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HVAC

HIGH-EFFICIENCY FURNACE, RESIDENTIAL

SWHC031-01

CONTENTS

MEASURE NAME

High-efficiency Furnace, Residential

STATEWIDE MEASURE ID

SWHC031-01

TECHNOLOGY SUMMARY

A natural gas burning, forced-air furnace provides heat to a conditioned space by passing indoor air through a heat exchanger. A blower fan pulls cool air from inside the dwelling through the return air ducts and forces it through the furnace heat exchanger and heats the air by up to 50 °F. The cool air is then heated by passing over the heat exchanger connected to the combustion chamber. Warm air then flows back into the rooms through the ductwork. The combustion gases from the furnace are vented outside through the flue connected to the combustion unit near the heat exchanger.

The thermal efficiency of a furnace is represented by the annual fuel utilization efficiency (AFUE) rating. Expressed as a percentage, the AFUE is calculated as the ratio of energy output to energy input; a higher AFUE represents higher thermal efficiency. Furnaces with AFUE higher than 90% use two heat exchangers that lower the temperature of the combustion gases to the point at which the moisture condenses and is drained in a code-approved manner. These condensing furnaces use plastic flue piping and are thus easy to identify.

Most existing small-scale residential furnace blowers are relatively low cost, low efficiency, single-speed, with permanent split capacitor (PSC) motors. These motors usually range in power between ⅓ hp to 2 hp and turn ON and OFF as required by thermostat control. This results in temperature variations and high energy consumption of the furnace air handler blower motor.

Most major furnace manufacturers offer optional variable-speed motor (VSM) on their furnace air handlers; some VSMs are built into the unit. VSM motors have integrated electronic controls that modulate the motor and fan speed based on the cooling or heating load of the system; most VSMs are programmed to run at lower speed most of the time. Because of the (ideally) cubic relationship between fan power and fan speed, a small reduction in fan speed can result in considerable energy savings. Thus, VSM motors operate more efficiently and improve the quality of the air distribution. The price of a furnace with a VSM is considerably higher, however, than a furnace without a VSM.

Two Energy Center of Wisconsin studies and one PIER report address the VSM blower motor usage, the results of which are utilized in the energy use modeling to derive the energy savings for this measure.

Central Air Conditioning in Wisconsin: A compilation of recent field research (Energy Center of Wisconsin, May 2008 emended December 15, 2010).[1] This report summarizes field measurements of 61 furnace air hander units in residential homes in Wisconsin. The research found that furnaces with an electronically

[1] Pigg, S. (Energy Center of Wisconsin, ECW). 2010. *Central Air Conditioning in Wisconsin: A Compilation of Recent Field Research.* ECW Report Number 241-1. May 2008 amended December 15, 2010.

commutated motor (ECM) use an average 190 watts less power per 1,000 cfm of airflow than a conventional furnace with a standard permanent split capacitor (PSC) motor. As shown below, older PSC motors used 517 ±33 watts to 528 ±35 watts and ECM air handlers ranged from 320 ± 40 watts to 341 ±43 watts per 1,000 cfm of airflow. A 2007 field study confirmed this finding, with ECM air handlers averaging about 35% less power consumption than standard PSC air handlers.

Wisconsin Energy Center Field Study

	Mean air handler power (Watts per 1,000 cfm)		
	PSC (n=37)	ECM (n=24)	Difference
As-found	528 ± 35	341 ± 43	187 ± 60
Post-adjustment	517 ± 33	320 ± 40	197 ± 51

Efficiency Characteristics and Opportunities for New California Homes (ECO). (John Proctor, Proctor Engineering Group, Ltd, March 2011).[2] In this study, the New California Homes (ECO) project surveyed select energy efficiency measures in 80 single family and multifamily homes built under the 2005 Building Energy Efficiency Standards (Title 24) for residential buildings. Results of the HVAC Phase One research indicated that the split-system air conditioner evaporator blowers with PSC motors drew an average of 650 watts per 1,000 cfm of airflow for 45 HVAC systems. The fan power draw of one unit dropped by 102 watts and the efficiency increased by more than 4% after the PSC fan motor was replaced by a brushless permanent magnet (BPM) fan motor adjusted to the same supply airflow. This study was funded through the California Energy Commission (CEC) the Public Interest Energy Research (PIER) Program.

MEASURE CASE DESCRIPTION

This measure is defined as the replacement of a standard efficiency central gas furnace with a high-efficiency central gas furnace with a variable speed motor (VSM) that is installed in a residential multifamily building. The measure offerings are specified below; measure energy and demand impacts for each offering vary by building type and climate zone.

Measure Case Specification

Statewide Measure Offering ID	Measure Case Offering	AFUE
SWHC031A	Central gas furnace, high-efficiency, with variable speed motor	≥ 92%
SWHC031B	Central gas furnace, high-efficiency, with variable speed motor	≥ 95%
SWHC031C	Central gas furnace, high-efficiency, with variable speed motor	≥ 97%

[2] Proctor Engineering Group, Ltd. 2011. *Efficiency Characteristics and Opportunities for New California Homes* (ECO). Public Interest Energy Research (PIER) Program Final Project Report. Prepared for the California Energy Commission. CEC-500-2012-062. March. See Table 14 for summary of results.

Statewide Measure Offering ID	Measure Case Offering	AFUE

BASE CASE DESCRIPTION

The base case for this measure is defined as a non-condensing central gas furnace that meets the minimum AFUE of 80% for a furnace with input capacity ≤ 225,000 kBtuh.

CODE REQUIREMENTS

This measure is governed by the California Building Energy Efficiency Regulations (Title 24),[3] the California Appliance Efficiency Regulations (Title 20),[4] and federal standards, all of which stipulate the minimum thermal efficiency at 80% AFUE for gas furnaces with less than 225,000 kBtuh input capacity.

Additionally, the federal energy conservation standard requires electronically commutated motors for residential furnace fans.[5]

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2015)	Table E-6	July 1, 2015
CA Building Energy Efficiency Standards – Title 24 (2013)	Table 4-1	July 1, 2014
Federal Standards	10 CFR Part 430	July 3, 2019

NORMALIZING UNIT

Per household

[3] California Energy Commission (CEC). 2012. *2013 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)*. CEC-400-2012-004-CMF-REV2. May.

[4] California Energy Commission (CEC). 2015. *2015 Appliance Efficiency Regulations.* CEC 400-2015-021. July.

[5] U.S. Department of Energy (DOE), Energy Conservation Program. 2014. "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans." *Federal Register.* Vol. 79, No. 128. July 3.

U.S. Department of Energy (DOE), Energy Conservation Program. 2019. "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans; Correction." *Federal Register.* Vol. 84, No. 26. February 7.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Normal replacement	DnDeemed	Res
Normal replacement	DnDeemDI	Res
Normal replacement	UpDeemed	Res
New construction	DnDeemed	Res
New construction	DnDeemDI	Res
New construction	UpDeemed	Res

Eligibility requirements for this measure include:

- The customer must have natural gas distributed to the installation address.
- The new furnace must replace an existing gas furnace.

Eligible Products

This measure must meet the minimum AFUE efficiency ratings in the Measure Case Description.

A brushless DC motor, also known as an electronically commutated motor (ECM) may be eligible for the high-efficiency furnace with a variable speed motor (VSM).

A list of eligible furnaces can be found at https://www.ahridirectory.org/ahridirectory/pages/home.aspx (search for qualifying products that meet or exceed the measure case specification).

A licensed contractor must verify the furnace has a built-in VSM, if applicable.

Eligible Building Types and Vintages

This measure is applicable for any existing residential building (single family, multifamily, mobile home) of any vintage.

Eligible Climate Zones

The high-efficiency furnace measure offerings are applicable in any California climate zones.

PROGRAM EXCLUSIONS

None.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (KWH)

The electric unit energy savings (UES) for this measure were retrieved directly from the Database of Energy Efficient Resources (DEER). The version used to calculate savings for these measures is DEER 2020 (D20v1). Savings values vary by building type and climate zone.

The DEER energy impact ID and the associated Statewide Measure Offering ID and description for each are provided below.

Measure Offering IDs and DEER Measure IDs

Statewide Measure Offering ID	DEER Energy Impact ID	Measure Offering Description	DEER Version
SWHC031A	Scaled from: Res-GasFurnace-AFUE92-ECM	High Efficiency Furnace, Residential, AFUE 92%-VSM	D20v1
SWHC031B	Scaled from: Res-GasFurnace-AFUE95-ECM	High Efficiency Furnace, Residential, AFUE 95%-VSM	D20v1
SWHC031C	Scaled from: Res-GasFurnace-AFUE97-ECM	High Efficiency Furnace, Residential, AFUE 97%-VSM	D20v1

The annual electric savings values provided in DEER were in units of kWh per kBtuh. These values were converted to annual energy savings per household by multiplying the DEER value by the average furnace size (kBtuh) per household and climate zone that were used in the DEER building protypes.

The table below maps each California climate zone to an IOU service area to identify the appropriate saving value for each California climate zone if PA-independent values are not already available.

Program Administrator	Climate Zone
SCG	CZ06, CZ08, CZ09, CZ10
SCE	CZ14, CZ15, CZ16

Program Administrator	Climate Zone
PG&E	CZ01, CZ02, CZ03, CZ04, CZ05, CZ11, CZ12, CZ13
SDG&E	CZ07

PEAK ELECTRIC DEMAND REDUCTION (KW)

The approach to estimate peak demand reduction during the 4 p.m. to 9 p.m. peak period[6] is the same approach to estimate electric energy savings; see Electric Savings.

GAS SAVINGS (THERMS)

The gas unit energy savings (UES) from the high-efficiency central gas furnace were retrieved directly from the Database of Energy Efficient Resources (DEER). The version used to calculate savings for these measures is DEER 2020 (D20v1). Savings values vary by building type and climate zone. The results were reported in the Remote Ex-Ante Database Interface (READI) tool.

The DEER energy impact ID and associated Measure Offering ID and description for each measure offering are provided below.

Measure Offering IDs and DEER Measure IDs

Statewide Measure Offering ID	DEER Energy Impact ID	Measure Offering Description	DEER Version
SWHC031A	Scaled from: Res-GasFurnace-AFUE92-ECM	High Efficiency Furnace, Residential, AFUE 92%-VSM	D20v1
SWHC031B	Scaled from: Res-GasFurnace-AFUE95-ECM	High Efficiency Furnace, Residential, AFUE 95%-VSM	D20v1
SWHC031C	Scaled from: Res-GasFurnace-AFUE97-ECM	High Efficiency Furnace, Residential, AFUE 97%-VSM	D20v1

The annual gas savings values provided in DEER were in units of therms per kBtuh. These values were converted to annual energy savings per household by multiplying the DEER value by the average furnace size (kBtuh) per household and climate zone that were used in the DEER building protypes.

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

[6] California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. OP 1.

The EUL and RUL specified for high efficiency furnaces are specified below. The EUL adopted for this measure was specified in the *Energy Efficiency Policy Manual*. Note that RUL is only applicable for add-on equipment and accelerated replacement measures thus not applicable for this measure.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	20.0	California Public Utilities Commission (CPUC), Energy Division. 2003. *Energy Efficiency Policy Manual v 2.0.* Page 16-17.
RUL (yrs)	n/a	-

BASE CASE MATERIAL COST ($/UNIT)

Base case costs were derived from furnace cost data obtained in 2017 from online list prices of HVAC equipment vendors that sell residential gas furnaces nationwide. The base case furnace cost per kBtuh was calculated as the average cost per kBtuh across all units in the database that meet the base case furnace specification. (Note that the base equipment cost of an 80% AFUE central natural gas furnace is not provided in the Database for Energy Efficient Resources, DEER.)

The average cost per kBtuh was then multiplied by the average furnace size per household to derive the average base case cost per household.[7] The average furnace size per each residential building type (below) was calculated as the average furnace size used in the DEER building prototypes across all climate zones and AFUE rating for each building type.

Base Case Cost Inputs

Parameter	Value	Source
Base case furnace, 80% AFUE ($/kBtuh)	$12.00	Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx." See "Database" tab.
Average furnace size by household (kBtuh/household)		DEER building prototypes (DEER2020 Res-Furnace-dHIR)
Single family	57.6	
Multifamily	19.0	
Double-wide Mobile Home	55.0	

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case equipment costs for a 92%, 95% and a 97% AFUE gas furnace with a VSM motor were derived as the average of data obtained in 2017 from online list prices of HVAC equipment vendors of equipment manufacturers of forced-draft residential gas furnaces that meet the measure case specification. (Note that the measure case equipment costs for a central gas natural furnace with a VSM motor were not provided in the Database for Energy Efficient Resources, DEER.)

[7] Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx."

The average cost per kBtuh was then multiplied by the average furnace size per household to derive the average measure case cost per household.[8] The average furnace size per each residential building type (below) was calculated as the average furnace size used in the DEER building prototypes across all climate zones and AFUE rating for each building type.

Measure Cost Inputs

Parameter	Value	Source
Furnace, 92% AFUE-VSM ($/kBtuh)	$14.06	Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx." See "Database" tab.
Furnace, 95% AFUE-VSM ($/kBtuh)	$17.98	
Furnace, 97% AFUE-VSM ($/kBtuh)	$30.51	
Average furnace size by household (kBtuh/household)		DEER building prototypes (DEER2020 Res-Furnace-dHIR)
Single family	57.6	
Multifamily	19.0	
Double-wide Mobile Home	55.0	

BASE CASE LABOR COST ($/UNIT)

The base case installation labor costs ($/kBtuh) were obtained from the Database of Energy Efficient Resources (DEER) version 2008 (v2.05).

The average labor cost per kBtuh was then multiplied by the average furnace size per household to derive the average base case labor cost per household. The average furnace size per each residential building type (below) was calculated as the average furnace size used in the DEER building prototypes across all climate zones and AFUE rating for each building type.[9]

Base Case Installation Labor Cost Inputs

Parameter	Value	Source
Installation labor cost ($/kBtuh)	$5.84	Database of Energy Efficient Resources (DEER) version 2008 (20v1).
Average furnace size (kBtuh/household)		DEER building prototypes (DEER2020 Res-Furnace-dHIR)
Single family	57.6	
Multifamily	19.0	
Double-wide Mobile Home	55.0	

[8] Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx."

[9] Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx."

MEASURE CASE LABOR COST ($/UNIT)

Measure installation labor costs were obtained from the Database of Energy Efficient Resources (DEER) version 2008 (v2.05). The installation cost per kBtuh in the DEER 2008 database is the same regardless of the measure case efficiency. See Base Case Material Cost for the conversion to a per-household value. [10]

The average labor cost per kBtuh was then multiplied by the average furnace size per household to derive the average labor cost per household. The average furnace size per each residential building type (below) was calculated as the average furnace size used in the DEER building prototypes across all climate zones and AFUE rating for each building type.[11]

Measure Case Installation Labor Cost Inputs

Parameter	Value	Source
Installation labor cost ($/kBtuh)	$5.84	Database of Energy Efficient Resources (DEER) version 2008 (v2.05).
Average furnace size (kBtuh/household)		DEER building prototypes (DEER2020 Res-Furnace-dHIR)
Single family	57.6	
Multifamily	19.0	
Double-wide Mobile Home	55.0	

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. This NTG value is based upon the average of all NTG ratios for all evaluated 2006 – 2008 residential programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. This sector average NTG ("default NTG") is applicable to all energy efficiency measures that have been offered through residential sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG – residential	0.55	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

[10] Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx."

[11] Southern California Gas Company (SCG). 2017. "SWHC031-01 Res Furnaces Cost Data v2.xlsx."

Gross Savings Installation Adjustment Rates

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31.

NON-ENERGY IMPACTS

Non-energy benefits for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods used from the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	Yes
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes
DEER Version	DEER2020
Reason for Deviation from DEER	DEER values were converted to savings per household.
DEER Measure IDs Used	Res-GasFurnace-AFUE92-ECM Res-GasFurnace-AFUE95-ECM Res-GasFurnace-AFUE97-ECM
NTG	Source: DEER2016. The NTG of 0.55 is associated with NTG ID: *Res-Default>2*
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER2017, DEER2016, DEER2014, DEER2011. The value of 20 years is associated with EUL ID: *HV-EffFurn*.

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	06/30/2018	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: WPSCGREHC130115A, Revision 4 (January 1, 2017) PGECOHVC147, Revision 3 (January 1, 2017) PGECOHVC145, Revision 3 (January 1, 2017) PGECOHVC139 Revision 3 PGECOHVC145, 12 (May 7, 2014) Consensus reached among Cal TF members.
	07/3/2019	Raad Bashar, SoCalGas Jennifer Holmes Cal TF Staff	Revisions for submittal of version 01.
	07/05/2019	Raad Bashar, SoCalGas Jennifer Holmes Cal TF Staff	Update to code and remove offerings without a VSM