**Work Paper SCE13HC028**

**Revision 3**

**Southern California Edison Company**

**Brushless Fan Motor for Residential Central AC**

# At-a-Glance Summary

|  |  |
| --- | --- |
| ****Applicable Measure Codes:**** | *AC-68273* |
| **Measure Description:** | Central brushless fan motors (BFM or DC Motor) specifically configured to be a drop in retrofit for standard permanent split capacity (PSC) residential HVAC fan motors. |
| **Base Case Description:** | Standard PSC residential HVAC fan motors. |
| **Energy Impact Common Units:** | Cap-Ton: kW/ton, kWh/ton, Therms/ton |
| **Energy Savings :** | Refer to Excel Calculation Attachment |
| **Gross Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Measure Incremental Cost ($/unit):** | Refer to Excel Calculation Attachment |
| **Effective Useful Life (years):** | 5 years, Source: 5/2/13 ED Disposition [367] |
| **Measure Application Type:** | Replace on Burnout (ROB) |
| **Net-to-Gross Ratios:** | 0.85 for Direct Install, Source: DEER2011  0.70 for Down-Stream Incentive - Deemed, for all other residential measures with moderate market share and no convincing strategies to discourage free ridership | Source: 5/2/13 ED Disposition [367] |
| **Important Comments:** | This work paper document does not contain a data set in conformance with the 4/1/14 CPUC Ex Ante Database Specification  This workpaper adopts energy and demand savings from READI v.2.1.0, Measure Description: Res AC – Blower Motor Retrofit; EnergyImpactID: PGE-TK10; Version ExAnte2013. |

# Document Revision History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Workpaper and Revision # | Tech. Revision | MM/DD/YY | Author/Affiliation | Summary of Changes |
| SCE13HC028.0 | No | 04/13/12 | James Gowen/Matrix | Updated work paper to new template |
| SCE13HC028.1 | Yes | 12/04/13 | Jason Wang/SCE | Updated per 5/2/13 ED Disposition:   * EUL changed to 5 years * NTG changed to 0.70 * Updated savings to ED-provided values |
| SCE13HC028.2 | No | 04/24/14 | Ryan Cho/SCE | Work paper Updated for reporting period, effective 07/01/14-12/31/14. |
| SCE13HC028.3 | Yes | 11/21/14 | Andres Fergadiotti/SCE | Work paper Updated for reporting period, effective 01/01/2015 - 12/31/2015.  Incorporated measure Energy and Demand savings documentation from READI v.2.1.0, Measure Description: Res AC – Blower Motor Retrofit; EnergyImpactID: PGE-TK10; Version ExAnte2013. Savings are reported for all IOU territories (all 16 Climate Zones)  Expanded measure installation requirements  Revised Cost documentation per “2010-2012 WO017 Ex Ante Measure Cost Study - Final Report”  Per program feedback on 01/08/2015, the Program Delivery Method is “Financial Support/Direct install |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

Measure Description: Central brushless fan motors (BFM or DC Motor) specifically configured to be a drop in retrofit for standard permanent split capacity (PSC) residential fan (blower) motors serving central HVAC systems.

Basecase Description: Standard PSC residential fan motors serving HVAC system.

Table 1 Measure Names

|  |  |
| --- | --- |
| Solution Code | Measure name |
| AC-68273 | Central AC Brushless Fan Motor Replacing Permanent Split Capacitor (PSC) Motor |

This measure can be applied to all residential building types including SFM, MFM, and DMO that use central air-cooled direct expansion cooling and/or furnace HVAC equipment under all IOUs within respective territories (climate zones). The participant must have electricity distributed by applicable IOU to the installation service address. The following requirements must be met under the measure:

* HVAC system must be operable and drawing power
* HVAC system shall be capable of delivering a supply air flow rate of at least 350 cfm/ton
* When serving central air-cooled DX HVAC system, unit must have a condenser over ambient temperature (COAT) of at least 3 degrees
* Replacement BFM motor capacity and rated voltage shall match that of existing fan motor being replace
* Replacement BFM motor (and/or motor and controls assembly) shall be “UL Listed”
* Replacement BFM motor shall have a warranty of at least 2 years from date of installation
* Measure shall include HVAC system start-up. During the start-up, the installer shall ensure that system maintain programmed level airflows under both cooling and/or heating and that these are adequate
* Installation (as applicable) shall comply with all applicable regulations including but not limited to California Energy Standards (Title-24), California Electrical Code, and NEC

The minimum 350 cfm/ton airflow requirement ensures that the refrigerant system can be properly diagnosed and charged as part of a maintenance service. If the system is not delivering 350 cfm/ton upon initial inspection, an assessment should be made to determine if the system will be able to deliver 350 cfm/ton by implementing repairs related to airflow. If it is determined that the supply fan and duct system in place do not have the capability to deliver at least 350 cfm/ton with or without airflow repairs, the savings in this work paper are invalid.

The measure applies to units with shaded pole or permanent split capacitor motors currently installed. As stated previously, the replacement motor is to be a brushless direct current motor with selectable speed control designed to replace a PSC motor in a residential direct drive fan application.

## 1.2 Technical Description

**BFM compared to PSC Motor**

A BFM has several advantages over a PSC motor:

* PSC motors are typically used at two speeds, a cooling speed (high speed) and a heating speed (low speed).
* As shown in Figure 1, PSC motor uses almost the same watt draw regardless of whether it is set on a high cooling speed or a low heating speed. Since a BFM has a higher efficiency at its design rating point and is much more efficient at lower speeds than the PSC, it reduces fan watt draw and saves energy during both heating and cooling. It is also configured to produce the same airflow as the PSC motor it replaces, so these is no loss in performance.
* In cooling a BFM rejects less heat into the airstream (heat that the air conditioner must remove). However, a BFM applied to a gas furnace produces a small increase in gas consumption since the heat normally rejected by the motor into the airstream must be provided by natural gas.
* In cooling it recovers the moisture on the coil as sensible cooling at very low watt draw.
* The mode of operation where a furnace fan runs continuously (independent of compressor operation) is becoming more widespread in residences for the purposes of ventilation and/or added filtration. Therefore, more savings can be realized by the BFM because of these longer operating hours.



Figure 1 Fan Watt Draw

For this work paper, a BFM is compared to a PSC as if they were both installed on identical systems (duct and furnace) at the same CFM and external static pressure.

**BFM compared to Electronically Commutated Motor (ECM)**

Compared to an ECM motor the BFM with shut-off time delay has multiple advantages:

* Unlike an ECM motor, the BFM motor does not require a separate speed controller.
* Unlike an ECM motor, the BFM motor is available for retrofitting in existing furnaces.
* An ECM motor is controlled to attempt to produce a given airflow regardless of the amount of power required; on the other hand, a BFM motor is controlled to produce the same airflow as the PSC it replaces, resulting in significantly higher energy and peak savings. LBNL modeling indicates that an ECM motor controlled to produce a given airflow will increase watt draw on units with restrictive duct systems [360].
* A DOE report [361] projected a savings of 75% (three times the savings of an ECM) for a Brushless Motor that was tuned to the capacity of the air conditioner and furnace.
* A BFM motor costs less than an ECM motor.
* A BFM with shut-off time delay recovers moisture on the coil as sensible cooling. This recovery is extremely efficient because the BFM runs at low speed and very low watt draw during the recovery phase.

**Laboratory Test Data**

Multiple laboratory tests have been accomplished on PSCs, ECMs, and BFMs. Figure 2 shows the results of three sets of tests with the same furnace. One set of tests was performed with a PSC, the second with an ECM, and the third with a BFM.



Figure 2 Furnace Fan Watt Draw – Back to Back Tests

These results are also displayed in Table 2.

Table 2 BFM vs. PSC Fan Watt Draw – Controlled Test

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PSC Speed Setting** | **Flow (CFM)** | **Static Pressure (IWC)** | **PSC Watt Draw** | **BFM Watt Draw** | **Watt Reduction** | **PSC Watts / 1000 CFM** | **BFM Watts / 1000 CFM** | **Percent Reduction** |
| HI | 1183 | 0.88 | 831 | 503 | 327 | 702 | 425 | 39% |
| MED | 1115 | 0.79 | 765 | 426 | 339 | 687 | 383 | 44% |
| LO | 903 | 0.54 | 743 | 230 | 513 | 822 | 255 | 69% |

The data show a standard situation where the advantage of a brushless motor increases at lower airflow. At a 3 ton cooling airflow, the wattage reduction is approximately 330 watts. At a lower airflow as used for heating, the BFM watt savings approaches 70% (500+ watt reduction).

## 1.3 Measure Application Type

Note: See Appendix A for a comparison of the application types used by and incorporated into SCE systems versus the application types available in the newest revision of DEER 2014. Appendix A will serve as a translation between the outputs of this workpaper and application types used by READi.

The Program Delivery Method are “Financial Support Down/Stream Incentive - Deemed” and “Financial Support/Direct install.” The install type is Replacement on Burnout (ROB).

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

Energy and demand impact on the measure are adopted from READI v.2.1.0 – DEER and Non-DEER Ex Anta data for the 2013-14 Cycle with measure described as “Res AC – Blower Motor Retrofit” with energy impact ID “PGE-TK10.” Table 3 below summarizes DEER version and Energy Impact ID

Table 3 DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | No |
| Deviation from DEER | No |
| DEER Version | DEER READi v2.1.0 |
| DEER Run ID and Measure Name (Sample) | EnergyImpactID – PGE-TK10 |

**Net to Gross**

The 5/2/13 ED Disposition [367] specified an NTG of 0.70, which is the DEER value for all other residential measures (markets) with moderate market share and delivery methods with no convincing strategies to discourage free ridership.

The relevant NTGR for this measure is shown in Table 4 below.

Table 4 Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | NTG\* |
| N/A | ED-specified NTG | Res | SFM | All | 0.70 |
| Res-Default-HTG-di | All other EEM with no evaluated NTGR; direct install hard-to-reach only. | Res | Any | DirInstall | 0.85 |

\*Denotes that the column is taken from the DEER NTG Table.

Note: Direct install measures that are not hard-to-reach will use the default NTG value.

**Installation Rate**

The installation rate (IR) is identified in the calculation attachment. This value is obtained from the support table available in READi. Currently there is no versioning on the installation rate table. To address appropriate selection of the installation rate the date of the workpaper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown in Table 5 below.

Table 5 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| GSIA\_ID | Description | Sector | BldgType | ProgDelivID | GSIAValue |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1.0 |

**Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the workpapers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

**READi Technology Fields**

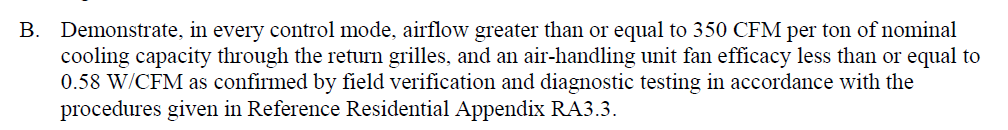
To support the development of the ED ex ante tables, select fields from the ex-ante database will be identified in the workpaper. For a full set of values associated with the measures in the workpaper refer the Excel calculation template.

6 READi Tech IDs

|  |  |
| --- | --- |
| READi Field Name | Values included in this workpaper |
| Measue Case UseCategory | HVAC |
| Measure Case UseSubCats | SpaceCool |
| Measure Case TechGroups | HV\_AirDist |
| Measure Case TechTypes | SupFanMtr |
| Base Case TechGroups | HV\_AirDist |
| Base Case TechTypes | SupFanMtr |

### 1.4.2 Codes and Standards Analysis

Title 24 (2013) Section 150.0(m)13.B [359] states the following regarding airflow:



The California Mechanical Code states that the replacement of any component part or assembly of an appliance that does not alter its original approval and complies with other applicable requirements of the mechanical code is exempt from the requirement to obtain a mechanical permit. In the event that a replacement motor requires a different voltage or number of phases than the original motor, the installation is to include disconnects not present on the original equipment, or the installation will alter the electrical system in any other way an electrical permit must be obtained pursuant to Title 24, Part 3 California Electrical Code.

Table 7 Code Summary

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | Section 150.0(m)13.B  California Mechanical Code  California Electrical Code | July 1, 2014 |

### 1.4.3 Non-DEER Study Review

Energy and demand savings on measure are based on the READI tool. Nonetheless, system air flow performance assumptions from READI including supply fan motor performance – Watts/CFM are consistent with several studies indicating a much higher blower motor power in the field than is used in the DEER prototypes.

A PIER report, “Characteristics and Opportunities for New California Homes” [A], determined the average blower motor power for 45 HVAC systems with PSC motors to be 0.65 Watts/CFM. READI assumptions consistent with this referenced report are 0.65 Watts/CFM to represent the base case with a PSC motor and 0.365 Watts/CFM (the DEER default assumption) to represent the measure case with a BPM motor.

The 5/2/2013 ED Disposition [367] was used for documenting measure’s EUL and Net-to-Gross.

### 1.4.4 Measure and Base Case Effective Useful Life

DEER2014 update documentation provides EUL and RUL information to be used for the 2015 program cycle extension on [www.deeresources.com](http://www.deeresources.com). The DEER documentation “Summary of EUL-RUL Analysis for the April 2008 Update to DEER” provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

The 5/2/13 ED Disposition for Residential HVAC Quality Maintenance [367] specified an EUL of 5 years for the following reason:

*“The blower motor is an addition to an existing system. Program rules limit the EUL of maintenance on an existing system to no more than system’s RUL. By rule, this is 1/3 of the 15 year EUL for a direct expansion HVAC system, or 5 years.”*

Table 8 below identifies the value used for the measures in this work paper.

Table 8 DEER2014 EUL Value/Methodology

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| READi EUL ID | Market | Enduse | Measure | EUL (Years) | RUL (Years) |
| n/a | Residential | Motors | HVAC Fan Motors | 5 | n/a |

# Section 2. Energy Savings & Demand Reduction Calculations

Energy savings and demand reductions are adopted from READI, using Energy Impact ID “PGE-TK10.” These numbers were presumably estimated using latest SFM DEER prototype with CZ2010 weather data and base and measure case airflow performance of 0.650 Watts/CFM on standard efficiency blower motor and 0.365 Watts/CFM on high efficiency blower motor respectively. Primary input parameters expected to have been used in this analysis include SUPPLY-KW/FLOW – design full-load power of the supply fan per unit of supply air flow rate at sea level used in conjunction with SUPPLY-DELTA-T, the temperature rise in the air stream across the supply fan. Energy and demand impacts are applicable for any residential building type with units normalized per Cap-Tons, e.g., kWh/ton, kW/ton, and Therm/ton.

# Section 3. Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the DEER:HVAC\_Split-Package\_AC load shape. See Table 9 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 9 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Residential Single Family | NON\_RES | DEER:HVAC\_Split-Package\_AC |
| Residential Multi Family | NON\_RES | DEER:HVAC\_Split-Package\_AC |
| Residential Mobile Home - Double-Wide | NON\_RES | DEER:HVAC\_Split-Package\_AC |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Cost

The base case cost is assumed to average $261.74 for a ½ hp permanent split capacitor motor per latest CPUC’s Ex Ante Measure Cost study [B] or $87.25 per ton.

Cost per ton is normalized based on a 3-ton unit severed by a ½ hp direct drive evaporator fan with a performance of 1200 cfm at 0.80 inches of water of external static pressure [C].

## 4.2 Measure Case Cost

The equipment cost is assumed to average $352.42 for a ½ hp brushless fan motor per latest CPUC’s Ex Ante Measure Cost study [B] or $117.47 per ton.

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Gross Measure Cost

For this measure the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

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

Further, the GMC for the measure approximates to $90.68 or $30.22 per ton.

### 4.3.2 Incremental Measure Cost

The incremental measure costs are equal to the gross measure costs.

The Program Delivery Method on the measure is “Financial Support/Direct install” in which the GMC on the measure is fully funded by the Utility. According to the Manufactured Housing Program, the GMC on the measure is in the order of $400.0 or $133.33 per ton. As this program is direct install, the costs used for reporting are as indicated above ($133.33/ton).

# Attachments

1.

2.

# References



[31]

[359]

[360]

[361]

[367]

[A] Results are summarized in “Table 14 – Mean System Airflow…” of the PIER report Efficiency Characteristics and Opportunities for New California Homes by Proctor, Chitwood and Wilcox for the CEC.

[B] 2010-2012 WO017 Ex Ante Measure Cost Study, Final Report, Itron, May 27, 2014

[C] Packaged Rooftop Air Conditioners Precedent™ 17 Plus — Cooling and Gas/Electric 3 to 5 Tons — 60 Hz

# Appendix A – SCE/ED Application Types

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SCE Program Type | ED Application Type | 1st Baseline Savings | 2nd Baseline Savings | 1st Baseline Cost | 2nd Baseline Cost | 1st Baseline Life | 2nd Baseline Life |
| New | New Construction (Nc) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Replace on Burnout (ROB) | Replace on Burnout (Rob)/Normal Replacement (NR) | Above Code/Standard | N/A | Incremental Cost | N/A | EUL | 0 |
| Retrofit (RET) | Early Replacement (ER) | Above Cust. Existing | Above Code/Standard | Full Cost | Incremental Cost | RUL | EUL-RUL |
| Retrofit – First Baseline Only (REF) | Early Replacement RUL (ErRul) | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |
| Retrofit Add-on (REA) | N/A | Above Cust. Existing | N/A | Full Cost | N/A | EUL | 0 |