**Work Paper PGECOHVC145**

**95 AFUE Furnace - Res**

**Revision # 1**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**High Efficiency Furnace 95 AFUE (1.04 HIR) – Residential**

**Measure Codes: HA68, HA78**

# At-a-Glance Summary

|  |  |  |
| --- | --- | --- |
| **Applicable Measure Codes:** | **HA68** | **HA78** |
| **Measure Description:** | Central Natural Gas Furnace – 95-96.9% AFUE without VSM | Central Natural Gas Furnace – 95-96.9% AFUE With VSM |
| **Energy Impact Common Units:** | per household | |
| **Base Case Description:** | Source: DEER2014 and Engineering calculations  Base Case gas furnace meeting federal standard requirements of 80% AFUE for units less than 225,000 Btu/h. | |
| **Base Case Energy Consumption:** | Source: DEER2014 and Engineering calculations  Varies based on climate zones and building types | |
| **Measure Energy Consumption:** | Source: DEER2014 and Engineering calculations  Varies based on climate zones and building types | |
| **Energy Savings**  **(Base Case – Measure):** | Source: DEER2014 and Engineering calculations  Varies based on climate zones and building types | |
| **Costs Common Units:** | $ per furnace | |
| **Base Case Equipment Cost ($/unit):** | Source: DEER2008 and Engineering Calculation.  $9.35/mBtuh, Total equipment cost varies, see At-A-Glance Measure List. | |
| **Measure Equipment Cost ($/unit):** | Source: DEER2008 and Engineering Calculation.  $17.23/mBtuh. Total equipment cost varies, see At-A-Glance Measure List | |
| **Gross Measure Cost ($/unit)** | Source: DEER2008 and Engineering Calculation.  Varies based on unit capacity size | |
| **Measure Incremental Cost ($/unit):** | Source: DEER2008 and Engineering Calculation.  Varies based on unit capacity size | |
| **Effective Useful Life (years):** | Source: DEER2014  20 years | |
| **Measure Application Type:** | Replace on Burnout (ROB) | |
| **Net-to-Gross Ratios:** | Source: DEER2011  0.55 NTGR, Res-Default>2 (All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years) | |
| **Important Comments:** |  | |

# Work Paper Approvals

|  |  |
| --- | --- |
|  |  |
| The following Manager(s) approved this work paper through the PG&E Electronic Data Routing System under Routing Requisition # \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |  |
| |  | | --- | |  | | **Grant Brohard**  Manager, Engineering Services | | **Carolyn Weiner**  Manager, Core Products | |  |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Revision Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| Revision 0 | 06/19/2012 | PGECOHVC145-R0\_Res 95\_furnace | Christopher Li (PG&E) |
| Revision 0 | 08/28/2012 | PGECOHVC145-R0\_Res 95\_furnace   * Update workpaper and At-A-Glance Measure list. * Add OTR definition. | Christopher Li (PG&E) |
| Revision 1 | 5/7/2014 | PGECOHVC145-R1-Res\_ 95\_furnace\_v1.docx   * Update impact savings based on new 2013 Title 24 CEC weather files. | Christopher Li (PG&E) |

# Table of Contents

Contents

[At-a-Glance Summary i](#_Toc387238549)

[Work Paper Approvals ii](#_Toc387238550)

[Document Revision History iii](#_Toc387238551)

[Table of Contents iv](#_Toc387238552)

[List of Tables v](#_Toc387238553)

[Section 1. General Measure & Baseline Data 1](#_Toc387238554)

[1.1 Product Measure Description & Background 1](#_Toc387238555)

[1.2 Product Technical Description 2](#_Toc387238556)

[1.3 Transaction Type 2](#_Toc387238557)

[1.4 Product Base Case and Measure Case Data 2](#_Toc387238558)

[1.4.1 DEER Base Case and Measure Case Information 2](#_Toc387238559)

[1.4.2 Codes & Standards Requirements Base Case and Measure Information 5](#_Toc387238560)

[1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information 6](#_Toc387238561)

[1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases 7](#_Toc387238562)

[1.4.5 Time-of-Use Adjustment Factor 7](#_Toc387238563)

[1.5 Summary of Inputs for Savings Calculations 8](#_Toc387238564)

[Section 2. Calculation Methods 8](#_Toc387238565)

[2.1 Electric Energy Savings Estimation Methodologies 8](#_Toc387238566)

[2.2. Demand Reduction Estimation Methodologies 9](#_Toc387238567)

[2.3. Gas Energy Savings Estimation Methodologies 9](#_Toc387238568)

[Section 3. Load Shapes 9](#_Toc387238569)

[3.1 Base Case Load Shapes 9](#_Toc387238570)

[3.2 Measure Load Shapes 9](#_Toc387238571)

[Section 4. Base Case & Measure Costs 10](#_Toc387238572)

[4.1 Base Case(s) Costs 10](#_Toc387238573)

[4.2 Measure Case Costs 11](#_Toc387238574)

[4.3 Incremental & Full Measure Costs 12](#_Toc387238575)

[4.3.1 Gross Measure Cost 12](#_Toc387238576)

[4.3.2 Incremental Measure Costs 13](#_Toc387238577)

[Input Appendices 14](#_Toc387238578)

[A. DEER Base Case and Measure Case Information 14](#_Toc387238579)

[B. Codes & Standards Requirements Base Case and Measure Information 15](#_Toc387238580)

[C. eQUEST Simulation Model for Furnace with Variable Speed Motor 16](#_Toc387238581)

[References 17](#_Toc387238582)

# List of Tables

[Table 1: Measure Application Type 2](#_Toc387238853)

[Table 2: DEER Net-to-Gross Ratios 5](#_Toc387238854)

[Table 3: Wisconsin Energy Center Field Study 7](#_Toc387238855)

[Table 4: Base Case Building Types and Load Shapes 9](#_Toc387238856)

[Table 5: Base case and Measure case cost analysis, per mBtuh 10](#_Toc387238857)

[Table 6: Base Case Costs 11](#_Toc387238858)

[Table 7: Measure Case Costs 12](#_Toc387238859)

[Table 8: Measure case cost for units with variable speed motor 12](#_Toc387238860)

[Table 9: Summary of Costs 13](#_Toc387238861)

# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description*** *–* The 95% AFUE central gas furnace for residential dwelling is part of PG&E’s deemed rebate program delivered under the downstream catalog rebate program. This measure is only offered to residential multifamily customers located in PG&E service territory.

***Program Restrictions and Guidelines***

This measure is applied to a residential multifamily homes located in PG&E’s service territory. To qualify the applicant must have natural gas distributed to the installation address for the gas furnace only rebate and have both natural gas and electricity for the natural gas furnace with variable speed motor (VSM) rebate. The central natural gas furnace must have an Annual Fuel Utilization Efficiency (AFUE) rating of ≥ 95% and ≤ 96.9%.

***Terms and Conditions:***

Furnace Only:

• Customer must have natural gas distributed by PG&E to the installation address.

• All installations must replace the previously installed gas furnace.

• The central natural gas forced air furnace must have an Annual Fuel Utilization Efficiency (AFUE) rating of 95 percent to 96.9 percent.

• Go to <https://www.ahridirectory.org/ahridirectory/pages/home.aspx> to search for qualifying products that meet or exceed the requirements in the Furnace Rebate Table.

Furnace with built-in Variable Speed Motor (VSM):

• Customer must have both natural gas and electricity distributed by PG&E to the installation address.

• Rebate is only available to homes located in climate zones (CZ) 11, 12, or 13. To find your climate zone go to <http://www.energy.ca.gov/maps/renewable/Climate_Zones_Zipcode.pdf>.

• All installations must replace the previously installed gas furnace.

• The central natural gas forced air furnace with Built-In Variable Speed Motor must have an AFUE rating of 95 percent to 96.9 percent.

• Go to <https://www.ahridirectory.org/ahridirectory/pages/home.aspx> to search for qualifying products that meet or exceed the requirements in the Furnace with VSM Rebate Table.

• A brushless DC motor, also known as an electronically commutated motor (ECM) may qualify for this rebate.

• Note: Consult with your licensed contractor to verify your furnace has a built-in VSM.

***Market Applicability:***

This measure only applies to residential multifamily buildings located in PG&E service territory.

## 1.2 Product Technical Description

**1.2.1 Furnace only:**

Natural gas burning, forced-air furnaces provide heat to the 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 heating it by up to 50 degrees Fahrenheit. The combustion gases from the furnace are vented outside through flue connected to the combustion unit near the heat exchanger. The AFUE 90 and higher furnaces use two heat exchangers which lower the temperature of the combustion gases to where the moisture condenses and drained in a code approved manner. These condensing furnaces use plastic flue piping making them easy to identify.

**1.2.2 Furnace with Variable Speed Motor:**

Most existing small-scale residential furnace blowers come with low cost, low efficiency, single speed PSC motors. These motors usually range in power between 1/3 to 2 hp. They 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 are now offering optional variable-speed motor on their air handlers, and some comes built into the unit. These motors have integrated electronic controls that modulate the motor and fan speed based on the cooling or heating load of the system; most variable speed motors are programmed to run at lower speed majority of the time. These motors provide much more efficient operation, and improve the quality of the air distribution; however, they come at a premium price.

This measure is designed to encourage the installation of such variable-speed motor air handlers in residential buildings. Because of the (ideally) cubic relationship between fan power and fan speed, a small reduction in fan speed can result in large energy savings.

## 1.3 Transaction Type

The Transaction type for this work paper covers measures for Replace on Burnout (ROB). ROB use the effective useful life (EUL) for the measure life basis.

The base case for ROB is a central natural gas furnace meeting minimum federal standards of 80% Annual Fuel Utilization Efficiency (AFUE).

Table 1: Measure Application Type

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| ROB | Replace on Burnout | measure applied when existing equipment fails or maintenance requires replacement |

## 1.4 Product Base Case and Measure Case Data

### 1.4.1 DEER Base Case and Measure Case Information

The DEER2014 READI tool (v1.0.5)[[1]](#endnote-1) data cited in this workpaper include: gas energy savings, equipment useful life, and net-to-gross of this measure (Res-GasFurnace-AFUE95). However, it does not contain information on equipment unit costs, equipment and incremental costs, therefore the data from DEER2008 v2.05 was used to estimate the equipment costs and incremental costs. For units with built-in variable speed motor, eQUEST[[2]](#endnote-2) modeling was used to estimate the energy and peak demand savings. Impact savings from the Residential HVAC Quality Maintenance workpaper (PGECOHVC139 R2) on the blower motor retrofit measure was used for this furnace with VSM product. See the calculation section (2) for this conversion

DEER use and Technology type for Furnace measures:

|  |  |  |  |
| --- | --- | --- | --- |
| *DEER USE and TECHNOLOGY TABLE* | | | |
| Use Category Description | Use Category | Use Sub Category Description | Use Sub Category |
| HVAC | HVAC | Space Heating | HVAC-SpHt |
|  |  |  |  |
| Technology Groups Description | Technology Groups | Technology Types Descriptions | Technology Types |
| Space Heating Equipment | SpaceHtg\_eq | Gas Furnace | GasFurnace |

**Delta Wattage Assumption (ΔW):** The wattage for the base case furnace with PSC motor is assumed to be 0.650 Watts/CFM and the assumed wattage of the measure case furnace with variable speed motor is 0.365 Watts/CFM. The wattage assumption was based on recent studies.

Table below shows kW Savings for furnace with VSM in multifamily homes in climate zone 13.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings kW** | **Deer units** | **DEER Version** | **Impact IDs** | **Measure Code** |
| MFM | Ex | Z13 | 0.309 | Household | DEER2014 | Res-GasFurnace-AFUE95 | HA78 |

**EUL Electric Savings** **(ΔW):**DEER does not have furnace with variable speed motor measure. However, within their eQUEST modeling, DEER assumes all furnace measures would have a low blower motor baseline power usage of 0.365 Watts/CFM. But based on three recent studies by Scott Pigg at Wisconsin Energy Center and a CEC PIER report, majority of existing furnaces would have older single speed PSC (Permanent Split Capacitor) blower motors, which uses on average 0.650 Watts/CFM. The savings methodology is reflected on Section 2 below for furnace with variable speed motor.

**RUL Electric Savings (ΔW):** RUL Electric Savings do not apply to this measure as the application type is ROB, no early retirement.

**Therms Savings Assumption (ΔTh):**  This measure is listed in the DEER2014 READI (v1.0.5) and the Impact savings is extracted from this database under measure ID, Res-GasFurnace-AFUE95.

**EUL Gas Savings** **(ΔTh):** EUL Gas Savings for this measure were downloaded from the DEER2014 READI tool with impact ID, Res-GasFurnace-AFUE95.

Table below shows Therm Savings for furnace in multifamily homes.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Interactive Only?**  **Yes / No** | **Gas Savings Therms** | **Deer units** | **DEER Version** | **Impact IDs** |
| MFM | EX | Z01 | Yes | 24.39 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z02 | Yes | 17.68 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z03 | Yes | 19.53 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z04 | Yes | 14.61 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z05 | Yes | 21.68 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z11 | Yes | 18.09 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z12 | Yes | 18.97 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z13 | Yes | 18.25 | Household | DEER2014 | Res-GasFurnace-AFUE95 |
| MFM | EX | Z16 | Yes | 32.38 | Household | DEER2014 | Res-GasFurnace-AFUE95 |

**RUL Gas Savings** (ΔTh): RUL Gas Savings do not apply to this measure as the application type is ROB, no early retirement.

**Hours of Operation:** Residential furnaces have a wide range of equivalent full load hours (EFLH) where it varies depending on PG&E’s climate zones. Since DEER data was used for the calculation of energy impacts, the hours of operation are assumed to been embedded in those values.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Hours of Operation hrs/yr** | **DEER Version** | **Measure IDs** |
| MFM | Ex | PGE | DEER hours | DEER2014 | Res-GasFurnace-AFUE95 |

**Base Case Costs and Measure Case Costs:** DEER does not contain any costs data for base case furnace of 80% AFUE and measure case 95% AFUE furnace, however it does contain costs data for 94% and 96% AFUE furnace. To determine the costs, an interpolation method was used. The DEER unit is “cost ($) per mBtuh”.

Table below shows costs for furnace in multifamily homes in climate zone 13.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | | **Costs ($)** | | |  |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Base Case** | **Measure Case** | **IMC** | **DEER Version** |
| MFM | Ex | Z13 | $298.27 | $549.64 | $251.37 | DEER2008 |

**Net-to-Gross Assumption:** The NTG ratio was based on the DEER 2011, the value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls”[[3]](#endnote-3) spreadsheet under the “DEER2011 NTGr Values tab.

Table 2 below summarizes all applicable DEER based Net-to-Gross ratios for programs that may be used by this measure.

See Section 1.1 Terms and Conditions and Market Applicability to reference the type of program delivery mechanism and customer status used to determine this entry.

Table 2: DEER Net-to-Gross Ratios

|  |  |  |  |
| --- | --- | --- | --- |
|  | | DEER Spreadsheet | |
| Program Approach | NTG | File name | Cell Number |
| All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | 0.55 | DEER2011\_NTGR\_2012-05-16.xls | U54 |

The NTG Ratios in Table 2 are appropriate for the measure because:

* The current DEER 2011 spreadsheet does not contain a NTG value for this measure.
* This measure is replacing a non-operable existing unit with a high efficiency unit.

**Effective Useful Life / Remaining Useful Life:**

The Effective Useful Life estimates were downloaded from DEER directly, matching the intended measures for climate zones and building types and building vintages. The Effective Useful Life of measures covered in this workpaper was derived from the DEER2014 EUL table update, “DEER2014-EUL-table-update\_2014-02-05.xlsx” spreadsheet, under the “Updated 2014 EUL table” tab.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **EUL (yrs)** | **RUL (yrs)** | **DEER Version** | **Impact IDs** | **Cell Number** | **EUL\_ID** |
| RES | Ex | PGE | 20 | 6.7 | DEER2014 | High Efficiency Gas Furnace | D107 | HV-EffFurn |

**In-service rate/first year installation rate:**

DEER does not have an in-service rate (ISR) for this measure. An assumption has been taken to assume the ISR will be 1 since majority of the customers will replace their furnace after the existing furnace burns out.

See Section 1.1 Terms and Conditions and Market Applicability to reference the type of program delivery mechanism and customer status used to determine this entry.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **In-service rate** | **DEER Version** |
| ANY | Ex | IOU | 1 | DEER2014 |

### 1.4.2 Codes & Standards Requirements Base Case and Measure Information

***Title 20:*** This measure does fall under Title 20 of the California Energy Regulations. Under section 1605.1(B) on Table E-4, the minimum standard for gas furnaces with less than 225,000 Btu/h is 78% AFUE.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Title 20 Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Natural Gas Furnaces | Base | 78% | AFUE | Table E-4, Title 20, 2013 |

***Title 24:*** This measure falls under Title 24 2013 of the California Energy Regulations. Under Title 24, table 4-1 provides the minimum standard for furnaces is 80% AFUE.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Title 24 Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Central Furnaces | Base | 80% | AFUE | Table 4-1, Title 24, 2013 (Residential Compliance Manual-Building HVAC Requirements) |

***Federal Standards:*** This measure falls under Federal DOE (10 CFR Part 430)[[4]](#endnote-4) Energy Regulations. Under this regulation, compliance with the standards in the direct final rule will be required on May 1, 2013 for non-weatherized furnaces and on January 1, 2015 for weatherized furnaces and central air conditioners and heat pumps. Because most residential type furnaces are installed inside the house, it’s considered as non-weatherized for which the minimum AFUE is 80% for units less than 225,000 Btu/h in input capacity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Federal Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Central Furnaces | Non-Weatherized gas | 80% AFUE | Per System | CFR Part 430 |

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

There are no EM&V study identified that address residential furnaces, however there is a report, “California Residential Efficiency Market Share Tracking, HVAC 2005”, prepared by Itron and completed on December 2005, that address the average annual AFUE ratings of central gas furnaces, which ranges from 81.0 to 82.6, during the study period. This study also tracks the market share of Energy Star qualified units sold in California.

For furnaces with variable speed motors, there are two Energy Center of Wisconsin studies and one PIER report that address the baseline blower motor usage, used in the eQUEST modeling.

**Scott Pigg- Energy Center of Wisconsin Study[[5]](#endnote-5)**

“Central Air Conditioning in Wisconsin: A compilation of recent field research”, Scott Pigg, Energy Center of Wisconsin, May 2008 emended December 15, 2010.

The report summarizes the field measurements of 61 (37 PSC and 24 ECM) furnace air hander units involving residential homes in Wisconsin. Based on the results, the study found that furnaces with electronically commutated motor (ECM) uses on average 190 watts or less power per 1000 CFM of airflow than conventional furnaces with standard PSC motor. Table 3 shows that older PSC (Permanent Split Capacitor) motors used 517±33 watts to 528±35 watts and ECM air handler ranged from 320±40 watts to 341±43 watts per 1000 cfm of airflow. A 2007 focus field study confirmed this finding; with ECM air handlers averaging about 35 percent lower power consumption than standard PSC air handlers.

Table 3: Wisconsin Energy Center Field Study

|  |  |  |  |
| --- | --- | --- | --- |
|  | Mean air handler power (Watts per 1000 cfm) | | |
|  | PSC (n=37) | ECM (n=24) | Difference |
| As-found | 528 ± 35 | 341 ± 43 | 187 ± 60 |
| Post-adjustment | 517 ± 33 | 320 ± 40 | 197 ± 51 |

**CEC Public Interest Energy Research (PIER) Study[[6]](#endnote-6)**

“Efficiency Characteristics and Opportunities for New California Homes (ECO)”, John Proctor, Proctor Engineering Group, Ltd, March 2011.

In this study, the New California Homes (ECO) project surveyed selected energy efficiency measures in 80 single family and multifamily homes built under the 2005 Building Energy Efficiency Standards for residential buildings. The goal is to reduce end use energy consumption and peak electrical demand in California by improving the standards. During the HVAC Phase one research, the split system air conditioner evaporator blowers with PSC motor drew an average of 650 watts per 1000 CFM of airflow for 45 HVAC systems. And in one test, one unit had the PSC fan motor replaced by a BPM fan motor adjusted to the same supply airflow, the fan watt draw dropped by 102 watts and the efficiency increased by more than 4 percent.

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

**Gas Savings Assumption (ΔTherms):** This measure is located in the DEER 2014; gas impact savings were extracted from the READI tool (v1.0.5) and are used for this measure.

**Energy Savings Assumption (ΔW):** The DEER 2014 does not have this measure with variable speed motor (VSM). To determine the energy savings coming from the high efficiency blower motor, the DOE2 eQUEST2 simulation tool was used. The base case uses a new model simulating a furnace with a permanent split capacitor (PSC) motor and a measure case with an energy-efficient brushless permanent magnet (BPM) motor. Because the measure with VSM used in this workpaper is similar to the blower motor retrofit measure (measure code: TK10) in workpaper, PGECOHVC139, the impact savings will be identical. The process on calculating the savings for this measure will be located in Appendix B of workpaper, PGECOHVC139 R2.

### *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. The avoided-cost calculation performed in the E3 calculator has inherent and specific TOU adjustment factors. In order to apply the TOU adjustment factor correctly to each measure, the following equation was used to calculate the “% Eligible for TOU AC Adjustment” value found in the summary table:



Where,

*kWAC*is the kW savings associated with the A/C unit, and

*kWTotal* is the total kW savings for the sum of kW measures.

The TOU for this measure is 100%.

## 1.5 Summary of Inputs for Savings Calculations

The following sections provide the inputs for calculation:

|  |  |  |  |
| --- | --- | --- | --- |
| **Input Variable** | **Variations** | **Measure Case Average Value** | **Reference Section** |
| Electric Savings | Climate Zone (CZ) | 0.2991 kW/household  484.91 kWh/household | WP Section 2.1  WP Section 2.2 |
| Gas Savings | Climate Zone (CZ) | 20.07 therms/household | WP Section 2.3 |
| Hours of operation | Climate Zone (CZ) | DEER simulation hours | WP Section 1 |
| Full Cost | Replace on Burnout (ROB) | $458.93 | WP Section 1 |
| Incremental Cost | ROB | $292.78 | WP Section 1 |
| Effective Useful Life (EUL) / Remaining Useful Life (RUL) | ROB | 20.0 | WP Section 1 |
| Net to Gross (NTG) | None | 0.55 | WP Section 1 |
| In Service Rate (ISR) | Applies -- Yes | 1.0 | WP Section 1 |
| Time of Use (TOU) Factor | A/C projects only | 0% | WP Section 1 |

### **Section 2. Calculation Methods**

|  |  |  |  |
| --- | --- | --- | --- |
| **Install/Program Type** | **Measure Life Basis** | **First Baseline Period Gross Measure Cost (RUL)** | **Second Baseline Period Gross Measure Cost (EUL – RUL)** |
| ***ROB*** | EUL | Calculated as Incremental Measure Cost | N/A |

Note: For ROB measures, First Baseline is the baseline for the full EUL. There is no second baseline.

## 2.1 Electric Energy Savings Estimation Methodologies

The DEER 2014 does not have this measure with variable speed motor (VSM). To determine the energy savings coming from the high efficiency blower motor, the DOE2 eQUEST2 simulation tool was used. The base case uses a new model simulating a furnace with a permanent split capacitor (PSC) motor and a measure case with an energy-efficient brushless permanent magnet (BPM) motor. Because the measure with VSM used in this workpaper is similar to the blower motor retrofit measure (measure code: TK10) in workpaper, PGECOHVC139, the impact savings will be identical. The process on calculating the savings for this measure will be located in Appendix B of workpaper, PGECOHVC139 R2.

**∆kWh/unit:** The energy difference (kilowatts per unit) is simply the difference between the electric energy use of the base case unit and the electric energy use of the energy efficient unit. It is used in the calculations for energy savings.

EUL ∆kWh/unit = (Weighted EUL Base Case kWh/unit) – (Weighted Measure Case Unit kWh/unit)

Where,

Weighted EUL Base Case = code/industry standard weighted with DEER ratios

Weighted EUL Measure Case = measure case weighted with DEER ratios

ROB measures will have no annual RUL electric savings.

## 2.2. Demand Reduction Estimation Methodologies

The Demand Savings follow the same methodology as the Electric Energy Savings Calculations above.

## 2.3. Gas Energy Savings Estimation Methodologies

Gas savings for the high efficiency furnace 95 AFUE measure (Impact ID: Res-GasFurnace-AFUE95) were downloaded from the DEER2014 READI tool (v1.0.5).

Specified values vary by building types and climate zones. For this work paper, a building type of residential multifamily was chosen, along with using “existing (weighted DEER vintages)” building vintage and all PG&E nine (9) California Climate Zones.

# *Section 3. Load Shapes*

## 3.1 Base Case Load Shapes

The closes load shape chosen for this measure is the “DEER: Res.Elc.&Ht.Pump Heating” load shape. See Table 5 for a list of all Building Types and Load Shapes. See the KEMA[[7]](#endnote-7) report for a more thorough discussion regarding the load shapes for this measure.

Table 4: Base Case Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Multifamily | RES | DEER: Res.Elc.&Ht.Pump Heating |

## 3.2 Measure Load Shapes

The measure load shape is the same as the base case load shape, DEER: Res.Elc.&Ht.Pump Heating.

# Section 4. Base Case & Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Install/Program Type** | **Measure Life Basis** | **First Baseline Period Gross Measure Cost (RUL)** | **Second Baseline Period Gross Measure Cost (EUL – RUL)** |
| ROB | EUL | Calculated as Incremental Measure Cost | N/A |

Note: For ROB measures, First Baseline is the baseline for the full EUL. There is no second baseline.

## 4.1 Base Case(s) Costs

DEER2014 does not show any base case cost for 80% AFUE furnace. However, DEER2008 does contain base case costs for 78% and 81% AFUE furnaces. To estimate the base case cost, an excel “FORECAST” function was used to interpolate the cost of an 80% AFUE furnace, as shown on equation 1 below. Using the excel FORECAST function, the base case cost of an 80% AFUE furnace is estimated at $9.35 per mBtuh, as shown on Table 5 below, the material cost is then converted to a “per furnace” basis by using the number energy of common units in mBtuh furnace size from DEER.

Equation 1: 80% AFUE Base case cost

(therms/household) = FORECAST(x, known\_y’s, known\_x’s)

Where, FORECAST = MS Excel function

x = 80% AFUE

Known\_y’s = DEER Gas Impacts for 78% and 81% AFUE furnaces

Known\_x’s = 78% and 81% AFUE

Table 5: Base case and Measure case cost analysis, per mBtuh

|  |  |
| --- | --- |
| **80% Base case cost ($/mBtuh)** | |
| 78% | $8.66 |
| 80% | $9.35 |
| 81% | $9.69 |
| 90% | $12.79 |
| 92% | $14.46 |
| 94% | $16.26 |
| 96% | $18.20 |
| 95% | $17.23 |
| 97% | $19.03 |
| **Labor Cost ($/mBtuh)** | |
|  | $5.84 |
| **With VSM motor based on HVAC distributor, MARS** | |
| Material Cost: | $198.88 |

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

Table 6: Base Case Costs

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Building Type** | **Measure Application Type** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Base Case Cost** |
| HA68 | MFM | ROB | Code | $161.76 | $101.03 | $0 | $262.79 |
| HA68 | MFM | ROB | Code | $243.10 | $151.84 | $0 | $394.94 |
| HA68 | MFM | ROB | Code | $239.36 | $149.50 | $0 | $388.86 |
| HA68 | MFM | ROB | Code | $231.88 | $144.83 | $0 | $376.71 |
| HA68 | MFM | ROB | Code | $242.17 | $151.26 | $0 | $393.42 |
| HA68 | MFM | ROB | Code | $319.77 | $199.73 | $0 | $519.50 |
| HA68 | MFM | ROB | Code | $286.11 | $178.70 | $0 | $464.81 |
| HA68 | MFM | ROB | Code | $298.27 | $186.30 | $0 | $484.56 |
| HA68 | MFM | ROB | Code | $265.54 | $165.86 | $0 | $431.40 |
| HA78 | MFM | ROB | Code | $319.77 | $199.73 | $0 | $519.50 |
| HA78 | MFM | ROB | Code | $286.11 | $178.70 | $0 | $464.81 |
| HA78 | MFM | ROB | Code | $298.27 | $186.30 | $0 | $484.56 |

*All costs are noted as $ per household*

## 4.2 Measure Case Costs

Similarly to base case costs, DEER2014 does not have cost data for this measure case. The measure case costs is estimated by using the excel “FORECAST” function and using DEER2008 cost data for 94% and 96% AFUE furnaces in equation 1 above. Table 7 shows the estimated measure cost per mBtuh for this measure. The estimated cost is then converted to a “per furnace” basis using the DEER number energy common units in mBtuh furnace heating capacity.

The Measure Application Types of ROB are appropriate to these measures. The Measure Case Costs are:

Table 7: Measure Case Costs

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Building Type** | **Measure Application Type** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Measure Case Cost** |
| HA68 | MFM | ROB | Code | $298.08 | $101.03 | $0 | $399.11 |
| HA68 | MFM | ROB | Code | $447.98 | $151.84 | $0 | $599.82 |
| HA68 | MFM | ROB | Code | $441.09 | $149.50 | $0 | $590.59 |
| HA68 | MFM | ROB | Code | $427.30 | $144.83 | $0 | $572.14 |
| HA68 | MFM | ROB | Code | $446.26 | $151.26 | $0 | $597.51 |
| HA68 | MFM | ROB | Code | $589.27 | $199.73 | $0 | $788.99 |
| HA68 | MFM | ROB | Code | $527.24 | $178.70 | $0 | $705.94 |
| HA68 | MFM | ROB | Code | $549.64 | $186.30 | $0 | $735.93 |
| HA68 | MFM | ROB | Code | $489.33 | $165.86 | $0 | $655.19 |
| HA78 | MFM | ROB | Code | $589.27 | $199.73 | $0 | $788.99 |
| HA78 | MFM | ROB | Code | $527.24 | $178.70 | $0 | $705.94 |
| HA78 | MFM | ROB | Code | $549.64 | $186.30 | $0 | $735.93 |

All costs are noted as $ per household

There are no DEER data available for furnace with VSM measure. The costs estimates were based on a data sheet from an HVAC distributor, MARS- Motors & Armatures, Inc. distributor[[8]](#endnote-8). The estimated charge for a brushless permanent magnet (BPM) blower motor is $198.88 per motor. Table 8 below shows the estimated cost for Measure case furnace with variable speed motor.

Table 8: Measure case cost for units with variable speed motor

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Building Type** | **Measure Application Type** | **Climate Zone** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Measure Case Cost** |
| HA68 | MFM | ROB | Z11 | $589.27 | $199.73 | $0 | $788.99 |
| HA68 | MFM | ROB | Z12 | $527.24 | $178.70 | $0 | $705.94 |
| HA68 | MFM | ROB | Z13 | $549.64 | $186.30 | $0 | $735.93 |

## 4.3 Incremental & Full Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Install/Program Type** | **Gross Measure Cost**  **(RUL Period/First Baseline)** | **Gross 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 Gross Measure Cost

Gross 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 Application Types are: ROB, so the Gross Measure Cost (GMC) is represented by the equation below (choose):

GMC = Measure Equipment Cost – Base Case Equipment Cost

\*Note: Various complicated price fluctuations are not addressed in these equations, such as future costs due to inflation in labor, future costs due to deflation in material cost, and other variables that cannot be accurately described at this time. We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value.

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

IMC = Measure Equipment Cost – Base Case Equipment Cost

\*Note: Various complicated price fluctuations are not addressed in these equations, such as future costs due to inflation in labor, future costs due to deflation in material cost, and other variables that cannot be accurately described at this time. We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value.

Table 9: Summary of Costs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Building Type** | **Measure Application Type** | **Base Case Total Cost** | **Measure Case Total Cost** | **Gross Measure Case Cost** | **Incremental Measure Cost** |
| HA68 | MFM | ROB | $161.76 | $298.08 | $136.32 | $136.32 |
| HA68 | MFM | ROB | $243.10 | $447.98 | $204.88 | $204.88 |
| HA68 | MFM | ROB | $239.36 | $441.09 | $201.73 | $201.73 |
| HA68 | MFM | ROB | $231.88 | $427.30 | $195.42 | $195.42 |
| HA68 | MFM | ROB | $242.17 | $446.26 | $204.09 | $204.09 |
| HA68 | MFM | ROB | $319.77 | $589.27 | $269.50 | $269.50 |
| HA68 | MFM | ROB | $286.11 | $527.24 | $241.13 | $241.13 |
| HA68 | MFM | ROB | $298.27 | $549.64 | $251.37 | $251.37 |
| HA78 | MFM | ROB | $265.54 | $489.33 | $223.79 | $223.79 |
| HA78 | MFM | ROB | $319.77 | $589.27 | $543.88 | $543.88 |
| HA78 | MFM | ROB | $286.11 | $527.24 | $515.51 | $515.51 |

*All costs are noted as $ per furnace*

# Input Appendices

## A. DEER Base Case and Measure Case Information

DEER Base case and Measure case inputs are found in the accompanying calculation spreadsheet.

## B. Codes & Standards Requirements Base Case and Measure Information

***Title 20:*** This measure does fall under Title 20 of the California Energy Regulations. Under section 1605.1(B) on Table E-4, the minimum standard for gas furnaces with less than 225,000 Btu/h is 78% AFUE.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Title 20 Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Natural Gas Furnaces | Base | 78% | AFUE | Table E-4, Title 20, 2013 |

***Title 24:*** This measure does fall under Title 24 2013 of the California Energy Regulations. Under Title 24, table 4-1 provides the minimum standard for furnaces is 80% AFUE.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Title 24 Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Central Furnaces | Base | 80% | AFUE | Table 4-1, Title 24, 2013 (Residential Compliance Manual-Building HVAC Requirements) |

***Federal Standards:*** This measure do fall under Federal DOE (10 CFR Part 430)[[9]](#endnote-9) Energy Regulations. Under this regulation, compliance with the standards in the direct final rule will be required on May 1, 2013 for non-weatherized furnaces and on January 1, 2015 for weatherized furnaces and central air conditioners and heat pumps. Because most residential type furnaces are installed inside the house, it’s considered as non-weatherized for which the minimum AFUE is 80% for units less than 225,000 Btu/h in input capacity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Federal Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Central Furnaces | Non-Weatherized gas | 80% AFUE | Per System | CFR Part 430 |

## C. eQUEST Simulation Model for Furnace with Variable Speed Motor

Refer to the Residential HVAC Quality Maintenance (QM) workpaper, PGECOHVC139 R2, for more details on the eQUEST modeling for the VSM blower motor retrofit measure.

# References

1. Itron, Inc. “2014 Database for Energy Efficiency Resources”, Version 1.0.3, November 2013.

   <http://www.deeresources.com/> [↑](#endnote-ref-1)
2. eQUEST – Building Energy Use and Cost Analysis Software, developed by James J. Hirsch & Associates (JJH), version 3.64 was the latest release. <http://www.doe2.com/> [↑](#endnote-ref-2)
3. DEER 2011 Update Net-To-Gross Table, “DEER2011\_NTGR\_2012-05-16.xls”, May 23, 2012.

   <http://www.deeresources.com> [↑](#endnote-ref-3)
4. Department of Energy, “Energy Conservation Program: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps”, 10 CFR Part 430, Docket Number EERE-2011-BT-STD-0011, June 27, 2011. <http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cacfurn_dfr.pdf> [↑](#endnote-ref-4)
5. Pigg, Scott, Central Air Conditioning in Wisconsin: A Compilation of Recent Field Research, ECW Report Number 241-1, May 2008 amended December 15, 2010.

   <http://www.ecw.org/ecwresults/241-1.pdf> [↑](#endnote-ref-5)
6. 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. <http://www.energy.ca.gov/2012publications/CEC-500-2012-062/CEC-500-2012-062.pdf> [↑](#endnote-ref-6)
7. KEMA and JJ Hirsch and Associates, Itron Inc. “Final Report- Load Shape Update Initiative”. November 17, 2006. <http://www.nwcouncil.org/dropbox/6th%20Plan%20Industrial/Industrial%20Conservation%20Data%20Catalogue/ISC%20Document%20Catalogue_Public%20Version-5%20June%202009/Documents/Tier%202/SCE%20EE%20Work%20Papers%20November%202007%20Final/References/LSUI%20final%20report%2011-17-06%20Revision.pdf> [↑](#endnote-ref-7)
8. ControlsCentral.com for MARS- Motors & Armatures, Inc. on a ½ hp high efficiency BPM motor.

   <http://controlscentral.com/eCatalog.aspx?SearchID=5&SearchValue=azure&SearchPartNumber=Part+Number&SearchManufacturer=MARS+-+Motors+%26+Armatures%2c+Inc.&ViewType=2> [↑](#endnote-ref-8)
9. Department of Energy, “Energy Conservation Program: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps”, 10 CFR Part 430, Docket Number EERE-2011-BT-STD-0011, June 27, 2011. <http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cacfurn_dfr.pdf> [↑](#endnote-ref-9)