

Work Paper PGE3PREF123

Revision 2

Pacific Gas & Electric Company

ECM for Walk-In Evaporator Fan

For Work Paper Reviewer Use Only

List all major comments that occurred during the review. This table may only be removed during management review.

Major Comment	Reviewer Name	Date	Outcome/Resolution
E.g. Please remove measure LT-12345 (LD123) from this work paper because it is no longer eligible for incentives.	Reviewer 1	6/1/15	E.g. Comment incorporated. LT-12345 was removed.

January 1, 2016

AT-A-GLANCE SUMMARY

Measure Codes	HA52 HA73 HA74 HA75 HA76 HA77
Measure Description	Install new electronically commutated permanent magnet (ECM) motors on low and medium temperature walk-in coolers and freezers.
Base Case Description	Existing shaded pole evaporator fan motors on walk-in coolers and freezers
Units	per motor
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	15 years (Source: DEER 2016, GrocWkIn-WEvapFanMtr)
Measure Installation Type	Replace on Burnout (ROB)
Net-to-Gross Ratio	0.6 (Source: DEER2016, Com-Default>2yrs)
Important Comments	

REVISION HISTORY

Rev	Date	Author	Summary of Changes
0	6/7/12	Joseph Flores (DENV KEMA)	PGE3PREF123.0 – ECM for Walk-In Evaporator Fan 3P
0	8/30/12	Balaji, Arun K. PG&E	Modified Building Vintage, Building type and Unit Definition. Added Incentive delivery option.
1	11/17/15	Yin Yin Wu (BASE Energy, Inc.) Jim Wyatt (PG&E)	<ul style="list-style-type: none"> Updated the work paper based on July 1, 2014 DEER code update Used the updated eQuest prototype from MASControl version 3.00.20 Updated the eQuest model weather files per DEER2014 CZ2010 weather data files This revision uses SCE solution code RF-65986 values for all existing PG&E measure codes. Savings will drop to around 460 kWh per motor and .05 kW per motor. Units are both "Each".
2	3/30/16	Linda Wan (PG&E)	Updated to ex ante format 2016

COMMISSION STAFF AND CAL TF COMMENTS

Rev	Party	Submittal Date	Comment Date	Comments	WP Developer Response
N/A					

Cal TF website: <http://www.caltf.org/>

The "Approved Measures" section of the Cal TF website, <http://www.caltf.org/approved-measures/>

SECTION 1. GENERAL MEASURE & BASELINE DATA

1.1 MEASURE DESCRIPTION & BACKGROUND

This work paper details the replacement of shaded pole (SHP) evaporator fan motors with new electronically commutated permanent magnet (ECM) motors on low and medium temperature walk-in coolers and freezers.

Base, Standard, and Measure Cases

Case	Description of Typical Scenario
Measure	Electronically commutated permanent magnet (ECM) evaporator fan motors on low and medium temperature walk-in coolers and freezers.
Existing Condition	Shaded pole (SHP) evaporator fan motors in Walk-in coolers and walk-in freezers were manufactured before January 1, 2009
Code/Standard	N/A
Industry Standard Practice	N/A

Measures and Codes

Measure Codes				Measure Name
SCG	SDG&E	SCE	PG&E	
		RF-65986	HA52 HA73	Walk-in Cooler Evaporator Fan ECM Motor replacing Shaded Pole Motor
			HA74 HA75 HA76 HA77	Walk-in Freezer Evaporator Fan ECM Motor replacing Shaded Pole Motor

Eligibility Requirements

These measures are applicable when replacing an existing standard efficiency shaded pole evaporator fan motor with an electronically commutated permanent magnet (ECM) motor in refrigerated walk-in coolers/freezers. The evaporator fan motor shaft output is typically rated between 6 Watts and 373 Watts (1/2 hp). Shaded pole motors are to be replaced by ECMs on walk-in coolers/freezers. These measures cannot be used in conjunction with the Evaporator Fan Controller measure.

These measures are applicable to refrigerated walk-in coolers/freezers that are found in a variety of building types: schools, groceries, restaurants, lodging, hospitals, and others. However, these measures are predominantly implemented in grocery stores and restaurants. These measures are applicable to climate zones within Pacific Gas and Electric service territory.

Requirements:

- Walk-in coolers and walk-in freezers were manufactured before January 1, 2009.
- Installation address must have a commercial electric account with PG&E.
- Must replace existing standard efficiency shaded-pole evaporator fan motors in refrigerated walk-in coolers and freezers.
- Shaded-pole motors must be replaced by Electronically Commutated Motors (ECM).

Exclusions: Cannot be used in conjunction with the “Evaporative Fan Controller for Walk-In Coolers and Freezers” rebate.

1.2 TECHNICAL DESCRIPTION

High efficiency motors, with lower energy (heat) losses, reduce both electrical energy consumption of the evaporator fans and the internal cooling load required by the cases. ECM motors operate efficiently over a wide range of speeds. ECM motors optimize airflow while minimizing energy use and waste heat. Some manufacturers now offer ECM motors in lieu of shaded pole motors, or have standardized their equipment to include ECM motors in their refrigerated walk-in coolers/freezers.

1.3 INSTALLATION TYPES AND DELIVERY MECHANISMS

This work paper addresses replace on burnout (ROB) installations of replacing shaded pole evaporator fan motors with new electronically commutated evaporator fan motors. The delivery method is Financial Support, and the incentive methods are Direct Install and Down Stream Incentive.

Installation Type Descriptions

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

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

Delivery Method Descriptions

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

Incentive Method Descriptions

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

1.4 MEASURE PARAMETERS

1.4.1 DEER Data

The Database for Energy Efficient Resources does not address the replacement of shaded pole (SHP) evaporator fan motors with new electronically commutated permanent magnet (ECM) motors in walk-in coolers and freezers. DEER does include measure D03-202 which addresses the replacement of SHP fan motors with permanent split capacitor (PSC) fan motors on walk-in coolers/freezers for vintages before 2005. This differs from the measures of this work paper.

DEER Difference Summary

DEER Item	Used for Workpaper?
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes
DEER Version	DEER 2016
Reason for Deviation from DEER	DEER use permanent split capacitor (PSC) fan motors as measure case.
DEER Measure IDs Used	D03-203

Net-to-Gross Ratio

The Net-to-Gross (NTG) Ratio is used to estimate and describe free-ridership. 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
Com-Default>2yrs	All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years	Com	Any	Any	0.6

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 Installation Rate (IR) addresses the percentage of units that are claimed but not installed. 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 is an estimate of the median number of years that an installed measure will remain in place and is operational. 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.

EUL ID	Description	Sector	UseCategory	EUL (Years)	RUL (Years)
GrocWkIn-WEvapFanMtr	High Efficiency Evaporator Fan Motors	Com	ComRefrig	15	5

1.4.2 Codes and Standards Analysis

Walk-ins: California's Title 20 Appliance Efficiency Standards does regulate the efficiency of evaporator fans in newly constructed walk-in coolers and freezers manufactured on or after January 1, 2009 [1]. Since replacing the existing evaporator fan shaded pole (SHP) motors with electronically commutated permanent magnet (ECM) motors for walk-in coolers and walk-in freezers is considered as replace-on-burnout (ROB) in this workpaper, only walk-ins manufactured before 2009 would qualify for incentive.

Walk-In Coolers and Walk-In Freezers.

Walk-in coolers and walk-in freezers manufactured on or after January 1, 2009 shall:

For evaporator fan motors of under one horsepower and less than 460 volts, use:

- 1. electronically commutated motors (brushless direct current motors); or*
- 2. 3-phase motors;*

Code Summary

Code	Reference	Effective Dates
Title 20 (2014)	Section 1605.1(a)(4)(E)(1) Refrigerators, Refrigerator-Freezers, and Freezers	May, 2014
Title 24 (2013)	N/A	N/A

1.5 EM&V, MARKET POTENTIAL, AND OTHER STUDIES – BASE CASE AND MEASURE CASE INFORMATION

1.5.1 Study 1: Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment

This study was prepared by Navigant Consulting, Inc. for U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy – Building Technologies Office in December, 2013. The objectives of the study are to characterize motor technologies used in residential and commercial equipment, and to identify opportunities to reduce energy consumption of electric motor-driven systems through the use of advanced motor technologies.

The study includes the technical potential of installing more efficient motors on evaporator fans. It considers baseline evaporator fan motor efficiency to be 29% and the maximum attainable motor efficiency of brushless direct current (permanent magnet) motors to be 70%. The baseline efficiency of 29% is within the efficiency range of SHP motors considered in this workpaper. However, the study doesn't discuss the motor efficiency for ECM motors.

1.6 DATA QUALITY AND FUTURE DATA NEEDS

The following data can be collected to support the result of this work paper: measurement and verification (M&V) data on evaporator fans and the refrigeration system (compressors and condenser fans) of walk-ins before and after implementation of high efficiency ECM motors.

SECTION 2. CALCULATION METHODOLOGY

The following assumptions were made for the calculations of this work paper:

- The building simulation models were generated for a Grocery Store with multiplex-compressor systems. Single-compressor systems are less efficient than multiplex-compressor systems. According to the DEER Report [2], single-compressor systems were typically designed prior to 1980. To be conservative, it is assumed that the generated energy savings of this work paper will also be applied to single-compressor systems.
- The resulting savings involve savings of evaporator fan power reduction and refrigeration load reduction. The building simulation models were generated for a Grocery Store. Since the walk-ins are well insulated, and the heat gain of a walk-in mainly depends on the temperature maintained for the walk-in and the surrounding space temperature, it is assumed that the building types would not have significant impact on the energy savings. Thus, the resulted savings of Grocery Store is applied to all other building types considered in this work paper.

The walk-ins are applicable to, but not limited to, grocery stores. ECM motors are more efficient than SHP motors. According to a commercial refrigeration study report by U.S. Department of Energy [3], typical SHP fan motor efficiencies range between about 15% to 38%, while typical PSC fan motor efficiencies range between about 40% to 70%, and typical ECM fan motor efficiencies range between about 71% to 83% for rated shaft output between 6-watt and 373-watt (1/2 hp). Therefore, replacing the evaporator fan SHP motors with ECM motors will reduce the evaporator fan energy consumption as well as the refrigeration cooling load for cooling the heat rejected by the motors, resulting in electrical energy savings.

The measures of this work paper are weather sensitive. The building energy simulation tool eQuest was used to determine the annual impacts. The built-in DEER building prototypes, generated by MASControl v3.00.20 of grocery store, were used for simulations. The DEER building prototypes consider multiplex-compressor systems as the refrigeration type.

Walk-Ins

The Database for Energy Efficient Resources (DEER05) does not address the replacement of shaded pole (SHP) evaporator fan motors with new electronically commutated permanent magnet (ECM) motors on walk-in coolers and freezers. DEER does contain measure D03-202 which addresses the replacement of SHP fan motors with permanent split capacitor (PSC) fan motors on walk-ins for vintages before 2005. This differs from the walk-in measures of this work paper. The walk-in evaporator fan input power provided in the D03-202 DEER models are used to modify the baseline models generated by MASControl v3.00.20. The ECM motor power modified in the measure models are estimated based on the SHP power input and the ECM/SHP efficiency ratios provided from a commercial refrigeration study report by U.S. Department of Energy [3]. To be conservative, the eQuest models were simulated for vintage 2014. The walk-in evaporator fan power inputs modified in the eQuest simulations are included in the table below.

Summary of Walk-In Evaporator Fan Input Power used in eQuest Simulation

Walk-In Type	SHP Motor (Baseline)*	ECM Motor (Measure)**
Walk-In Cooler	SHP Motor: 0.000169 kW/CFM	0.0000761 kW/CFM Est. per SHP power

*Provided in build-in DEER prototype models.

** Estimated based on the SHP power and the ECM/SHP efficiency ratio provided from a commercial refrigeration study report by U.S. Department of Energy [3], page 115, Table 5-3.

Note: The solution codes of this workpaper were created as a combination for all walk-ins, which were not separated for walk-in coolers and walk-in freezers. To be conservative, the eQuest energy savings were evaluated based on walk-in coolers and applied to all solution codes.

eQuest Output Savings

Once the base case and measure case model simulations were completed, the energy savings and demand reduction could be determined. Comparing the total energy consumption (electricity and natural gas) of both models, the total energy savings were determined. The unit energy savings, in kWh/yr-motor for electricity and therm/yr-motor for natural gas, were calculated by dividing the total energy savings by the total number of motors of the walk-ins.

The baseline and measure peak demands were averaged for the hourly demand outputs between 2 P.M. and 5 P.M. on the DEER peak days. The measure results were subtracted from the baseline results to determine the demand reduction. The unit demand reduction, in kW/motor, was calculated by dividing the total demand reduction by the total motors of the walk-ins.

Refer to Attachment-A for eQuest models, and Attachment-B for the eQuest output savings summary.

Table below summarizes the 2014 DEER Peak-Demand periods for all climate zones.

Climate Zone	Dates	Climate Zone	Dates
CZ01	Sep 16-18	CZ09	Sep 1-3
CZ02	Jul 8-10	CZ10	Sep 1-3
CZ03	Jul 8-10	CZ11	Jul 8-10
CZ04	Sep 1-3	CZ12	Jul 8-10
CZ05	Sep 8-10	CZ13	Jul 8-10
CZ06	Sep 1-3	CZ14	Aug 26-28
CZ07	Sep 1-3	CZ15	Aug 25-27
CZ08	Sep 1-3	CZ16	Jul 8-10

SECTION 3. LOAD SHAPES

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

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

Building Type	Load Shape	E3 Alternate Building Type
Assembly	Refrigeration	Assembly
Grocery	Refrigeration	Grocery_Store
Food Store	Refrigeration	Food_Store
Restaurant - Fast-Food	Refrigeration	Fast_Food_Restaurant
Restaurant - Sit-Down	Refrigeration	Sit_Down_Restaurant
Retail - Multistory Large	Refrigeration	Large_Retail_Store
Retail - Single-Story Large	Refrigeration	Large_Retail_Store
Retail - Small	Refrigeration	Small_Retail_Store

SECTION 4. COSTS

4.1 BASE CASE COST

For the ROB measure category, the base case cost is assumed to be installing the same type of shaded pole motor. The base case material cost is taken as the average of shaded pole motor in various sizes from Grainger cost data [C]. The labor cost is from DEER11 Measure Cost Summary [4] for installing an evaporator fan motor.

Base Case cost (SHP) = \$83.55 (material) + \$73.65(labor) = \$157.2 per motor

Note that this workpaper is applicable to walk-ins manufactured before 2009, which are not regulated by Title 20 for the evaporator fan motors.

4.2 MEASURE CASE COST

The cost of the measure is from DEER11 Measure Cost Summary [4].

Measure Case cost (ECM) = \$230.94 (material) + \$73.65(labor) = \$304.59 per motor

4.3 FULL AND INCREMENTAL MEASURE COST

Full and Incremental Measure Cost Equations

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

MEC = Measure Equipment Cost; MLC = Measure Labor Cost
 BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

4.3.1 Full Measure Cost

The full measure cost (FMC) can be calculated as follows:

$FMC = (MEC + MLC) - (BEC + BLC) = (\$230.94 + \$73.65) + (\$83.55 + \$73.65) = \147.39 per motor

4.3.2 Incremental Measure Cost

The incremental measure cost (IMC) can be calculated as follows:

$FMC = (MEC + MLC) - (BEC + BLC) = (\$230.94 + \$73.65) + (\$83.55 + \$73.65) = \147.39 per motor

ATTACHMENTS



A. PGE3PREF123_R 1_eQuest Models.rar



eQuest Savings
Summary

B.



Baseline SHP Cost

C.

REFERENCES

[1] 2014 Appliance Efficiency Regulations (Title 20), CEC-400-2014-009-CMF (2014).

[2] Itron, Inc., JJ Hirsh & Associates, Synergy Consulting, & Quantum, Inc. (2005). 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study.

[3] Arthur D. Little, Inc. (n.d.). Energy Savings Potential for Commercial Refrigeration Equipment.

[4] 2008 Database for Energy Efficiency Resources. (2008). Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008).