Work Paper SCE13HC028

**Revision 4**

**Southern California Edison**

**Brushless Fan Motor for Residential Central AC**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **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. |
| **Units** | Cap-Ton: kW/ton, kWh/ton, Therms/ton |
| **Energy Savings** | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Effective Useful Life** | 5 years, Source: 5/2/13 ED Disposition [367] |
| **Measure Installation Type** | Replace on Burnout (ROB) |
| **Net-to-Gross Ratio** | 0.85 for Direct Install  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 has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 04/13/12 | James Gowen/Matrix | Updated work paper to new template |
| 1 | 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 |
| 2 | 04/24/14 | Ryan Cho/SCE | Work paper Updated for reporting period, effective 07/01/14-12/31/14. |
| 3 | 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 |
| 4 | 02/02/2016 | Andres Fergadiotti/SCE | -New template update for 2016 program year  -WP effective from 1/1/2016 thru 12/31/2016  -Removed SCE building types  -No value modifications  -Language added on Multi-Family Energy Efficiency Rebate (MFEER) Direct Install Program |

# Commission Staff and Cal TF Comments

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

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

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.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Central brushless fan motors (BFM or DC Motor) |
| Existing Condition | Standard permanent split capacity (PSC) residential fan (blower) motors |
| Code/Standard | N/A |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| N/A | N/A | AC-68273 | N/A | 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 2Furnace Fan Watt Draw – Back to Back Tests

These results are also displayed in following table.

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 Installation Types and Delivery Mechanisms

The Program Delivery Method are “Financial Support Down/Stream Incentive - Deemed” and “Financial Support/Direct install.”

The install type is Replacement on Burnout (ROB).

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Replace on Burnout (ROB) | Above Code or Standard | N/A | EUL | N/A |

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

**Delivery Method Descriptions**

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

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 below summarizes DEER version and Energy Impact ID

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | Yes |
| DEER Measure Case | Yes |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes |
| DEER Version | DEER READi v2.1.0 |
| Reason for Deviation from DEER | N/A |
| DEER Measure IDs Used | EnergyImpactID – PGE-TK10 |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Res-Default-HTR-di | All other EEM with no evaluated NTGR; direct install hard-to-reach only. | Res | Any | DirInstall | 0.85 |
| All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | Any | Any | Any | 0.70 |

Per referenced Workpaper disposition, the NTG shall be 0.70, which is the DEER value for all other residential measures with moderate market share and no convincing strategies to discourage free ridership.

This work paper includes measures that are offered via direct install activities into hard-to-reach (HTR) customer homes. “Final Resolution E-4700”, dated December 18, 2014, defines specific criteria to classify customer homes as HTR. The “Required Corrections to Measure Level Input Parameters Identified by Commission Staff per D.14-10-046 Order Paragraph 16”, dated November 3, 2014, includes additional clarification for the geographic criteria.

SCE’s Multi-Family Energy Efficiency Rebate (MFEER) program addresses the ongoing concern with “split incentives”, where the residents are not the owners of the property, so they lack incentive to improve their energy usage. Similarly, the property owners do not live on-site and pay higher utility expenses due to inefficient appliances, thus lack any incentive to upgrade. The MFEER is designed to drive this customer segment toward participation by offering property owners a variety of energy efficiency measures and services. The MFEER program will offer and track measure installations in both common and dwelling areas of multifamily complexes and common areas of mobile home parks and condominiums. Measures offered via direct install activities in both common and dwelling areas of multifamily complexes and common areas of mobile home parks and condominiums will receive the HTR NTG. Other measures in the MFEER program will receive default NTG (NTGR\_ID: Res-Default>2), unless otherwise specified in DEER.

**Spillage Rate**

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

**Installation Rate**

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

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

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

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

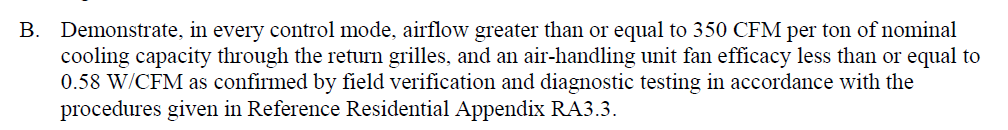
*“The blower motor is an addition to an existing system. Program rules limit the EUL of maintenance on an existing system to no more than system’s RUL. By rule, this is 1/3 of the 15 year EUL for a direct expansion HVAC system, or 5 years.”*

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HV-ResRCx | HVAC Fan Motors | Residential | Motors | 5 | N/A |

### 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.

Code Summary

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

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

### 1.5.1 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.

# Section 2. Calculation Methodology

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.

The following table indicates which measures are taken directly from or created with the DEER READI tool.

READI Data Used

|  |  |  |
| --- | --- | --- |
| **Measure Code** | **Measure Name** | **READI Data** |
| PGE-TK10 | HV-AirDist | See attachment 2 |

# Section 3. Load Shapes

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

Building Types and Load Shapes

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

# Section 4. 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 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

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

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| AC-68273 | ROB | $30.22 | $30.22 | N/A |

# Attachments

1. 

2.

# References



[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