**Work Paper PGECOHVC146**

**95 AFUE Furnace - Nonres**

**Revision # 3**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**High Efficiency Gas Furnace 95% AFUE**

**(1.04 HIR) - Nonresidential**

**Measure Codes: SA16, SA17**

# At-a-Glance Summary

|  |  |  |
| --- | --- | --- |
| **Solution and Measure Codes:** | SA16 | SA17 |
| **Measure Description:** | Central natural gas furnace rated at 95% AFUE, with built-in variable speed motor (VSM) | Central natural gas furnace rated at 95% AFUE, without built-in variable speed motor (VSM) |
| **Base Case Description:** | Non-residential base case gas furnace meeting 2015 federal standard requirements of 81% AFUE for weatherized furnaces. | |
| **Units:** | Per furnace | |
| **Energy Savings:** | Refer to Excel Calculation Attachment | |
| **Gross Measure Cost ($/unit):** | Refer to Excel Calculation Attachment | |
| **Measure Incremental Cost ($/unit):** | Refer to Excel Calculation Attachment | |
| **Effective Useful Life:** | Source: DEER2014  20 Years | Source: DEER2014  20 years |
| **Measure Application Type:** | ROB and NC | |
| **Net-to-Gross Ratio:** | Source: DEER2011 NTGR values for ‘Default Commercial > 2 years’  NTG: 0.60 | |
| **Important Comments:** |  | |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision # | Revision Date | Author (Affiliation) | Summary of Changes |
| Revision 0 | 5/26/2012 | Matt Zwiesler (kW Engineering),  Judy Jennings (PG&E) | * Based new work paper on HVC124 94 AFUE Furnace * Revised calculations and costs from baseline 78 AFUE to 80 AFUE and proposed 94 AFUE to 95 AFUE using scaling factor * Revised assumption of average input capacity furnace size from 90,000 Btu/h (based on GAMA 2005 report) to 80,000 Btu/h (based on DOE 10 CFR Part 430 Report dated June 27, 2011iv) * Updated to DEER 2011 savings and cost values * Changed work paper name and measure code |
| Revision 0 | 8/29/2012 | Judith Jennings (PG&E) | * Added OTR description in AAG summary and section 2 fixed ROB, units, vintages, GRR, cover and footnote dates, reformatted AAG measure list, fixed misc. errors. Removed embedded files. Updated table of contents and list of figures. |
| Revision 1 | 5/27/2014 | Christopher Li (PG&E) | * Update impact savings based on new 2013 Title 24 CEC weather files. |
| Revision 2 | 12/08/14 | Christopher Li (PG&E) | * Update impact savings to reflect new federal code baseline equipment of 81% AFUE for weatherized furnaces. |
| Revision 3 | 1/1/2016 | Henry Liu  (PG&E) | * Updated ex-ante format. * Updated costs from WO017. |

# Section 1: General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper documents the rationale for the savings methodologies and assumptions for High Efficiency Non-Residential Central Natural Gas Furnaces, as listed in the Heating Ventilation and Air Conditioning (HVAC) Catalog. PG&E offers incentives to non-residential customers for installing qualifying high efficiency equipment. This measure is intended for the replacement of standard efficiency furnaces with high efficiency furnaces, with or without a Variable Speed Motor (VSM) with an Annual Fuel Utilization Efficiency (AFUE) rating of 95% or greater. Rebates under this measure code are also extended to high efficiency furnaces equipped with Variable Frequency Drives (VFDs).

Table 1: Measures and Codes

|  |  |  |
| --- | --- | --- |
| SCG Solution Code | PG&E Measure Code | Measure Name |
|  | SA16 | CENTRAL NATURAL GAS FURNACE - 95-96.9% AFUE WITH VSM |
|  | SA17 | CENTRAL NATURAL GAS FURNACE - 95-96.9% AFUE WITHOUT VSM |

* **Eligibility requirements**: This measure is applied to nonresidential buildings 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%.
* **Implementation requirements**:

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):

• Installation address must have both commercial natural gas and electric accounts with PG&E. <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.

• Only residential furnaces installed on a small commercial setting qualify for the rebate.

• 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.

* **Other program restrictions and guidelines: Must be a weatherized unit to qualify.**

## 1.2 Technical Description

**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.

**Furnace with Variable Speed Motor:**

Most existing small-scale residential and small commercial 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 Application Types and Delivery Mechanisms

The Delivery Mechanism of these measures is Down-Stream Incentive - Deemed. On the Down-Stream Incentive – Deemed, the rebate generally will go to the customers, however there are some cases where the customer will defer the rebate to the install contractors.

See Appendices A and B for definitions of application types and delivery mechanisms.

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Measure and Base Case Analysis

The data cited by DEER is not exactly applicable to the measures because the DEER data are scaled and converted to the appropriate savings per unit for incentive purposes. See the calculation section (2) for this conversion. DEER values are used for Net-to-Gross, EUL, and ISR.

Table 2: DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Referenced versions of DEER and READI | DEER2016, READi v.2.3.0 |
| Summary of deviation from DEER | Use Engineering Calculation to convert DEER unit of “per Area-1kFP” to a “per furnace/each” basis. |
| DEER measures scaled? | Yes, only for electrical energy savings |
| DEER eQUEST prototypes used? | No |
| DEER operating hours used? | No |

**Net-to-Gross Ratio**

The NTG value was obtained from READi v.2.3.0. The relevant NTGR for this measure is shown in Table 3 below.

Table 3: Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR ID | Description | Sector | BldgType | ProgDelivID | NTG |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | COM | COM | PreRebDown | 0.60 |

**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.

Table 4: Installation Rate

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

**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.

**Technology Fields**

The Technology Fields were obtained from the Ex Ante Database Specification. The relevant Use Category, Use Sub-category, Technology Group, and Technology Type values for the measures in this work paper are in the table below.

Table 5: Technology Fields

|  |  |
| --- | --- |
| Classification | Value |
| Measure Case UseCategory | HVAC |
| Measure Case UseSubCats | SpaceHeat |
| Measure Case TechGroups | SpaceHtg\_eq |
| Measure Case TechTypes | GasFurnace |
| Base Case TechGroups | SpaceHtg\_eq |
| Base Case TechTypes | GasFurnace |

**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.

Table 6: EUL and RUL

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| EUL ID | Description | Sector | UseCategory | EUL (Years) | RUL (Years) |
| HVAC-Frnc | High Efficiency Gas Furnace | Com | HVAC | 20 | 6.7 |

### 1.4.2 Codes and Standards Analysis

***Title 20:*** This measure does fall under Title 20 of the California Energy Regulations. Under section 1605.1 on Table E-6, 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 | 80% | AFUE | Table E-6, Title 20, 2014 |

***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)[A] 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 commercial type furnaces less than 225,000 Btu/h input capacity are installed outside of the commercial building, it’s considered as weatherized for which the minimum AFUE is 81%.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 |
| Central Furnaces | Weatherized gas | 81% AFUE | Per System | CFR Part 430 |

### 1.4.3 Non-DEER Study Review

No Non-DEER studies were references in the work paper.

# Section 2: Calculation Methodology

The DEER does not have this measure with variable speed motor (VSM). The electrical energy savings for this measure with VSM are extrapolated from the results of a study that analyzed the electrical energy savings associated with a Brushless Permanent Magnet (BPM) instead of the less energy efficient but more prevalent Permanent Split Capacitor (PSC) motor in residential buildings. In this study, DOE-2 computer simulation models were developed to simulate the electrical energy consumption of furnace blowers operating in a variety of climate zones throughout the country and under a range of three operating duct conditions.

PSC motors are less energy-efficient than BPM motors but the former technology is more prevalent in the standard or code-minimum efficiency furnaces. High efficiency furnaces, usually two‑stage furnaces, typically use BPM motors instead of PSC motors in non-condensing furnaces. This serves as the basis for establishing electrical energy savings for the high efficiency furnaces equipped with built-in VSM.

The calculations are as follows:

**Equation 1:**

*Energy Savings [kWh/unit] = Annual Base Electricity Usage – Annual Energy Efficient*

*Electricity Usage*

**Normalization by Residential Furnace Gas Energy Savings**

The electricity savings for this measure with VSM are normalized and scaled from the results of DOE-2 eQUEST simulation outputs from the residential quality maintenance (PGECOHVC139 R2) workpaper. The study presents the electrical energy savings in units of “kWh/yr per furnace” for furnace sizes in the range of 45-140 MBtuh – this range covers the 80 MBtuh furnace size assumption made for estimating gas energy savings and equipment costs in Sections 2.0 and 4.0, respectively.

The natural gas energy savings are calculated from DEER2016 and results for each building type, PG&E climate zones, and DEER weighted vintages are used. The DEER calculation methodology is based on residential natural gas energy savings for the “Single Family Home” building type, since it resembles the description of residential buildings constructed in the DOE-2 simulation models.

A sample normalization calculation to project furnace with VSM electrical energy savings, EESvsm, is shown below:



Where,

 = is the electrical energy savings estimated from using a BPM motor from DOE2 models from the residential quality maintenance workpaper, PGECOHVC139 R2)

 = is the gas energy savings from DEER2015 for nonresidential buildings.

 = is the gas energy savings from DEER2015 for residential homes.

As an example, the annual electrical energy savings for climate zone 03 in a small office (OFS) DEER building type can be calculated as follows:





Peak electrical demand reduction for this measure with VSM is estimated from the results of a single meta‑analysis study using DOE-2 modeling and empirical data collected from furnace blower tests at two local research centers: Lawrence Berkeley National Laboratory (LBNL) and PG&E test laboratory (San Ramon)[B]. In this study, furnace blowers driven by BPM and PSC motors were tested under a variety of operating conditions. The furnace sizes in this test ranges between 80-88 MBtuh and consequently, no scaling of results are needed. From this study, it is estimated that the peak electrical demand reduction from installing a high efficiency furnace equipped with a built-in VSM per furnace operating in a typical California duct is 50 watts.

**Equation 2:**

*The demand difference (watts per unit) is simply the difference between the electric demand of the base unit and the electric demand of the energy efficient unit.*

*∆Watts/unit = Base Watts/unit - Energy Efficient Unit Watts*

Demand Reduction:

*Demand Reduction [kW/Unit] = ∆Watts/unit*

*= 0.05kW/unit*

Gas savings for the high efficiency furnace 95 AFUE measure (Impact ID: Com-Furnace-dHIR) were downloaded from the DEER2016 READI tool (v2.3.0).

**Scaling of DEER Results**

The gas savings for this measure are calculated from the DEER2015 database impact ID, Furnace-Pkg\_AFUE95, as described below. DEER presents the savings in annual therms/1,000 square feet served which are converted to units of therms/furnace. The calculation is described below under Normalization.

**Normalization by MBtuh Furnace Input Rating**

DEER2015 gas energy savings are presented in units of annual MBtu/1,000 square feet served. To convert the DEER units of therms/1,000sqft to therm/furnace, the units are first converted to therms/MBtuh using the Connected Load (MBtuh/ft2) from California’s Commercial End-Use Survey (CEUS)[C]. The calculation is shown below:



Where,

 = is the savings number converted to units of therms per furnace capacity.

 = is the DEER2015 (Measure ID: Furnace-Pkg\_AFUE95) savings data.

 = is the “connected load” data obtained from the CEUS website, that is, the average furnace capacity installed per surface area. The CEUS website provides this data for different forecast climate zones and building types.

 = is a conversion factor from MBtu to Therms.

As an example, the annual gas energy savings for climate zone 03 in a small office (OFS) DEER building type can be calculated as follows:





Assuming a furnace input rating of 80 MBtuh,



In order to convert CEUS Energy-use Indices data from the climate zones (zones 1 through 5 for PG&E service territory) to the CEC Title 24 climate zones that is used in DEER, a mapping based on kWh consumption was developed. It was assumed that kWh consumption would be a reasonable proxy for square footage for a given building type and climate zone.

To convert therms/MBtuh to therms/furnace, we estimated an average furnace input capacity of 80 Mbtuh[D]. This is based on the DOE Rules and Regulations Report: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps, which contains the average characteristics of residential furnaces, including the average input capacity for residential gas furnaces based on product literature and furnace manufacturer website data. It is assumed that residential input capacity is a good estimate for this non‑residential measure because the furnaces are of similar size since the standard is in AFUE – efficiency measurement for smaller furnaces. The range of sizes available for the residential‑scale furnaces is 60-140 MBtuh. Non-residential furnaces can range from 45 to 400 MBtuh in size. However, furnaces sized greater than 225 MBtuh are rated by thermal efficiency, not AFUE and are not covered by this work paper. The largest furnace listed at 95% AFUE or greater on the AHRI.net website is 126 MBtuh input rating.

PG&E billing data, by account, were assigned to CEUS Forecast Climate Zones and Title 24 climate zones, using the service zip code of the account. Then the kWh usage was cross‑referenced by each climate zone for each key building type (Food, Hotel, Hospital, Large Office, Misc, Restaurant, Retail, School, Small Office, University, Warehouse – non‑refrigerated, and Warehouse – refrigerated) since CEUS and DEER building types are dissimilar.

A sample weather normalization calculation to convert CEUS to DEER climate zone is shown in the references section of this workpaper.

# 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.

Table 8: Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| Building Type | Load Shape | E3 Alt. Building Type |
| All Commercial | PGE:3 = Commercial HVAC | NON\_RES |

# 

# Section 4: Base Case & Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Install/Program Type** | **Gross Measure Cost**  **(First Baseline Period)** | **Gross Measure Cost**  **(Second Baseline Period)** | **Incremental Measure Cost** |
| ROB (Replace on Burnout and NC | (Measure Equipment Cost + Measure Labor Cost) –  (Base Case Equipment Cost + Base Case Labor Cost) | N/A | (Measure Equipment Cost + Measure Labor Cost) –  (Base Case Equipment Cost + Base Case Labor Cost) |

\*Note: For a more thorough discussion on the install/program type, see the install type document.

## 4.1 Base Case Cost

Residential cost data is assumed to be applicable to the cost of non-residential furnaces because of the similarity in size and type of equipment. The base equipment cost of 81% AFUE central natural gas furnace (weatherized) is not in DEER, an interpolation method was used to determine the base case cost using WO017 cost data for an 81% AFUE furnace. As a result the base case cost for an 81% AFUE furnace is $9.42/mBtuh. The interpolated values are then converted to the rebate unit of $/furnace or $/each using an assumed furnace input rating capacity of 80 mBtuh.

The Base Case Costs are:

|  |  |  |  |
| --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Baseline** | **Average Equipment Cost** |
| SA16, SA17 | ROB, NC | Federal code | $753.37 |

*All costs are noted as $ per measure unit*

## 4.2 Measure Case Cost

Residential cost data is assumed to be applicable to the cost of non-residential furnaces because of the similarity in size and type of equipment. The measure equipment cost of 95% AFUE central natural gas furnace (weatherized) is not in DEER, an interpolation method was used to determine the base case cost using WO017 cost data for a 81%, 90%, 91%, and 96% AFUE furnace. As a result the base case cost for a 95% AFUE furnace is $14.17/mBtuh. The interpolated values are then converted to the rebate unit of $/furnace or $/each using an assumed furnace input rating capacity of 80 mBtuh.

The Measure Case Costs are:

|  |  |  |  |
| --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Baseline** | **Average Equipment Cost** |
| SA17 | ROB, NC | Existing code | $1,133.30 |
| SA16 | ROB, NC | Existing code | $1,253.32 |

*All costs are noted as $ per measure unit*

## 4.3 Gross and Incremental Measure Cost

### 4.3.1 Incremental Measure Cost (IMC)

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 straight forward definition, depending on the install type the equation does vary. The incremental cost is only used to help determine program incentives. It is not affected by the first and second baseline periods and may differ from the cost used for cost effectiveness calculations.

For ROB and NC measures, there exists a theoretical base case that the measure can be compared to in cost. Because a base case exists for **NC, and ROB** IMC is represented by the equation below:

IMC = (Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: Unless stated otherwise the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

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

# Attachments

See accompanying file, PGECOHVC146 95 AFUE NONRES R3 9-11-2015.xlsx

# References



[A] 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>

[B] Residential Furnace Blower Performance, Walker, I.S., page 3, published by Lawrence Berkeley National Laboratory (LBNL), LBNL-61467, October 2006.

[C] California Commercial End-Use Survey (CEUS), published by the California Energy Commission (CEC), CEC-400-2006-005, accessed at <http://www.energy.ca.gov/ceus/index.html>, March 2006.

[D] Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps, Table IV.1, published by Department of Energy, EERE-2011-BT-STD, June 2011.

[E] Natural Gas Furnace Market Assessment, Habart, J., pp. i-ii, published by Energy Trust of Oregon, August 2005, page 22.

# Appendix A: Application Types

This table shows the application types in PG&E systems with those in DEER.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Application (Program) Type | DEER Application Type | Savings | | Cost | | Life | |
| **1st Baseline (BL)** | **2nd BL** | **1st BL** | **2nd BL** | **1st BL** | **2nd BL** |
| ROB, NC | N/A | Above Customer Existing | N/A | Full Cost | N/A | EUL | 0 |

# Appendix B: Delivery Mechanisms

A delivery mechanism is a delivery method paired with an incentive method. PG&E’s delivery methods include:

* Downstream Programs

The following table describes the incentive methods.

|  |  |
| --- | --- |
| Incentive Method | Description |
| Down-Stream Incentive - Deemed | 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. |