Guidelines***

This measure applies to any unitary air conditioner with a standard Permanent Split Capacitor (PSC) indoor fan motor.

***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 comprised of climate zones 11, 12 and 13.

This measure replaces the lower efficiency indoor fan motor in existing HVAC systems and 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

This work paper documents the values used to forecast the savings for upgrading unitary air conditioning equipment to operate at higher efficiency in the California climate. The savings documented here are for the installation of a Brushless Permanent Magnet (BPM) indoor fan motor specifically configured to be a drop in retrofit for standard PSC furnace fan motors. The savings include the Western Cooling Control™ (WCC) enhanced time delay, which is integrated into the controls of some BPM retrofit models and available as an add-on for other models. The savings for WCC installed into a system with a BPM fan motor are detailed in Workpaper PGE3PHVC150, Section 1.5.

The standard furnace fan motors are permanent split capacitor (PSC) motors. The characteristics of these motors are moderate efficiency and constant no load speed. Lower speeds are accomplished by “slip” which drops the speed of the motor, but has only a small effect on the watt draw. Brushless Permanent Magnet (BPM) motors, also referred to as brushless DC or electronically commutated motors (ECM),are more efficient than PSC motors and are capable of operating at reduced speed without the large efficiency losses experienced by PSC motors.

The BPM motor measure is retrofit into the indoor air handler of central air conditioning systems and has four significant energy saving characteristics.

1. During air conditioning operation the BPM motor draws 45% less watts than the PSC motor it replaced, while producing the same airflow. This has the added benefit of improving air conditioner capacity and efficiency due to less motor heat rejected to the indoor airstream.
2. During heating operation the BPM motor draws less than 50% of the watts of the PSC motor it replaced.
3. During constant fan operation the BPM motor runs at reduced speed and up to 90% lower watt draw than the PSC motor it replaced. This results in very large savings in buildings that operate the fan continuously for ventilation or filtration purposes.
4. During air conditioning the WCC enhanced time delay controls the indoor fan run time following each air conditioner compressor cycle to deliver additional sensible cooling to the conditioned space. The additional cooling is very efficient since it is provided using only the small watt draw of fan motor. The WCC control recalculates the optimal delay time during each air conditioner compressor cycle.

## 1.3 Measure Application Type

The BPM fan motor measures are retrofit measures.

The BPM motors are retrofit into existing furnaces and air handlers. There are two potential scenarios which produce identical energy savings with identical measure life:

1. The existing PSC fan motor is functional and is replaced with the BPM fan motor. The savings are the difference in HVAC system energy use with the PSC vs. BPM fan motors over the remaining life of the furnace.
2. The existing PSC fan motor is not functioning and would normally be replaced with an equivalent PSC motor, but is replaced with the BPM motor instead. The savings are the difference in HVAC system energy use with the PSC vs. BPM fan motors over the remaining life of the furnace.

Proctor Engineering implements BPM replacement measures in several states with results to date indicating that the majority of installations are replacements of functional existing motors. The calculations in this workpaper assume replacement of a functional existing motor. This is the conservative assumption because savings are identical in both cases, but incremental costs would be lower in the replace on burnout case. This workpaper assumes the full measure cost as the incremental cost.

Table  Measure Application Type

*Identifies the measure application type in the Measure Implementation table in DEER2014.*

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| ER | Early retirement | *Measure is more efficient than code/std; Dual baseline, full measure costs required* |
| ROB | Replace on Burnout | *Single baseline (above code), incremental or full costs* |
| NC | New Construction | *Single baseline (above code), incremental or full costs* |
| REA | Retrofit Add On | *Single baseline (above pre-existing), full measure costs required* |

## 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 |

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 and 90 AFUE gas furnaces, as listed in Tables 3 and 4. This calculation adjusts for the 2014 weather file update as well as any changes in the customer average building models used in the DEER calculations.

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 and residential AFUE90 gas furnace measures. This assumption is valid because the DEER update documentation does not indicate any substantive changes to the residential split system SEER 14 or AFUE90 gas furnace measures. The base use values adjusted to DEER 2014 are shown in Table 5. The calculations for every PG&E climate zone are provided in Appendix A.

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| DEER2008 Impact ID | Zone | Vintage | End Use  (kWh/unit) | Tons of Cooling Capacity | End Use (Therms/unit) |
| SFM-w11-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 11 | PG&E Weighted | 1644 | 3.51 | 283.9 |
| SFM-w12-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 12 | PG&E Weighted | 1038 | 3.32 | 274.9 |
| SFM-w13-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 13 | PG&E Weighted | 1957 | 3.40 | 274.2 |
| SFM-wPGE-vEx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | PG&E Weighted | PG&E Weighted | 1159 | 3.27 | 283.4 |
| DMO-w11-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 11 | PG&E Weighted | 3948 | 3.50 | 377.2 |
| DMO-w12-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 12 | PG&E Weighted | 3218 | 3.50 | 271.1 |
| DMO-w13-vPGx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | 13 | PG&E Weighted | 4737 | 3.50 | 316.6 |
| DMO-wPGE-vEx-hAC-tWt-bCA-eMS-mRE-HV-ResAC-14S | PG&E Weighted | PG&E Weighted | 3360 | 3.50 | 342.4 |

Table 3: DEER 2008 to 2014 Adjustment, Cooling kWh

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 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 2008 to 2014 Adjustment, Heating Therms

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| DEER2014 Impact ID | Zone | Vintage | Building Type | DEER 2008 savings, customer average base  (Therms/unit) | DEER 2014 savings, customer average base  (Therms/unit) | DEER 2014/2008 Therms Ratio |
| Res-Furnace-dHIR | 11 | Ex | SFM | 30.5 | 29.0 | 0.95 |
| Res-Furnace-dHIR | 12 | Ex | SFM | 29.5 | 28.5 | 0.96 |
| Res-Furnace-dHIR | 13 | Ex | SFM | 29.4 | 28.5 | 0.97 |
| Res-Furnace-dHIR | PGE | Ex | SFM | 30.4 | 30.0 | 0.99 |
| Res-Furnace-dHIR | 11 | Ex | DMO | 47.4 | 30.0 | 0.63 |
| Res-Furnace-dHIR | 12 | Ex | DMO | 33.9 | 26.7 | 0.79 |
| Res-Furnace-dHIR | 13 | Ex | DMO | 40.0 | 25.9 | 0.65 |
| Res-Furnace-dHIR | PGE | Ex | DMO | 43.0 | 28.8 | 0.67 |

Table 5: DEER 2014 Impact IDs and Baseline Annual Energy Use

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| DEER2014 Impact ID | Building Type | Climate Zone | Vintage | Annual Cooling kWh/unit | Tons of Cooling Capacity | Annual Heating Therms/unit |
| RE-HV-ResAC-14S | SFM | 11 | PG&E Weighted | 1738 | 3.46 | 271 |
| RE-HV-ResAC-14S | SFM | 12 | PG&E Weighted | 1070 | 3.28 | 265 |
| RE-HV-ResAC-14S | SFM | 13 | PG&E Weighted | 2001 | 3.36 | 266 |
| RE-HV-ResAC-14S | SFM | PG&E Weighted | PG&E Weighted | 1187 | 3.24 | 279 |
| RE-HV-ResAC-14S | DMO | 11 | PG&E Weighted | 3955 | 3.50 | 238 |
| RE-HV-ResAC-14S | DMO | 12 | PG&E Weighted | 2917 | 3.50 | 213 |
| RE-HV-ResAC-14S | DMO | 13 | PG&E Weighted | 4229 | 3.50 | 205 |
| RE-HV-ResAC-14S | DMO | PG&E Weighted | PG&E Weighted | 3124 | 3.50 | 229 |

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.

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 tabulated below. Savings for the three climate zones primarily targeted by the program are tabulated below. Savings calculations and detailed DEER information for all PG&E climate zones are included in Appendix A.

Table 6: Measure Electric and Gas Energy Savings

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings kWh/yr** | **Gas Savings Therms/yr** | **Units** | **DEER Version** |
| SFM (auto fan) | PG&E Weighted | 11 | 608 | -5.77 | Per Air Conditioner | 2008 base adjusted to 2014 |
| SFM (auto fan) | PG&E Weighted | 12 | 424 | -5.66 | Per Air Conditioner | 2008 base adjusted to 2014 |
| SFM (auto fan) | PG&E Weighted | 13 | 677 | -5.68 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM (auto fan) | PG&E Weighted | 11 | 381 | -3.62 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM (auto fan) | PG&E Weighted | 12 | 255 | -3.41 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM (auto fan) | PG&E Weighted | 13 | 439 | -3.67 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO (auto fan) | PG&E Weighted | 11 | 1195 | -5.07 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO (auto fan) | PG&E Weighted | 12 | 900 | -4.55 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO (auto fan) | PG&E Weighted | 13 | 1253 | -4.37 | Per Air Conditioner | 2008 base adjusted to 2014 |
| SFM (continuous fan) | PG&E Weighted | PG&E Weighted | 3430 | -73.19 | Per Air Conditioner | 2008 base adjusted to 2014 |
| MFM (continuous fan) | PG&E Weighted | PG&E Weighted | 3430 | -73.19 | Per Air Conditioner | 2008 base adjusted to 2014 |
| DMO (continuous fan) | PG&E Weighted | PG&E Weighted | 3430 | -73.19 | Per Air Conditioner | 2008 base adjusted to 2014 |

#### 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 7: Net to Gross Ratios

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NTGR\_ID | Description | Sector | NTGR | Documentation |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Res | 0.55 | 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. There are two potential scenarios which produce identical energy savings with identical measure life:

1. The existing PSC fan motor is functional and is replaced with the BPM fan motor. The savings are the difference in HVAC system energy use with the PSC vs. BPM fan motors over the remaining life of the furnace.
2. The existing PSC fan motor is not function and would normally be replaced with an equivalent PSC motor, but is replaced with the BPM motor instead. The savings are the difference in HVAC system energy use with the PSC vs. BPM fan motors over the remaining life of the furnace.

The mean life of a residential central air conditioner is 20.5 years according to ASHRAE Transactions ResearchRef 4. 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 15 years derived from the DEER 2014:

* EUL\_ID Motors-fan: is "HVAC Fan Motors".

#### 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 motor. The measure is a potential retrofit to any unit that does not already have a premium furnace fan motor.

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

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

|  |  |
| --- | --- |
| Table 8: Motor Replacement Annual Savings | |
| Compressor Cycle Savings | 9% |
| Fan Cycle Integrated ETD Savings | 20% |
| Total Interacted Cooling Savings | 27% |
|  |  |
| Heating Electrical Savings | 0.5 kWh per therm |
| Continuous Fan Savings | 3430 kWh |

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, ACEEE Report “The Efficiency Boom: Cashing In on the Savings from Appliance Standards”

This section presents the results of a national energy saving potential study considering the impacts of implementing new appliance efficiency standards, including a standard for residential furnace fans that would require BPM motors in place of the PSC motors typically used today.

The March, 2012 ACEEE report “The Efficiency Boom: Cashing In on the Savings from Appliance Standards” evaluated the impact of new standards for 14 residential, 13 commercial, and 7 lighting products. The report included evaluation of a standards change to require BPM fan motors instead of PSC fan motors in residential air handlers.

Of the 34 products evaluated, the report concluded:

“Residential air handler standards would deliver the largest peak electric demand savings (about 12 GW in 2035), or roughly 18% of the total.”

Of the 34 products evaluated, residential air handlers ranked as the 3rd highest potential energy savings, with 2.9 Quads of cumulative savings through 2035. The study found national average energy savings of 554 kWh per year per for each air handling unit equipped with a BPM fan motor. These national average savings do not include the additional dry climate savings provided by the Enhanced Time Delay.

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings kWh/year** | **Study units** | **Specific study reference** |
| Residential | All | US National Average | 554 | HVAC System | Ref 5 |

#### 1.4.3.2 Study #2, CEC Study “Furnace Fan Watt Draw and Air Flow in Cooling and Air Distribution Modes”

This section presents field measured data documenting the baseline performance characteristics of furnace / air conditioner air handler systems in California homes.

This measure addresses the efficiency of existing furnace / air handling units. The typical characteristics of these units in California homes were documented in a study for the 2008 California Building Energy Efficiency Standards.

Figure 1: Fan Watt Draw

###### 

Figure 2: Typical Cooling Airflow



Typical furnace / air handling units in California have the following characteristics as determined by field measurements for the California Energy Commission on 60 furnacesRef 3:

* Median Fan Watts in Cooling Speed = 632 Watts (Figure 1)
* Median Cooling Airflow = 358 cfm per ton (Figure 2)
* Median Watts per cfm = 0.51

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Baseline Electric Use (W)** | **Study units** | **Specific study reference** |
| Residential | All | CA - ALL | 632 W  (0.51 W per cfm) | HVAC System | Ref 3 |

#### 1.4.3.3 Study #3 Electricity Use by New Furnaces - A Wisconsin Field Study

This section presents field monitored data documenting the energy savings that occur during the heating and continuous fan modes of operation.

The Energy Center of Wisconsin monitored 31 new Wisconsin furnaces. They found that the heating mode electricity usage on Brushless Motors was 0.5 kWh per therm compared with 1.0 kWh per therm for conventional PSC motors (Pigg 2003, page iii Top Finding #2)Ref 2. This information is imbedded in the References section of this workpaper.

The Wisconsin Study found for units where the fan operated continuously the furnaces with variable speed BPM (ECM) fan motors used 1295 kWh/year compared to 4725 kWh/year for furnaces with PSC fan motors (page 41 Table 3).Ref 2 The estimated savings per air conditioner that operates the fan continuously is:

4725 - 1295 = 3430 kWh/year.

This estimate does not include the additional savings that occur during cooling as a result of reduced fan motor heat being rejected to the airstream.

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings kWh/year** | **Study units** | **Specific study reference** |
| Residential  (auto fan) | All | N/A | 0.5 kWh per Heating Therm | HVAC System | Ref 2 |
| Residential  (continuous fan) | All | N/A | 3430 kWh | HVAC System | Ref 2 |

#### 1.4.3.4 Study #5 2013 California Building Energy Efficiency Standards Case Report

This section presents laboratory measured data documenting the effect on air conditioner 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 9. 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 analysis included net performance with and without assumed duct losses equivalent to 20% of capacity when the system is operating at full capacity, and with PSC and BPM fan motors.

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** |
|  |  |

The laboratory measured cycle average sensible EER at the end of the compressor cycle with the PSC fan motor during these tests averaged:

* 4.51 at the unit (without duct losses)
* 2.52 with duct losses

Table 9 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 range from 16% for the BPM fan motor only to greater than 30% with the BPM fan motor and fan time delay.

Table 9: BPM motor and Fan Delay Savings over PSC motor without Fan Delay

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **BPM Motor @ 350 CFM/ton** | | **BPM Motor @ 350 CFM/ton - 216 CFM/ton** | |
| **Cycle** | **Condition** | **Cycle Average Sensible EER** | **% Energy Savings over PSC Motor and No Delay** | **Cycle Average Sensible EER** | **% Energy Savings over PSC Motor and No Delay** |
| No fan delay | At Unit | 5.35 | 16% | 5.35 | 16% |
| With Duct Loss | 3.15 | 20% | 3.15 | 20% |
| 200 sec fan delay | At Unit | 7.63 | 41% | 6.9 | 35% |
| With Duct Loss | 4.71 | 46% | 3.62 | 30% |
| 300 sec fan delay | At Unit | 8.85 | 49% | 7.84 | 42% |
| With Duct Loss | 5.21 | 52% | 3.94 | 36% |
| 600 sec fan delay | At Unit |  |  | 9.59 | 53% |
| With Duct Loss |  |  | 4.24 | 41% |

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **% Energy Savings BPM with Enhanced Fan Delay** | **Study units** | **Specific study reference** |
| N/A | N/A | N/A | > 30% | Air Conditioner | Ref 9 |

#### 1.4.3.5 Study #4 US Department of Energy Residential Furnace Fans Standards Rulemaking Documents

This section presents national average residential HVAC fan usage estimates documented in the US Department of Energy rulemaking for residential furnace fans.

As shown in section 1.4.3.3, the energy savings associated with continuous fan operation are very large. The fan usage characteristics of homes within the program area are not known. The RASS data do not include information on continuous fan operation, and there is no other known source of CA specific data regarding indoor fan operation characteristics.

The US Department of Energy documentation for the proposed Test Procedures

for Residential Furnace FansRef 7 include a discussion of national fan operation characteristics and national average run hours in the cooling, heating, and fan only modes.

The DOE estimates that the percentage of US homes that operate the central HVAC system indoor fan continuously year round is 5%, with an additional 6% of homes operating the fan constantly for a portion of the year. The DOE notes that there is regional variation in fan operation characteristics, with the highest usage occurring in the North region and the lowest in the South Hot Humid region.

The DOE estimates that 7% of homes in the Hot Dry region, which includes California, operate the indoor fan continuously.

**Study Findings:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **% Year Round Continuous Fan Operation** | **Study units** | **Specific study reference** |
| Residential | All | US Hot Dry Region Average | 7% | Homes | Ref 7 |

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

#### 1.4.4.1 Field Measured Data

This section presents field measured data documenting the reduction in fan motor watt draw when the HVAC system is operating in cooling mode.

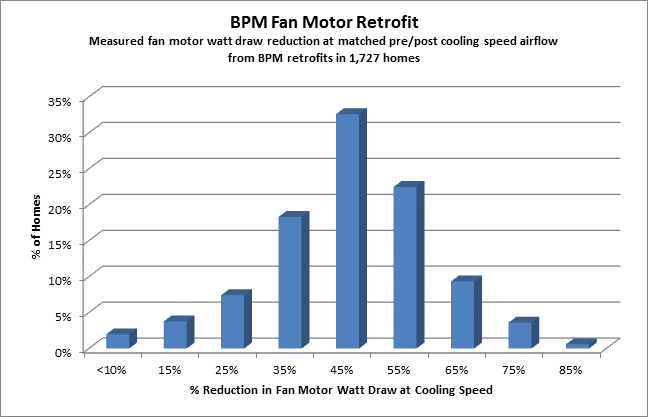
Proctor Engineering Group provides the BPM retrofit measure in several utility programs in California and in other states. Proctor Engineering’s implementation of this measure includes pre/post measurement of fan motor amp draw at cooling (high) speed, at matched pre/post cooling speed airflow. The results from over 1500 retrofits reported under these programs through show an average fan motor input power reduction of 45%.

The average reduction in fan input power at cooling speed for these retrofits was 297 W.

The average change in static pressure measured in the supply plenum was 0.2%, indicating the pre/post airflows were matched very closely.

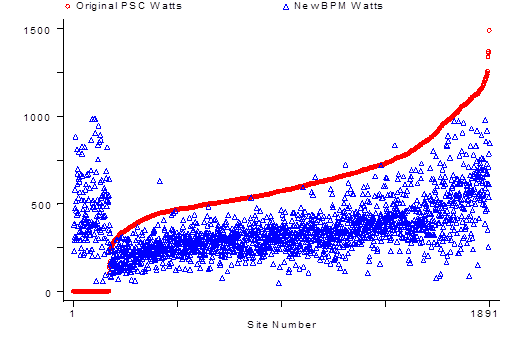
Average fan watt draw reductions and a comparison of pre and post retrofit fan watt draw at each site are shown in figures 5 and 6.

Figure 5: Fan Input Power Reduction in Cooling Mode



*\* Source: Proctor Engineering Group CheckMe! Database*

Figure 6: Field Measured Fan Power Pre and Post BPM Retrofit

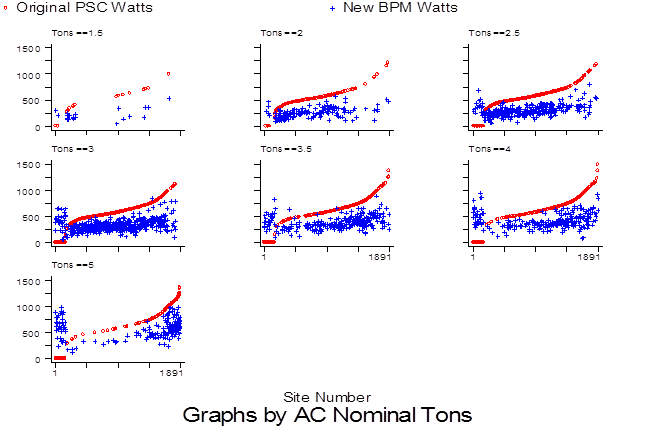


ROB

*\* Source: Proctor Engineering Group CheckMe! Database*

These installations resulted in similar savings characteristics across all residential air conditioner sizes as shown in Figure 7.

Figure 7: Pre and Post Retrofit Watts for Various Air Conditioner Sizes

****

*\* Source: Proctor Engineering Group CheckMe! Database*

Of the 492 systems with 3 tons of nominal cooling capacity, the average watt draw of the original fan motor was 580 W, and the average watt draw of the BPM motor was 314 W. These values are used in modeling the cooling performance of a 3 ton air conditioner in section 1.4.4.4.

Table 10: Average Fan Watt Draw for Units with 3 Tons of Cooling Capacity

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Obs | Mean | Std. Dev. | Min | Max |
| preW | 492 | 579.5 | 152.9 | 102 | 1110.8 |
| postW | 492 | 313.7 | 97.0 | 103.7 | 836.4 |

**Measured Energy Savings (ΔW):**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings** | **Study units** | **Specific study reference** |
| Residential | All | N/A | 45% (297 W)\* | HVAC System | Proctor Engineering CheckMe Database |

*\*This is the measured reduction in fan motor power when the system is operating in cooling speed. It does not include interactive effects with air conditioner efficiency, which increases the cooling savings as described and calculated in section 1.4.4.3. It does not include dry climate fan controls, which increase the cooling savings as documented in workpaper PGE3PHVC150.*

#### 1.4.4.2 Laboratory Measured Data

This section presents laboratory measured data comparing the fan motor watt draw of PSC and two types of BPM motors across the full range of operating speeds.

Figure 8 compares the performance of a PSC motor to two types of BPM motors in the laboratory. The furnace, fan, and duct configuration remained identical between tests. Only the motor was changed. The BPM motors draw significantly lower watts than the PSC across the full range of speeds and airflows. Figure 8 shows that the Concept 3 BPM retrofit motor operates at virtually identical efficiency to the GE ECM motors used in top end furnaces.

Figure 8: BPM Motor Performance



The difference in fan motor power increases at lower speeds where the BPMs are capable of drawing under 60 W compared to over 600 W for the PSC at its minimum speed. This illustrates the significant advantage of a variable speed BPM over a PSC for constant ventilation applications. 90% savings are possible through the retrofit installation of a BPM fan motor with low speed/low watt draw ventilation capability.

The BPM motor watt draw at low (fan only) speed is conservatively estimated at 100W.

#### 1.4.4.3 Cooling Compressor Cycle Energy Savings – Engineering Calculation

This section presents engineering calculations to estimate the energy savings that occur during the compressor cycle in the cooling mode of operation.

The total cooling savings is larger than the heating savings in most California Climates. The lower watt draw of the Brushless Motor not only reduces the overall watt draw of the air conditioner; it also reduces the fan motor heat that is put into the airstream.

The higher efficiency of the BPM motor is estimated to reduce cooling energy use by 9% on average. Higher blower motor efficiency during cooling saves energy by:

1. Reducing the watt draw of the motor
2. Reducing heat generated by motor inefficiency and rejected to the air stream, which must be removed by the air conditioner

The net effect is lower system watt draw and higher system sensible capacity. Since:

*Net Sensible EER = Net Sensible Capacity / Total System Watt Draw*

The higher efficiency BPM motor increases the sensible efficiency of the air conditioner and reduces both annual kWh and peak kW.

Engineering calculations are as follows:

As established in Section 1.4.3.2, typical California central HVAC air handlers have the following characteristics:

* Median Fan Watts in Cooling Speed = 632 Watts
* Median Cooling Airflow = 358 cfm per ton
* Median Watts per cfm = 0.51 W/cfm

*Fan Watts per ton = Fan Watts per cfm x Cooling Airflow per ton*

*= 0.51 x 358 = 182.6 Watts per ton*

*Representative Tons of Median Fan Watt Draw = *

*= 632 / 182.6 = 3.46 Tons*

*AC Gross Sensible Capacity = Sensible Heat Ratio x Tonnage x 12,000 Btuh per ton*

*= .80 x 3.46 x 12,000 =* ***33,216 Btuh***

The Field data presented in section 1.4.4.1 show the cooling speed watt draw of the BPM motor is 45% than that of the PSC motor.

*Fan Motor Watts =* ***632 Watts*** *(Standard)*

*= 632 x (1-0.45) =* ***348 Watts*** *(BPM)*

*Fan Motor Heat into Airstream = Fan Motor Watts x 3.412 Btu/Watt hr*

*= 623 x 3.412 =* ***2156 Btuh*** *(Standard)*

*= 348 x 3.412 =* ***1187 Btuh*** *(BPM)*

*AC Net Sensible Capacity = AC Gross Sensible Capacity – Fan Motor Heat into Airstream*

*= 33,216 - 2156 =* ***31,060 Btuh*** *(Standard)*

*= 33,216 - 1187 =* ***32,029 Btuh*** *(BPM)*

*Nominal Power Draw = *

*for an EER 10 system:*

*Nominal Power Draw = 3.46 x 12000 / 10 =4152 Watts*

*Condenser Unit Power Draw = Nominal Power Draw – Nominal Fan Power Draw x Tonnage*

*where:  
 Nominal Fan Power Draw = 365 W/1000 cfm x 400 cfm per ton)= 146 W per ton*

*Condenser Unit Power Draw = 4152 Watts – 146 W per Ton x 3.46*

*=* ***3647 Watts***

*Total Power Draw = Outdoor Unit Watt Draw + Fan Watt Draw*

*= 3647 + 632 =* ***4279 Watts*** *(Standard)*

*= 3647 + 348 =* ***3995 Watts*** *(BPM)*

*Net Sensible EER = *

*= 31060 / 4279 =* ***7.26 Btuh/W*** *(Standard)*

*=32029 / 3995 =* ***8.02 Btuh/W*** *(BPM)*

*Energy Savings Percentage = *

*where:*

*subscript 1 = initial condition*

*subscript 2 = final condition*

*= (7.26 – 8.02) / 8.02 =* ***9% savings***

|  |  |  |
| --- | --- | --- |
| Table 11: Motor Replacement Compressor Cycle Savings | | |
|  | **Standard PSC motor** | **BPM motor** |
| AC Gross Sensible Capacity (Btuh) | 33,216 | 33,216 |
| Fan Motor Heat (Btuh) | 2156 | 1187 |
| AC Net Sensible Capacity (Btuh) | 31,060 | 32,029 |
|  |  |  |
| AC Condenser Unit Watts | 3647 | 3647 |
| Fan Motor Watts | 632 | 348 |
| Total Watts | 4279 | 3995 |
|  |  |  |
| Net Sensible EER | 7.26 | 8.02 |
| **% Savings** |  | **9%** |

#### 1.4.4.4 Cooling Compressor Cycle Energy Savings – Modeled Performance

This section presents the results of air conditioner performance modeling using the US Department of Energy / Oak Ridge National Laboratory Mark VI Heat Pump Design Model.

The DOE/ORNL model is a widely used modeling tool that can be accessed via a web based interface hosted on the ORNL website. Inputs into the model include physical characteristics of the heat exchange coils and refrigerant lines, refrigerant type, compressor performance coefficients, refrigerant metering characteristics, indoor and outdoor fan performance, and indoor and outdoor temperature and humidity conditions.

The model is a SEER 12 split system air conditioner with performance characteristics matched to a 3 ton unit that was tested in the laboratory at Purdue University at the AHRI test condition A (80F indoor dry bulb, 67F indoor wet bulb, 95F outdoor dry bulb). The indoor fan watts were set to the average field measured watt draw for PSC and BPM fan motors in 3 ton air conditioning units shown in section 1.4.4.1, Table 10. The model results are shown in table 12, and the source models are provided in ref 8.

Table 12: Modeled Compressor Cycle Cooling Savings

|  |  |  |
| --- | --- | --- |
|  | Standard PSC | BPM |
| Indoor Fan Motor Power | 580 | 314 |
| Total Power | 3663 | 3389 |
| Capacity | 35863 | 36603 |
| EER | 9.79 | 10.80 |
| **% Savings** |  | **9.4%** |

#### 1.4.4.5 Cooling Fan Cycle Energy Savings

The Western Cooling Control™ (WCC) enhanced time delay fan control for dry climates is integrated into the Concept 3 BPM fan motor and is available as an external add-on for other BPM models. The WCC savings are detailed in Workpaper PGE3PHVC150, Section 1.5.

WCC with BPM Motor Savings: 20% of cooling energy use

#### 1.4.4.6 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 6).

Among the cities studied, the Fresno, CA population found the lowest fraction of operating units cycling at peak. Of the Fresno units that were operating at peak, 55% were cycling.

Of all units in the Fresno study, 36% were running continuously at peak.

***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. Since this is not an A/C measure, the TOU adjustment factor is 0.

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

The measure savings are based on the following:

* Sections 1.4.4.3 and 1.4.4.4 show 9% energy savings during the compressor portion of the air conditioner cycle from replacing a PSC fan motor with a BPM motor
* Section 1.4.3.4 and 1.4.4.5 show 20% savings from adding an extended fan delay to the cooling cycle when the system is equipped with a BPM fan motor
* Section 1.4.3.4 shows combined cooling savings exceeding 30% for the BPM motor plus fan delay
* Section 1.4.3.3 shows 0.5 kWh saved per therm of heating energy use
* Section 1.4.3.3 shows 3430 kWh saved annually in homes that operate the fan continually

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 Cooling**  **- Auto Fan**  **- Compressor Cycle** | CZ, BT | DEER2014 Existing |  | *9% cooling energy use reduction* | *Section 1.4.4.3 and*  *Section 1.4.4.4* |
| **Electric Savings Cooling**  **- Auto Fan**  **- Dry Climate Fan Cycle** | CZ, BT | DEER2014 Existing |  | *20% cooling energy use reduction* | *Section 1.4.3.4*  *And*  *Section 1.4.4.5* |
| **Electric Savings Heating**  **- Auto Fan** | CZ, BT | DEER2014 Existing |  | *0.5 kWh reduction per heating Therm* | *Section 1.4.3.3* |
| **Electric Savings – Continuous Fan** | CZ, BT | DEER2014 Existing |  | *3430 kWh/year reduction* | *Section 1.4.3.3* |
|  |  |  |  |  |  |
| **Hours of operation** | CZ, BT | DEER2014 Existing |  |  |  |
| **Full Cost** | ROB |  |  | $156.69 | Section 4.3.1 |
| **Incremental Cost** | ROB |  |  | $156.69 | Section 4.3.2 |
| **EUL /RUL** | ROB |  |  | 10 | Section 1.4.1.4 |
| **NTG** | .55 |  |  |  | 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

***2.1.1 Annual Cooling kWh Savings***

The Annual Energy Savings were calculated as follows:



*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 - 5.*

 *is the interacted compressor cycle and dry climate fan cycle cooling energy savings*



*where,*

 *is 9%*

 *is 20%*

 *is 9% + 20%\*(100%-9%)*

*= 27%*

***2.1.2 Annual Heating kWh Savings***

The Annual Heating Fan Energy Savings was calculated as follows:



*where,*

 *is the Baseline Annual Energy Consumption from:  
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 - 5.*

***2.1.3 Annual Continuous Fan kWh Savings***

The Annual Electrical Savings for Units with Continuous Fan was set to the Wisconsin Field Data results as follows:



## 2.2. Demand Reduction Estimation Methodologies

### 2.2.1 Summer Demand Reduction for Units with Auto Fan

The Demand Reduction values for units operating at the auto fan setting were calculated as:



*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 - 5.*

 *is the Peak EER of 7*

 *is 27% for units that are cycling at peak (section 2.1.1)*

 *is 632W – 348W = 284W for units that are operating continuously at peak (section 1.4.4.3)*

 *is 55% is percentage of operating air conditioning units that are cycling at peak (section 1.4.4.5)*

 *is 36% is percentage of all air conditioning units that are running continuously at peak (section 1.4.4.5)*

### 2.2.2 Summer Demand Reduction for Units with Continuous Fan

The Demand Reduction values for units operating at the continuous fan setting were calculated as:

*where,*

*PctOn* *is the fraction of units with the air conditioner compressor operating at peak.*

*= 0.7*

 *is the reduction in fan motor watt draw at cooling speed*

*= 632W – 348W = 284W (section 1.4.4.3)*

 *is the reduction in fan motor watt draw at fan only speed*

*= 632W – 100W = 532W (section 1.4.4.2)*

## 2.3. Gas Energy Savings Estimation Methodologies

The Annual Heating Gas Energy Increase was calculated as follows:



*where,*

*Feff* *is the typical furnace efficiency, estimated at 0.80*

*HeatingFanEnergySavings is the fraction of fraction of the annual kWh savings that occur during heating*

# *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 measure load shape for this measure is determined based on the applicable residential market sector and the air conditioning end-use. This load shape is different from the base case due to the savings impact of the measures and is shown by the load shapes listed below.

The closest load shape chosen for this measure is the Residential: 26 = Res. Central Air Conditioning load shape. See Table 14 for a list of all Building Types and Load Shapes. See the KEMA report [31] for a more thorough discussion regarding the load shapes for this measure.

Table 14: Base Case Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **E3 Alt. Building Type** | **Load Shape** |
| SFM | RES | 26 = Res. Central Air Conditioning |
| MFM | RES | 26 = Res. Central Air Conditioning |
| DMO | RES | 26 = Res. Central Air Conditioning |

# Section 4. Base Case & Measure Costs

The 2010-12 Ex Ante Measure Cost Study contains cost data for residential HVAC fan motors through a review of distributor price lists. The study also estimated labor hours and labor rates using a 2014 NREL field study on retrofit installations of eight variable speed furnace fan motors and RS Means, respectively.

## 4.1 Base Case(s) Costs

The base case is a 0.5 HP permanent split capacitor (PSC) motor. As noted in the measure cost study, the base equipment cost is $261.74 and labor cost is $173.18 (2.59 hours at a labor rate of $55.58 with 18% markup).

The following Measure Application Type is appropriate to these measures. The Base Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Base Case Cost** |
| H797, H798 | ROB | Industry Practice | $261.74 | $173.18 | $0 | $434.92 |

*All costs are noted as $ per measure unit*

## 4.2 Measure Case Costs

The measure case is a 0.5 HP brushless fan motor with an efficient fan controller. As noted in the measure cost study, the measure equipment cost for the BPM motor is $352.42 with a labor cost of $173.18 (2.59 hours at a labor rate of $55.58 with 18% markup). The measure equipment material cost for the efficient fan controller was determined by reviewing the purchased price for two fan delay controllers tested in the ET laboratory report [A]. The price paid was $25 per controller, plus $3.50 for shipping and handling.

The total measure equipment cost is:

$352.42 per BPM motor + $28.50 per EFC = $380.92

It is assumed that no additional labor is added for the installation of the efficient fan controller.

The following Measure Application Types are appropriate to these measures. 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** |
| H797, H798 | ROB | Industry Practice | $380.92 | $173.18 | $0 | $554.10 |

*All costs are noted as $ per measure unit*

## 4.3 Incremental & Full Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Full Measure Cost**  **(RUL Period/First Baseline)** | **Full Measure Cost**  **(EUL-RUL Period/ Second Baseline)** | **Incremental Measure Cost** |
| ROB | Measure Equipment Cost  – Base Case Equipment Cost | N/A | Measure Equipment Cost  – Base Case Equipment Cost |

# *4.3.1 Full Measure Cost*

Full 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) ROB, so the Full Measure Cost (FMC) is represented by the equation below:

FMC = (Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

FMC = Measure Equipment Cost – Base Case Equipment *Cost*

*FMC = $380.92 per (unit) - $261.74 per (unit) = $119.18 per unit*

# *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: ROB, so the Incremental Measure Cost (IMC) is represented by the appropriate equation below:

IMC = (Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: Unless stated otherwise the measure case and base case labor costs are typically the same, reducing the equation to the following:

IMC = Measure Equipment Cost – Base Case Equipment Cost

*IMC = $380.92 per (unit) - $261.74 per (unit) = $119.18 per unit*

**Summary Table for Section 4**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure ID** | **Measure Application Types** | **Base Case Total Cost** | **Measure Case Total Cost** | **Full Measure Case Cost** | **Incremental Measure Cost** |
| H797, H798 | ROB | $434.92 | $554.10 | $119.18 | $119.18 |

# 

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