**Work Paper PGECOHVC139**

**Residential HVAC Quality Maintenance**

**Revision # 2**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Residential HVAC Quality Maintenance**

**Measure Codes: TK07, TK10, TK12, TK101, TK102, TK103**

# At-A-Glance Summary

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Applicable Measure Codes:** | TK07 | TK10 | TK12 | TK101 | TK102 | TK103 |
| **Measure Description:** | ANSI/ACCA Standard 4 System Assessment and Report | Blower Motor Retrofit | 1-Year QM Service Agreement | Single Measure Kicker | Comprehensive Kicker | Refrigeration System Assessment w/Savings |
| **Energy Impact Common Units:** | Per Installation | Savings/Ton | Per Installation | Per Installation | Per Installation | Savings/Ton |
| **Base case Description:** | Source: DEER2014 and Engineering calculations. Central Air Conditioner/heat pump system is not treated or maintained in a single family home or duplex structure. | | | | | |
| **Base case Energy Consumption:** | Source: Engineering calculations. Base case consumption is based on DOE2 eQUEST batch runs for single family homes with AC unit not treated. | | | | | |
| **Measure Energy Consumption:** | Source: DEER2014 and Engineering calculations. Measure consumption is based on DOE2 eQUEST batch runs for single family homes with AC unit been treated with QM measures. | | | | | |
| **Energy Savings (Base case – Measure)** | Source: DEER2014 and Engineering calculations.  Varies by climate zone | | | | | |
| **Costs Common Units:** | $ per Installation | $ per Ton | $ per Installation | $ per Installation | $ per Installation | $ per Ton |
| **Base case Equipment Cost ($/unit):** | Source: DEER2008.  $0/unit | | | | | |
| **Measure Equipment Cost ($/unit):** | Source: DEER2008.  Varies based on climate zone (which drives AC unit capacity or tonnage). | | | | | |
| **Measure Incremental Cost ($/unit):** | Source: DEER2008.  Varies based on climate zone (which drives AC unit capacity or tonnage). | | | | | |
| **Effective Useful Life (years):** | Source: DEER2014  5 years, based on May 16, 2013 ED disposition. | | | | | |
| **Program Type:** | Replace on Burnout (ROB) | | | | | |
| **Net-to-Gross Ratios:** | Source: DEER2011  0. 70, All-Default<=2yrs, “All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years.” | | | | | |
| **Important Comments:** | Expected value analysis approach was removed and individual measures were added in replacement. | | | | | |

## 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, Technical Product Support |
| **Carolyn Weiner**  Manager, HVAC and Motors Products |

# Document Revision History

**Revision # Date Description Author (Company)**

|  |  |  |  |
| --- | --- | --- | --- |
| Revision 0 | **03/12/2012** | **Residential HVAC Quality Maintenance – PGECOHVC139 R0** | **Christopher Li (PG&E), Marshall Hunt (PG&E) and Janice Peterson (PECI)** |
| **Revision 0** | **06/26/2012** | **Update NTG to reflect 2012 NTG ratio** | **Christopher Li (PG&E)** |
| **Revision 0** | **08/29/2012** | **Update At-A-Glance Table** | **Christopher Li (PG&E)** |
| **Revision 1** | **1/08/2014** | * **Removed Expected Values Analysis** * **Removed TK08 and TK09 measure codes** * **Add TK101, TK102, and TK103 measure codes** * **Add Multifamily (MFM) and Mobile Homes (DMO) building types for Blower Motor measure (TK10) using scaling method.** * **Update all NTG, ISR, EUL** | **Christopher Li (PG&E)** |
| **Revision 2** | **4/8/2014** | * **Update impact values to include new CEC title 24 weather files (CZ2010)** | **Christopher Li (PG&E)** |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description***

The Residential HVAC Quality Maintenance (QM) Program for residential dwellings is a customer based program delivered through PG&E’s QM Implementer.M  The PG&E QM and 3P Implementers contract specifies the program performance criteria, marketing tasks, rules for recruiting contractors, and required training of licensed HVAC contractors and their technicians to offer comprehensive quality maintenance service to the customers. The service scope is defined on ACCA 4B,[[1]](#endnote-2) Quality Maintenance Standard. The qualified HVACH technician performs work on the refrigeration system assessment service and blower motor retrofit. The QM program also offers an incentive for the resident and/or homeowner to purchase an optional “one-year service agreement” with the qualified HVAC contractor. In addition, the QM program offers two bonus incentive options for the resident and/or homeowners, Single Measure (TK101) or Comprehensive Measure (TK102) Kicker for completing measures such as Blower Motor Retrofit (TK10) and/or Refrigerant Charge Correction (TK103).

***Program Restrictions and Guidelines***

***Terms and Conditions:***

Measures/treatments are applied to a residential single family or duplex structure located in PG&E’s climate zones 2, 4, 11, 12, 13, and 16 and cooled using a central air conditioner or heat pump meeting in accordance with ANSI/AHRI Standard 210/240-2008.A This standard covers both split (condenser outside and evaporator inside) and packaged (condenser and evaporator in the same exterior mounted package) air conditioners and heat pumps.

The blower motor retrofit measure is offered to residential homes, including single family, multifamily, and mobile homes located in PG&E’s nine (9) climate zones 1, 2, 3, 4, 5, 11, 12, 13, and 16.

Customer must be an electric customer at Pacific Gas and Electric Company (PG&E)L to the installation service address.

The rebate is downstream provided to the customer at the time of installation upon receipt of installation. This is a direct install program.

## 1.2 Product Technical Description

This work paper covers Residential HVAC Quality Maintenance (QM) program, and Brushless Permanent Magnet (BPM) Blower Motor retrofit. The QM measure contains multiple treatments, whereas the Motor retrofit applies to the replacements of blower fan motor.

In response to the long standing problem of there not being a clear definition of what maintenance activities should be done to maintain residential HVAC equipment, the industry developed ANSI/ACCA Standard 4B - Maintenance of Residential HVAC Systems. This standard applies to HVAC contractors and technicians to determine what is required to properly maintain residential HVAC systems.

The Residential HVAC QM program provides criteria that must be met to receive incentives for treatments that save energy by restoring the system to a higher level of efficiency and performance. After the service system performance can be sustained with the execution of an ACCA Standard 4 compliant service agreement.

Deemed energy savings from the implementation of QM maintenance measures were generated from using the DEER2014 READi tool. Energy savings for the blower motor retrofit were estimated separately using eQUEST simulation models and engineering calculations. In some cases, quantities of measures have negative therm impacts due the reduction of blower motor heat being introduced to the supply air stream.

The components of the QM measures are composed of six measures/treatments, which are listed in Table 1. Measure code TK07 is a market transformation measure known as “System Inventory & Assessment” and implements the requirements of ACCA Standard 4 with the treatment being the technician’s inventory and assessment work. TK12 are also market transformation measure that supports the purchase of an ACCA Standard 4 complying service agreement. TK101 and TK102 are bonus incentive measures known as “Single Measure Kicker and Comprehensive Kicker”, these measures are also part of market transformation, which provides the homeowner an incentive to perform treatments TK10 and/or TK103.

Measure TK10 is a single treatment and is the retrofit of a high efficiency blower motor and is discussed in Section 2 below. TK103 refers to refrigerant charge correction, where it improves the systems performance when system is correctly charged to manufacturer’s recommendation. When measurement uncertainty is considered there is a ±10% of correct refrigerant charge range where savings from charge correction is uncertain. Many if not a majority of systems will fall within this the range so no charge corrections will be needed.

Table 1: Estimation Methods for QM Measure Treatments

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Code** | **Treatment Number** | **Treatment** | **Estimation Method** |
| TK07 | 1 | System Inventory & Assessment | Market Transformation – No Savings |
| TK10 | 2 | Permanent Magnet Blower Motor Retrofit | CFM/watts blower efficiency |
| TK12 | 3 | One-year Service Agreement | Market Transformation – No Savings |
| TK101 | 4 | Single Measure Kicker | Market Transformation – No Savings |
| TK102 | 5 | Comprehensive Kicker | Market Transformation – No Savings |
| TK103 | 6 | Refrigerant Charge Correction | System EER Improvement |

## 1.3 Measure Application Types

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 cases for ROB are pre-existing condition of customer’s existing residential HVAC unit.

Measure Transaction 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 data cited in this work paper include: peak demand reduction, electric savings, interactive gas savings, equipment unit costs, equipment incremental costs, equipment useful life, Net-to-Gross and measure load shapes.

DEER use and Technology type for refrigerant charge correction measure:

|  |  |  |  |
| --- | --- | --- | --- |
| ***DEER USE and TECHNOLOGY TABLE*** | | | |
| **Use Category Description** | **Use Category** | **Use Sub Category Description** | **Use Sub Category** |
| HVAC | HVAC | Space Cooling | HVAC-SpCl |
| **Technology Groups Description** | **Technology Groups** | **Technology Types Descriptions** | **Technology Types** |
| dX AC Equipment | dxAC\_equip | Split or Packaged DX AC Refrigerant System | refrig |

DEER use and Technology type for blower fan motor retrofit measure:

|  |  |  |  |
| --- | --- | --- | --- |
|  | ***DEER USE and TECHNOLOGY TABLE*** | |  |
| **Use Category Description** | **Use Category** | **Use Sub Category Description** | **Use Sub Category** |
| HVAC | HVAC | Space Heating and Cooling | HVAC-HtCl |
| **Technology Groups Description** | **Technology Groups** | **Technology Types Descriptions** | **Technology Types** |
| HVAC Air Distribution | HV\_AirDist | HVAC Ventilation Fan - General Purpose Motor | VentFanMtr |

**Delta Wattage Assumption (ΔW):**

Electric kW savings were downloaded from DEER2014 READI tool (v1.0.5) for the refrigerant charge assessment measure, whereas the electric kW savings for the blower motor retrofit was determined from using the eQUEST modeling tool.

Example of kW Savings for Blower Motor Retrofit in single family homes

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings kW** | **Deer units** | **DEER Version** | **Impact IDs** | **Measure Code** |
| SFM | EX | Z01 | 0.0105 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z02 | 0.0933 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z03 | 0.0418 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z04 | 0.0835 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z05 | 0.0337 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z11 | 0.1233 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z12 | 0.0967 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z13 | 0.1063 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z16 | 0.0515 | CAP-TONS | NA | NA | TK10 |

Refer to attached calculation spreadsheet for complete table.

**Annual kWh Savings Assumption (∆ kWh)**

Annual kWh savings were downloaded from DEER2014 READI tool (v1.0.5) for the refrigerant charge assessment measure, whereas the electric kW savings for the blower motor retrofit was determined from running the eQUEST modeling tool.

Example of kWh Savings for Blower Motor Retrofit in single family homes

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings kWh** | **DEER units** | **DEER Version** | **Impact IDs** | **Measure Code** |
| SFM | EX | Z01 | 150.78 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z02 | 86.72 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z03 | 100.39 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z04 | 106.49 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z05 | 92.71 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z11 | 154.08 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z12 | 106.36 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z13 | 161.33 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z16 | 122.35 | CAP-TONS | NA | NA | TK10 |

Refer to attached calculation spreadsheet for complete table.

**Therm Savings Assumption (ΔTh):**

Therm savings were downloaded from DEER2014 READI tool (v1.0.5) for the refrigerant charge assessment measure, whereas the electric kW savings for the blower motor retrofit was determined from running the eQUEST modeling tool.

Example of Therm Savings for Blower Motor Retrofit in single family homes

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Interactive Only?**  **Yes / No** | **Gas Savings Therms** | **DEER units** | **DEER Version** | **Impact IDs** | **Measure Code** |
| SFM | EX | Z01 | Yes | -6.86 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z02 | Yes | -2.32 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z03 | Yes | -4.37 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z04 | Yes | -2.61 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z05 | Yes | -4.03 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z11 | Yes | -1.80 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z12 | Yes | -1.90 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z13 | Yes | -1.65 | CAP-TONS | NA | NA | TK10 |
| SFM | EX | Z16 | Yes | -5.14 | CAP-TONS | NA | NA | TK10 |

Refer to attached calculation spreadsheet for complete table.

**Remaining Useful Life (RUL):**

RUL Savings do not apply to this measure as the application type is ROB, no early retirement.

**Hours of Operation**:

The hours of operation are not applicable for this type of measure. The saving values and DEER single family prototype were downloaded from DEER and the DEER MASControl (v3.00.19)[[2]](#endnote-3) directly. All measures listed on this work paper have a wide range of equivalent full load hours (EFLH) where it varies depending on PG&E’s climate zones, building types, and building vintages. Since DEER data was used for the calculation of energy impacts, the hours of operation are embedded in those values. DEER simulations calculate the values based on the use of building vintages for each climate zone that are then weighted by the climate zone specific distribution of the vintages to get values for Existing (Ex).

**Base Case Costs and Measure Case Costs:**

The Base Case, Measure Case, and Incremental Costs were downloaded from DEER directly; matching the intended measures for climate zones and building types and vintages.

Example of Costs for Blower Motor Retrofit in single family homes

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | **Costs ($)/ton of total cooling capacity** | | |  | | |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Base Case** | **Measure Case** | **IMC** | **DEER Version** | **Impact IDs** | **Measure Code** |
| SFM | EX | Z01 | SFM | $93.36 | $238.00 | $128.81 | Engineering Estimate | TK10 |
| SFM | EX | Z02 | SFM | $59.32 | $357.00 | $81.84 | Engineering Estimate | TK10 |
| SFM | EX | Z03 | SFM | $67.51 | $476.00 | $93.14 | Engineering Estimate | TK10 |
| SFM | EX | Z04 | SFM | $72.53 | $596.00 | $100.07 | Engineering Estimate | TK10 |
| SFM | EX | Z05 | SFM | $64.06 | $908.00 | $88.38 | Engineering Estimate | TK10 |
| SFM | EX | Z11 | SFM | $56.75 | $274.00 | $78.30 | Engineering Estimate | TK10 |
| SFM | EX | Z12 | SFM | $59.87 | $411.00 | $82.60 | Engineering Estimate | TK10 |
| SFM | EX | Z13 | SFM | $59.74 | $548.00 | $82.43 | Engineering Estimate | TK10 |
| SFM | EX | Z16 | SFM | $60.33 | $685.00 | $83.23 | Engineering Estimate | TK10 |

Refer to attached calculation spreadsheet for complete table.

**Net-to-Gross Assumption:**

The NTG ratio was based on DEER 2011[[3]](#endnote-4). The value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls” spreadsheet under the “DEER2011 NTGr Values” tab on the [www.deeresources.com](http://www.deeresources.com) website. 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: Net-to-Gross Ratios

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | | **DEER Spreadsheet** | |
| Measure | Program Approach | NTG | File name | Cell Number |
| Refrigerant Charge Correction | Res-sAll-mHVAC-RCA | 0.78 | DEER2011\_NTGR\_2012-05-16.xls | T28 |
| Blower Motor Retrofit | All-Default<=2yrs | 0.70 | DEER2011\_NTGR\_2012-05-16.xls | T66 |

**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[[4]](#endnote-5) EUL table update, “DEER2014-EUL-table-update\_2014-02-05.xlsx” spreadsheet, under the “Updated 2014 EUL table” tab. This is a ROB program so RUL is not used but only reported here for completeness.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **EUL (yrs)** | **RUL (yrs)** | **DEER Version** | **Impact IDs** |
| RES | Ex | PGE | 10 | 3.3 | DEER2014 | RB-HV-SFRefChrg-Inc-typ-24pct-12pct |
| RES | Ex | PGE | 5 | 1.66 | ED Disposition | Blower Motor Retrofit |

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

An in-service rate (ISR) of 0.57 will be used for the refrigerant charge correction measure and 1.0 for the blower motor retrofit measure. The ISR used in this workpaper is based on the May 16, 2013 ED disposition of the residential quality maintenance workpaper.

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.

**In service rate:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **In service rate** | **DEER Version** | **Impact IDs** |
| RES | Ex | PGE | 0.57 | ED Disposition | RB-HV-SFRefChrg-Inc-typ-24pct-12pct |
| RES | Ex | PGE | 1.0 | ED Disposition | Blower Motor Retrofit |

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

**Title 20[[5]](#endnote-6):**

These measures are not governed by either state or federal codes and standards.

**Title 24[[6]](#endnote-7):**

These measures are not governed by either state or federal codes and standards.

Title 24 does not deal with “quality maintenance” issues. This program requires the HVAC contractor to be licensed by the California State Licensing Board (CSLB) and the HVAC technicians to be EPA certified. Under state code, performance of maintenance and repairs does not require the homeowner to obtain a building permit.

In regards to the blower motor retrofit measure, the mechanical code states that the replacement of any component part or assembly of an appliance that does not alter its original approval and complies with other applicable requirements of the mechanical code is exempt from the requirement to obtain a mechanical permit. In the event that a replacement motor requires a different voltage or number of phases than the original motor, the installation is to include disconnects not present on the original equipment, or the installation will alter the electrical system in any other way an electrical permit must be obtained pursuant to Title 24, Part 3 California Electrical Code.

***Federal Standards:***

These measures are not governed by either state or federal codes and standards.

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

Several studies have been performed concerning the energy savings potential through RCA correction. The key reports are summarized in this section.

**1.4.3.1 Robert Mowris & Associates 2004 Study[[7]](#endnote-8)**

“Field Measurements of Air Conditioners with and without TXVs”, 2004 ACEEE Summer Study Proceedings, Robert Mowris and Associates, Anne Blankenship, and Ean Jones, 2004.

This study summarizes the field measurements of 4,168 air conditioners units with and without thermostatic expansion valves (TXVs). The report does not specify whether these are residential or commercial units, but the sizes studied were between three (3) and five (5) tons which is common for residences. Based on the results, approximately 72% of the units had improper refrigerant charge and 44% had improper airflow. The study also found that the EER measurement of air conditioners with improper refrigerant charge and airflow has a unit efficiency gain of 21% ±7% for units with TXV and an increase of 17.1% ±2.8% for units without TXV. Additionally, out of all the sampling, it was found approximately 25% of the units had TXVs, while 75% did not. Based on the results from the field data, the overall weighted average of savings for refrigerant charge and airflow correction is 18% (17.1×0.75 + 21×0.25 = 18%). The average energy savings for correcting the refrigerant charge and airflow in the units are 12.6% ±2.3%, this percentage was calculated by multiplying the overall weighted average of 18% by the numbers of units with improper refrigerant charge of 72%.

The direct airflow measurements were also quantified, but the actual corrected airflow measurement was taken by using the temperature split method. The results from the pre-retrofit airflow measurement were found to be 279 ± 10 cfm/ton for units without TXV and 308 ± 17 cfm/ton for units with TXV. The average airflow improvement was calculated to be 9.8% ± 2.5%.

The dataset of field measurements from this study were taken to derive the Refrigeration Impact Factor (RIF) as stated on Appendix B below.

**1.4.3.2 PG&E 2001 Study[[8]](#endnote-9)**

“Influence of the Expansion Device on the Performance of a Residential Split-System Air Conditioner”, Robert Davis, PG&E Performance Testing and Analysis Unit Technical and Ecological Services, January 2001.

A series of tests were conducted on a residential split-system air conditioner to determine the differences in the performance due to the type of expansion device used. The study examined both direct expansion and TXV units installed in the same system over various system conditions. The tests simulated different outside air conditions, inside air conditions and refrigerant charge levels. The tests concluded that at 20% overcharge with an outside air temperature of 95ºF, the EER for both types of systems was reduced by 5%. At 30% undercharge, the EER was reduced by 7% for the TXV and 28% for the fixed orifice system. Another thing to note is based on the data provided, system EER increases by approximately 1% for every 1ºF decrease in outside air temperature. Figure 2 below gives a graphical summary of the test results.6

Figure 1: Normalized EER vs. Charge and Outside Temperature



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

There are no further data or calculations provided for the support of the measures in this work paper. The savings were downloaded from DEER2014 directly.

### 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 these measures is 0%.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure** | **kWAC** | **kWTotal** | **%** |
| HVAC Quality Maintenance | Varies | Varies | 0 |
| Blower Motor Retrofit | Varies | Varies | 0 |

## 1.5 Base cases for Savings Estimates: Existing & Above Code

The following sections provide the inputs for calculation:

|  |  |  |  |
| --- | --- | --- | --- |
| **Input Variable** | **Variations** | **Measure Case Average Value** | **Reference Section** |
| Electric Savings | Climate Zone (CZ), Building Type (BT) | 0.06 kW/ton  114.70 kWh/ton | Section 2.1  Section 2.2 |
| Gas Savings | CZ, BT | -2.28 therms/ton | Section 2.3 |
| Hours of operation | CZ, BT | DEER hours | Section 1.4 |
| Full Cost | Replace On Burnout (ROB) | $102.47 | Section 4.0 |
| Incremental Cost | ROB | $102.47 | Section 4.0 |
| Effective Useful Life (EUL) /Remaining Useful Life (RUL) | ROB | 10 yrs for RCA  5 yrs blower motor | Section 1.4 |
| Net to Gross (NTG) | None | 0.78 for RCA  0.70 for blower motor | Section 1.4 |
| In Service Rate (ISR) | Applies -- Yes | 0.57 for RCA  1.0 for blower motor | Section 1.4 |
| Time of Use (TOU) Factor | A/C projects only | 0% | Section 1.4 |

Note: Values shown on this table are simple averages for the typical refrigerant charge (<20% rated charge) and blower motor retrofit measures in PG&E climate zones for single family, multifamily, and mobile homes.

# 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 measure, First Baseline is the baseline for the full EUL. There is no second baseline.

## 2.1 Electric Energy Savings Estimation Methodologies

Energy savings for the refrigerant charge correction (Impact ID: RE-HV-RefChrg-Inc-typ) measure were downloaded from the DEER2014 READI tool (v1.0.5) directly. This measure includes HVAC interactive effects impacts.

Specified values for the refrigerant charge correction measure vary by building types, building vintages, and climate zones. For this work paper, a building type of residential single family, multifamily, and mobile homes was chosen, along with using “existing (weighted DEER vintages)” building vintage and all 16 California Climate Zones.

The blower motor retrofit measure is not included in the DEER2014 database. The approach taken to estimate the blower motor energy savings is to use the DOE2 eQUEST[[9]](#endnote-10) simulation model. The base case uses a new model simulating the replacement of the old blower (a permanent split capacitor) motor with an energy-efficient brushless permanent magnet (BPM) motor. This measure is a direct replacement which provides the technician with variable speed selection using spade connectors on the existing control board. This measure will be installed in existing air handlers and/or furnaces. The process on calculating the savings for this measure is shown on Appendix B.

The energy savings for the blower motor replacement is the differences between the baseline energy use and the measure energy use. Table 3 shows the kW, kWh, and therm savings per tonnage for blower motor replacement.

Table 3 : Replacement Blower Motor – Annual Savings for Single Family

|  |  |  |  |
| --- | --- | --- | --- |
| **Energy Savings from Blower Motor Replacement  (Fan System Efficiency 17% to 32%)** | | | |
|  | Annual Savings per Ton | | |
| Total Static 1" WC | Total Annual Energy Use | | |
|  | Demand | Energy | Gas |
| **Climate Zone** | **(kW/ton)** | **(kWh/ton)** | **(therms/ton)** |
| CZ-1 Arcata | 0.0105 | 150.78 | -6.86 |
| CZ-2 Santa Rosa | 0.0933 | 86.72 | -2.32 |
| CZ-3 Oakland | 0.0418 | 100.39 | -4.37 |
| CZ-4 San Jose | 0.0835 | 106.49 | -2.61 |
| CZ-5 Santa Maria | 0.0337 | 92.71 | -4.03 |
| CZ-11 Red Bluff | 0.1233 | 154.08 | -1.80 |
| CZ-12 Sacramento | 0.0967 | 106.36 | -1.90 |
| CZ-13 Fresno | 0.1063 | 161.33 | -1.65 |
| CZ-16 Blue Canyon | 0.0515 | 122.35 | -5.14 |

See accompanying calculation spreadsheet for complete list of measure savings values.

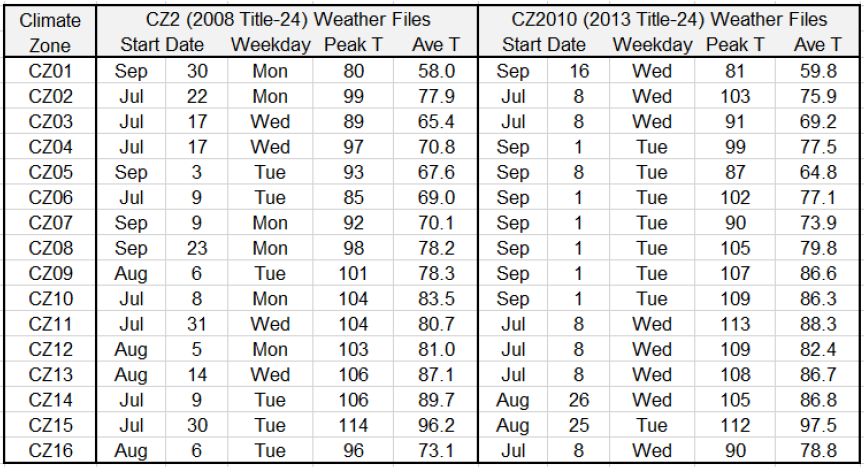
## 2.2 Demand Reduction Estimation Methodologies

Demand savings for the refrigerant charge correction (Impact ID: RE-HV-RefChrg-Inc-typ) measure were downloaded from the DEER2014 READI tool (v1.0.5) directly. This measure includes HVAC interactive effects impacts.

Specified values for the refrigerant charge correction measure vary by building types, building vintages, and climate zones. For this work paper, a building type of residential single family, multifamily, and mobile homes was chosen, along with using “existing (weighted DEER vintages)” building vintage and all 16 California Climate Zones.

The blower motor retrofit measure is not included in the DEER2014[[10]](#endnote-11) database. The approach taken to estimate the blower motor peak kW demand savings is to use the DOE2 eQUEST simulation model. The base case uses a new model simulating the replacement of the old blower (a permanent split capacitor (PSC)) motor with an energy-efficient brushless permanent magnet (BPM) motor. This measure is a direct replacement which provides the technician with variable speed selection using spade connectors on the existing control board. This measure will be installed in existing air handlers and/or furnaces. The process on calculating the demand savings for this measure is shown on Appendix B.

To determine the electric demand impacts, the “hourly results” from the perform simulation output was used. The “hourly results” output spreadsheet provides hourly energy usage thoughout the year for the modeled equipment. Two separate runs (base case and measure case) will be needed to determine the energy savings, which is the delta difference energy usage. To define the peak demand, our analysis uses the average kW reduction over a nine-hour window from 2-5pm over a three-day heat wave for each climate zone. The peak periods for use were determined based on the new CEC weather file data (CZ2010)[[11]](#endnote-12) and are shown below with previous peak demand period definitions.



The electric demand reductions per home were determined for both the one- and two- story homes in each climate zone and were then normalized to the cooling capacity in tons of the weighted average one- and two- story homes for each climate zone. The one- and two- story demand reductions were then weighted by the percentages of homes in the climate zone to obtain a single deemed demand reduction value for each climate zone and measure in units of kW/ton.

See accompanying calculation spreadsheet for complete details on the savings value, calculation and methodology.

## 2.3 Gas Energy Savings Estimation Methodologies

See section 2.1 for refrigerant charge correction and motor retrofit energy savings and the methodology.

# Section 3. Load Shapes

## 3.1 Base Case Load Shapes

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the DEER: 26 = Res. Central Air Conditioning load shape. See the KEMA report[[12]](#endnote-13) for a more thorough discussion regarding the load shapes for this measure.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **E3 Alt. Building Type** | **Load Shape** |
| Residential | RES | 26 = Res. Central Air Conditioning |

## 3.2 Measure Load Shapes

The measure load shape is the same as the base case load shape, DEER: 26 = Res. Central Air Conditioning.

# 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 measure, First Baseline is the baseline for the full EUL. There is no second baseline.

## 4.1 Base Case(s) Costs

These are service type measures. There are no base case costs.

## 4.2 Measure Case Costs

The following Transaction types are appropriate to these measures. The Base Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Measure Code*** | **Transaction** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Measure**  **Case Cost** |
| TK103 | ROB | Existing | $11.55 | $36.82 | $0.00 | $48.37 |
| TK10 | ROB | Existing | $198.88 | $75.50 | $0.00 | $274.38 |

All cost are noted as $ per measure unit, for TK103 (refrigerant charge correction), this unit is per ton. TK10 (Blower motor retrofit), the unit is per ton however costs values is based on a per motor ($198.88) and labor ($75.50) costs of $274.35.

The measure case costs for refrigerant charge correction were determined from DEER2008[[13]](#endnote-14) and for the blower motor retrofit, the material cost of a ½ horsepower motor was set at $198.88/motor from the MARS- Motors & Armatures, Inc.[[14]](#endnote-15) distributor data sheet and the labor cost of $75.50/hr for installation was derived from the RS Means.

## 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 install type.

This measure transaction type is: ROB, so the Gross Measure Cost (GMC) is represented by the equation below:

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

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

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.

### 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 straight forward definition depending on the install type, the equation does vary.

This measure transaction type is: ROBso the Incremental Measure Cost (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

\*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.

Table 4 : Summary Base Case and Measure Case Cost

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure ID** | **Transaction Type** | **Base Case Total Cost** | **Measure Case Total Cost** | **Gross Measure Case Cost** | **Incremental Measure Cost** |
| TK103 | ROB | $0.00 | $11.55 | $48.37 | $48.37 |
| TK10 | ROB | $0.00 | $198.88 | $274.38 | $274.38 |

All cost are noted as $ per measure unit, for TK103 (refrigerant charge correction), this unit is per ton. TK10 (Blower motor retrofit), the unit is per ton however costs values is based on a per motor ($198.88) and labor ($75.50) costs of $274.38.

# Input Appendices

# Appendix A – eQUEST Simulation Information

**DOE2 eQUEST Energy Simulation Process**

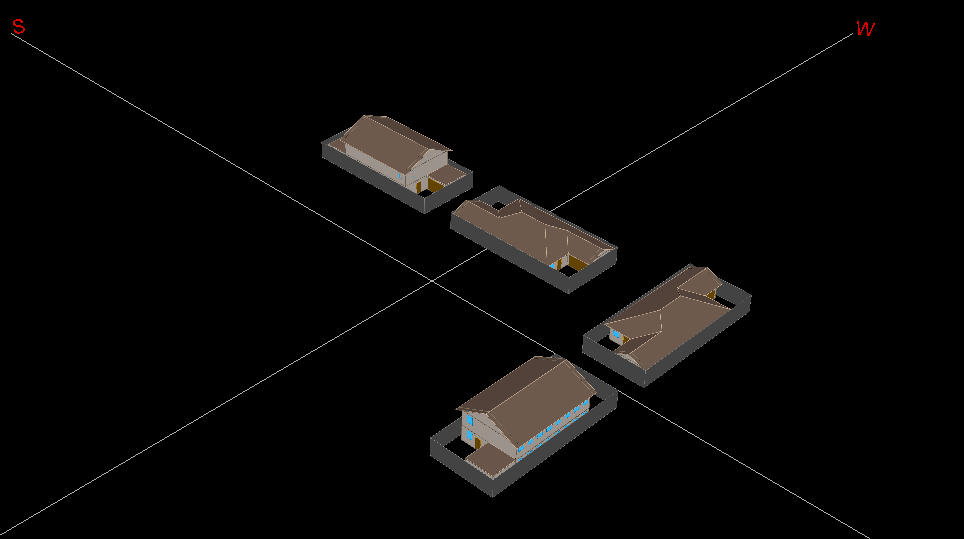
eQUEST is a DOE2 based simulation software package used to produce estimates of energy use of prototype residential building models. DEER single family prototypes were used as the basis for all eQUEST simulations. The single family prototype[[15]](#endnote-16) consists of two (2) one-story houses and two (2) two-story houses. One house in each pair is rotated 90 degrees to capture the effect of orientation as shown in Figure 2. The DEER database has separate prototypes for each of 6 vintages in each of the sixteen California climate zones. Each vintage has different values for building and system component properties based either on the current code or typical values. Prototypes were developed for representative vintages to approximate the range of housing stock in PG&E territory. Prototypes were pulled from DEER and then run through eQUEST with CZ2010 weather files. See Table 5 below for details.

Table 5 : CZ2010 Weather City by PG&E Climate Zone and HDD

|  |  |  |
| --- | --- | --- |
| **California Climate Zone Number** | **CZ2010 Weather**  **City Name** | **CZ2010 Heating Degree Days (HDD)** |
| CZ-1 | Arcata Airport | 5,094 |
| CZ-2 | Santa Rosa | 3,835 |
| CZ-3 | Oakland Metropolitan Airport | 3,257 |
| CZ-4 | San Jose International Airport | 3,050 |
| CZ-5 | Santa Maria Public Airport | 3,715 |
| CZ-11 | Red Bluff Municipal Airport | 3,027 |
| CZ-12 | Sacramento Metropolitan | 3,122 |
| CZ-13 | Fresno Yosemite Intl Airport | 3,322 |
| CZ-16 | Blue Canyon | 5,578 |

To approximate shading on the houses, the DEER prototypes include a surface exterior to the houses, similar to a fence. This surface is about 50% reflective and has a schedule for solar transmittance to simulate the variation in shading over the seasons.

Figure 2 : DEER Single Family Prototype



# Appendix B – Blower Motor Retrofit Calculation Information

**Motor Retrofit Electric Energy Savings**

The approach taken to estimate the energy savings for replacing a blower (supply fan) motor in residential air conditioner with gas furnace is shown below. The eQUEST simulation model created for the blower motor analysis was used for estimating the savings.

**Blower Motor Savings Calculation Methodology**

The following are the steps taken to calculate the savings for blower motor replacement. Each of these steps is explained in detail below.

1. Derive the typical factors afterthe QM measures are applied.
2. Convert these factors to eQUEST keyword inputs to simulate a one- and two- story prototype house in each climate zone that has had the QM measure applied.
3. Use the eQUEST simulation model with the QM measures applied as the base case and creates a new model simulating the replacement of the old blower motor (most likely a permanent split capacitor) with an energy-efficient brushless permanent magnet motor.

**Step 1: Derive the Quality Maintenance (QM) Factors**

Table 6 shows the values of the factors for each zone which represent the QM measure.

Table 6 : Factors after QM Treatment

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **One-Story** | | | | | | | | | |
| **Factors After QM Treatment** | **CZ\_01** | **CZ\_02** | **CZ\_3** | **CZ\_04** | **CZ\_05** | **CZ\_11** | **CZ\_12** | **CZ\_13** | **CZ\_16** |
| C\_ShellUA | 561.86 | 585.15 | 617.08 | 645.28 | 645.28 | 590 | 638.87 | 515.89 | 529.07 |
| C\_Tstat Offset | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 |
| C\_DuctUA | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 |
| C\_DuctLeak | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 |
| C\_AFUE | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 |
| C\_RIF | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| C\_Nom\_SEER | 10.011 | 10.085 | 10.081 | 10.112 | 10.148 | 10.238 | 10.223 | 10.234 | 10.129 |
| **Two-Story** | | | | | | | | | |
| **Factors After QM Treatment** | **CZ\_01** | **CZ\_02** | **CZ\_3** | **CZ\_04** | **CZ\_05** | **CZ\_11** | **CZ\_12** | **CZ\_13** | **CZ\_16** |
| C\_ShellUA | 719.59 | 757.92 | 827.04 | 811.46 | 811.46 | 765.72 | 785.21 | 704.0 | 726.08 |
| C\_Tstat Offset | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 | -2.2 |
| C\_DuctUA | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 | 236.4 |
| C\_DuctLeak | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 | 0.139 |
| C\_AFUE | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 | 0.798 |
| C\_RIF | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| C\_Nom\_SEER | 10.011 | 10.085 | 10.081 | 10.112 | 10.148 | 10.238 | 10.223 | 10.234 | 10.129 |

**Step 2: Translate the Factors into eQUEST Model Inputs**

**Factor 1: C\_Shell UA**

The QM shell UA is matched to a prototype shell UA as closely as possible. This prototype is then modified with the remaining factors in Table 7. As shown in Table 7 exact matches are not available but all are within 3% of the QM value. The Vintage and Climate Zone rows give the DEER prototype references.

Table 7 : Factor Shell UA

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **One-Story** | | | | | | | | | |
|  | CZ\_01 | CZ\_02 | CZ\_03 | CZ\_04 | CZ\_05 | CZ\_11 | CZ\_12 | CZ\_13 | CZ\_16 |
| Nearest Prototype UA to C\_ShellUA | 563 | 599 | 619 | 647 | 647 | 599 | 647 | 507 | 529 |
| Vintage and CZ | V85 CZ01 | V96 CZ08 | V85 CZ15 | V85 CZ13 | V85 CZ14 | V85 CZ15 | V85 CZ15 | V7 CZ10 | V96 CZ06 |
| Shell UA % Dif from C\_ShellUA | 0.24% | 2.43% | 0.28% | 0.30% | 0.30% | 1.58% | 1.31% | 1.69% | 0.05% |
| **Two-Story** | | | | | | | | | |
|  | CZ\_01 | CZ\_02 | CZ\_03 | CZ\_04 | CZ\_05 | CZ\_11 | CZ\_12 | CZ\_13 | CZ\_16 |
| Nearest Prototype UA to C\_ShellUA | 707 | 751 | 821 | 821 | 821 | 777 | 786 | 707 | 734 |
| Vintage and CZ | V7 CZ03 | V7 CZ08 | V85 CZ15 | V3 CZ09 | V3 CZ10 | V96 CZ09 | V3 CZ10 | V7  CZ03 | V3 CZ09 |
| Shell UA % Dif from C\_ShellUA | 1.70% | 0.87% | 0.77% | 1.14% | 1.14% | 1.53% | 0.10% | 0.22% | 1.04% |

Once a prototype with the matching shell-UA was selected, an eQUEST simulation run was made for the applicable climate zone to calculate the correct heating and cooling system capacity. For example for CZ13 the QM treatment for two-story home has a shell-UA of 707. The best match prototype was defined by DEER for CZ3, Oakland, has a shell-UA of 707. Fresno has a much hotter climate than Oakland; therefore the HVAC system size needs to be adjusted. Table 8 below shows the DEER HVAC sizes by climate zone indicating that CZ13 needs a system that is 1.41 times larger than CZ03. So the air flow, the total cooling capacity, the sensible cooling capacity and the heating capacity is multiplied by 1.41.

Table 8 : DEER HVAC system size comparison

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Weather Adjusted** | **Flow** | **Total Cap** | **SF Cap** | **Heating** |
| CZ-03 | 804 | 24,386 | 18,072 | (37,986) |
| CZ-13 | 1,137 | 34,486 | 25,557 | (53,719) |
| Multiplier | 1.41 | 1.41 | 1.41 | 1.41 |

**Factor 2: Thermostat Schedule (C\_Tstat Offset)**

For the QM space the thermostat offset is -2.2 or a cooling setpoint that on average is 2.2 degrees lower than the California Title-24 thermostat for cooling. The sum of 24 hours of cooling setting for Title 24 is 1912 which is then divided by 24 to get an average setting of 79.7°F. So, a setting of 2.2°F lower would be 77.5°F for cooling. For heating the set point was set at 68.5°F.

Table 9 : QM Thermostat Schedule

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Title-24** | | **QM Tstat** | |
| Hour | T-24 H | T-24 C | Heating | Cooling |
| 1 | 65 | 78 | 68.5 | 77.5 |
| 2 | 65 | 78 | 68.5 | 77.5 |
| 3 | 65 | 78 | 68.5 | 77.5 |
| 4 | 65 | 78 | 68.5 | 77.5 |
| 5 | 65 | 78 | 68.5 | 77.5 |
| 6 | 65 | 78 | 68.5 | 77.5 |
| 7 | 65 | 78 | 68.5 | 77.5 |
| 8 | 68 | 83 | 68.5 | 77.5 |
| 9 | 68 | 83 | 68.5 | 77.5 |
| 10 | 68 | 83 | 68.5 | 77.5 |
| 11 | 68 | 83 | 68.5 | 77.5 |
| 12 | 68 | 83 | 68.5 | 77.5 |
| 13 | 68 | 83 | 68.5 | 77.5 |
| 14 | 68 | 82 | 68.5 | 77.5 |
| 15 | 68 | 81 | 68.5 | 77.5 |
| 16 | 68 | 80 | 68.5 | 77.5 |
| 17 | 68 | 79 | 68.5 | 77.5 |
| 18 | 68 | 78 | 68.5 | 77.5 |
| 19 | 68 | 78 | 68.5 | 77.5 |
| 20 | 68 | 78 | 68.5 | 77.5 |
| 21 | 68 | 78 | 68.5 | 77.5 |
| 22 | 68 | 78 | 68.5 | 77.5 |
| 23 | 68 | 78 | 68.5 | 77.5 |
| 24 | 65 | 78 | 68.5 | 77.5 |
| Sum | 1608 | 1912 |  | 1860 |
| Sum/24 | 67.0 | 79.7 |  | 52.0 |
|  |  |  | **Factor** | **-2.2** |

**Factor 3: Duct Insulation (C\_DuctUA)**

Each DEER prototype single family homes, has both a supply duct and a return duct that are assumed to be insulated to the same R-value. The DuctUA factor was a combined value. For homes with the QM treatments, the combined Duct UA factor is determined to be 236.4, which is about 85% of the midpoint duct UA of 277. Using this ratio the eQUEST duct UA inputs were derived as shown in Table 10 below. By dividing the duct area results by the QM-DuctUA input, the average QM duct insulation R-value was calculated to be 4.7.

Table 10 : Duct UA Factors

|  |  |  |  |
| --- | --- | --- | --- |
| **DuctUA Factor** | **277** | **UA-values** | **Duct Areas** |
| **One-story** | **Supply** | 117 | 468 |
|  | **Return** | 22 | 87 |
| **Two-story** | **Supply** | 152 | 608 |
|  | **Return** | 87 | 346 |
| **QM DuctUA Factor** | **236.4** | **QM-DuctUA input to eQUEST** |  |
| **One-story** | **Supply** | 99.8 | 468 |
|  | **Return** | 18.5 | 87 |
| **Two-story** | **Supply** | 129.7 | 608 |
|  | **Return** | 73.9 | 346 |
|  |  | **Duct R-value** | **4.7** |

**Factor 4: Duct Leakage (C\_DuctLeak)**

Duct leakage in eQUEST has to be split between the return and supply ducts and some of the leakage are assumed to eventually leak into the conditioned space. In one-story homes, the leakage multiplier is 75% and for the two-story it is 67%. The QM Duct Leak Factor was 13.9% which is entered into eQUEST per Table 11.

Table 11 : Duct Leakage for eQUEST

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Regression A** |  | **Return** | **Supply** |
|  | **Total** | 13.9% | 6.95% | 6.95% |
| **One-story** | **Multiplier to attic** | 75% |  | 5.22% |
| **Two-story** | **Multiplier to attic** | 67% |  | 4.66% |

**Factor 5: Gas Furnace AFUE (C\_AFUE)**

The gas furnace Annual Fuel Utilization Efficiency (AFUE) factor after QM was the same as before QM, 80% because it is not a QM treatment. DEER used a conversion of AFUE to the eQUEST input of HIR (Heating Input Ratio) based on a correlation from equation N2-28 on the Nonresidential ACM Manual[[16]](#endnote-17), Section 2.5.2.10, Page 2-64 where:

*HIR = (0.011116 × AFUE (80%) - 0.098185)-1*

*HIR = 1.268*

This HIR value was used in all DEER single family prototypes.

**Factor 6: Refrigeration Impact Factor (C\_RIF)**

The refrigeration impact factor represents corrections to the air conditioner compressor power, the total cooling and sensible cooling capacity as a function of adjustments to refrigerant charge and air flow.

The post QM treatment value for C\_RIF is 1.0109 which is used to derive the four eQUEST multipliers for:

1. “Cooling-EIR impact fraction” that is multiplied by the rated compressor EIR (energy input ratio) that eQUEST uses to determine the power (kW) draw of the air conditioning compressor. The rated compressor EIR is determined by the SEER rating.
2. “Cooling Capacity base fraction” that is multiplied by the base cooling capacity of the air conditioner. eQUEST uses the modified total cooling capacity to determine the compressor runtime each hour as a fraction based on cooling load for the hour divided by the total cooling capacity.
3. “Cool-sh-cap base fraction” is multiplied by the rated sensible cooling capacity that is determined as a fraction of the total capacity.
4. “Typical CFM-ton” is the air flow associated with the system. The rated supply air flow of 400 CFM/Ton is adjusted down based on the RIF. So, for the QM RIF of 1.0109, the DEER air flow is multiplied by 0.984 (393.7/400) to get the airflow after the QM treatments.

Table 12 : Refrigeration Impact Factor

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RIF Refrig Impct Factor** | **Cooling-EIR base fraction** | **Cooling-Capacity base fraction** | **Cool-sh-cap base fraction** | **Typical CFM\_ton** |
| 1.000 | 1.000 | 1.000 | 1.000 | 400.0 |
| 1.0109 | 1.0122 | 0.9855 | 0.984 | 393.7 |
| 1.087 | 1.097 | 0.884 | 0.874 | 350.0 |
| 1.269 | 1.398 | 0.896 | 0.941 | 225.0 |

**Factor 7: SEER (C\_Nom\_SEER)**

SEER or Seasonal Energy Efficiency Ratio is a rating that indicates how much cooling energy (Btu) the HVAC system provides through a season for a given amount of electrical energy (Wh). EER (without the Seasonal) is a measure of the steady-state system efficiency, or how much cooling (Btu/hr) is provided for a given amount of power (W). For a nominal rated total power that the air conditioner uses, the available cooling is determined by the SEER. The C\_Nom\_SEER after the QM treatment is the same as the SEER before the treatment.

The eQUEST model needs to have the SEER converted to an EIR which is the inverse of the COP (coefficient of performance). (EIR = 1/COP = 3.413/EER) The following equation was derived for the Performance Characteristics of SEER-rated Cooling Systems from “EER & SEER as Predictors of Seasonal Cooling Performance” by James J. Hirsch and Associates, December 15, 2003.[[17]](#endnote-18)

*EER = 2.08 + 0.73 × SEER*

EER is then converted to EIR for input to eQUEST. The eQUEST model has the blower and the condenser fan both entered as separate items so the power for those two motors must be removed to get the proper EIRc based on compressor power only.

*EER = Capacity / Total Power*

*Total Power = EER / Capacity = Comp + Blower + Condenser*

*Comp = (EER / Capacity) – Blower – Condenser*

*EIRc = Comp × 3.413 / Capacity*

*EIRc = ((EER / Capacity) – Blower – Condenser) × 3.413 / Capacity*

The EIRc compressor only is then modified by the RIF factor to get the final EIR value that is entered into eQUEST.

**Step 3: eQUEST Model Simulations**

**Blower Motor Baseline Power**

Several studies have indicated a much higher blower motor power in the field than is used in the DEER prototypes. Pigg at the Wisconsin Energy Center did two studies, one in 2003 and a summary study[[18]](#endnote-19) in 2008. Table B8 shows that older PSC (Permanent Split Capacitor) blower motors used 0.517 to 0.528 Watts/CFM and that EC Motors ranged from 0.32 to 0.341 which close to the DEER assumption of 0.365 Watts/CFM.

Table 13 : 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 |

A PIER report, “Characteristics and Opportunities for New California Homes”[[19]](#endnote-20), determined the average blower motor power for 45 HVAC systems with PSC motors to be 0.65 Watts/CFM

For this analysis we chose 0.65 Watts/CFM to represent the base case with a PSC motor and 0.365 Watts/CFM (the DEER default assumption) to represent the measure case with a BPM motor. These power draws were converted into fan system efficiency at the DEER default 1 inch of water column using the following:

*e = 0.1175\*dP\*Q/P*

Where,

*e=fan system efficiency*

*dP=differential pressure across the fan (in. water column)*

*Q=supply air flow rate (CFM)*

*P=Power (W)*

*0.1175=conversion factor for IP pressure and flow to SI*

Conversion to efficiency rather than using specific fan power (w/CFM) allows the model to respond to changes in static pressure due to duct system improvements. Base case system efficiency was input as 17% and post-measure case efficiency was input as 32%.

##### Step 4 - Run the “QM” model with baseline and retrofit motor power assumptions

The eQUEST model was derived with each of the final QM Factors but the baseline blower system efficiency was reduced to the field baseline level of 17%. The energy use for the blower motor baseline for both the 1-story and 2-story prototypes as well as a weighted average home is summarized in Table 14. The home weightings were done by using the average number of stories per climate zone from the DEER Residential Look-Up Table[[20]](#endnote-21). The Blower Only Peak is from the end-use report generated by eQuest. Total Home data is from the eQUEST simulation report called BEPU (Building Utility Performance).

Table 14 : Baseline (17% eff) Blower and Total Home Annual Energy Use

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Annual End-Use Energy** | | | **Total Annual Energy Use** | | |
|  | **Cooling** | **Evap Fan** | **Heating** | **Demand** | **Energy** | **Gas** |
| **CZ** | **kWh/yr** | **kWh/yr** | **therms/yr** | **kW** | **kWh/yr** | **therms/yr** |
| **One-Story** | | | | | | |
| **1** | 1 | 520 | 592.5 | 0.59167 | 5317 | 2005 |
| **2** | 474 | 367 | 302 | 2.283582 | 5681.5 | 1585.5 |
| **3** | 43 | 312.5 | 369.5 | 1.136496 | 5414 | 1735.5 |
| **4** | 568 | 388.5 | 252.5 | 1.959892 | 5640 | 1488 |
| **5** | 65 | 330 | 336.5 | 1.028179 | 5036 | 1652 |
| **11** | 1996.5 | 773 | 311.5 | 3.329613 | 7961 | 1546 |
| **12** | 1065.5 | 521 | 304.5 | 2.735002 | 6721.5 | 1588 |
| **13** | 1985.5 | 728.5 | 232 | 2.837659 | 7379 | 1357.5 |
| **16** | 238 | 626 | 604.5 | 1.455383 | 5431.5 | 1996.5 |
| **Two-Story** | | | | | | |
| **1** | 18.5 | 871 | 926.5 | 1.200313 | 8774.5 | 2327.5 |
| **2** | 1375.5 | 821 | 549 | 4.828248 | 10676 | 1832 |
| **3** | 198.5 | 1004 | 497 | 2.660135 | 10117 | 1862.5 |
| **4** | 1311 | 769 | 445.5 | 4.088803 | 11073.5 | 1758 |
| **5** | 181.5 | 953.5 | 583 | 2.3971 | 10050.5 | 1974 |
| **11** | 4622 | 1531 | 460.5 | 6.41699 | 14788 | 1615.5 |
| **12** | 2799 | 1080.5 | 461.5 | 5.41059 | 12430.5 | 1666.5 |
| **13** | 4764 | 1537.5 | 413 | 5.591188 | 14945 | 1548.5 |
| **16** | 393 | 1114 | 1043 | 2.590406 | 9629 | 2221.5 |
| **Weighted Average Home** | | | | | | |
| **1** | 0 | 701.818 | 765.512 | 0.906947 | 7107.985 | 2172.055 |
| **2** | 879.675 | 571.3 | 413.15 | 3.428682 | 7929.025 | 1696.425 |
| **3** | 119.0395 | 650.6435 | 431.8475 | 1.881555 | 7713.767 | 1797.603 |
| **4** | 920.925 | 569.2375 | 344.175 | 2.971125 | 8220.913 | 1616.25 |
| **5** | 120.687 | 628.033 | 454.327 | 1.682523 | 7432.931 | 1805.916 |
| **11** | 2757.895 | 992.82 | 354.71 | 4.224952 | 9940.83 | 1566.155 |
| **12** | 1563.015 | 681.5765 | 349.559 | 3.502896 | 8359.983 | 1610.53 |
| **13** | 2802.379 | 966.346 | 285.214 | 3.647197 | 9603.404 | 1413.654 |
| **16** | 310.385 | 853.896 | 809.2795 | 1.985439 | 7391.733 | 2101.575 |

The only change from the baseline to the measure condition is a change in the motor/fan system efficiency from 17% to 32%. The annual energy use for the 32% efficient retrofit motor is shown in Table 15*.*

Table 15 : Replacement (32% eff) Blower and Total Home Annual Energy Use

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Annual End-Use Energy** | | | **Total Annual Energy Use** | | |
| **Cooling** | **Evap Fan** | **Heating** | **Demand** | **Energy** | **Gas** |
| **CZ** | **kWh/yr** | **kWh/yr** | **therms/yr** | **kW** | **kWh/yr** | **therms/yr** |
| **One-Story** | | | | | | |
| **1** | 1 | 282 | 603.5 | 0.585979 | 5079 | 2016 |
| **2** | 463 | 197 | 307 | 2.096773 | 5499.5 | 1591 |
| **3** | 42 | 169 | 376 | 1.077423 | 5270 | 1742 |
| **4** | 556.5 | 208 | 257.5 | 1.809698 | 5447.5 | 1493 |
| **5** | 63 | 179 | 343 | 0.964647 | 4882.5 | 1658.5 |
| **11** | 1946 | 409 | 317 | 2.991115 | 7542 | 1551.5 |
| **12** | 1044 | 277.5 | 310 | 2.494797 | 6454.5 | 1593.5 |
| **13** | 1923 | 381 | 236.5 | 2.561538 | 6966.5 | 1362 |
| **16** | 232.5 | 338.5 | 617 | 1.332452 | 5138 | 2008.5 |
| **Two-Story** | | | | | | |
| **1** | 18 | 473 | 945 | 1.162487 | 8375.5 | 2345.5 |
| **2** | 1339.5 | 437 | 559.5 | 4.363537 | 10254.5 | 1842.5 |
| **3** | 193 | 555.5 | 517 | 2.470217 | 9663 | 1882 |
| **4** | 1273 | 408 | 455 | 3.773288 | 10672.5 | 1767.5 |
| **5** | 177 | 525 | 602 | 2.248288 | 9617.5 | 1993 |
| **11** | 4503.5 | 803.5 | 469 | 5.74432 | 13937 | 1624 |
| **12** | 2734.5 | 570.5 | 470 | 4.879489 | 11853 | 1675 |
| **13** | 4648 | 805.5 | 420.5 | 5.039986 | 14092.5 | 1556.5 |
| **16** | 379 | 602 | 1065.5 | 2.367713 | 9102 | 2244 |
| **Weighted Average Home** | | | | | | |
| **1** | 9.806 | 380.938 | 780.397 | 0.88461 | 6786.587 | 2186.681 |
| **2** | 857.425 | 305 | 420.625 | 3.116817 | 7639.25 | 1704.175 |
| **3** | 115.839 | 357.9985 | 444.949 | 1.758499 | 7418.177 | 1810.46 |
| **4** | 896.8375 | 303 | 351.3125 | 2.742403 | 7929.375 | 1623.388 |
| **5** | 117.492 | 344.388 | 466.802 | 1.578227 | 7145.83 | 1818.391 |
| **11** | 2687.675 | 523.405 | 361.08 | 3.789544 | 9396.55 | 1572.525 |
| **12** | 1529.174 | 361.591 | 355.92 | 3.179204 | 8003.87 | 1616.891 |
| **13** | 2724.15 | 505.803 | 290.596 | 3.290202 | 9061.544 | 1419.183 |
| **16** | 300.9155 | 461.5545 | 826.4495 | 1.815919 | 6989.188 | 2118.479 |

##### Step 5 - Energy Savings and Demand Reduction

The energy savings for the blower motor replacement is the difference between the baseline energy use and the measure energy use as shown in Table 16. Demand reduction is the difference in the baseline motor power and measure motor power. This reduction was multiplied by the factors developed in Section 2.2 Demand Reduction Estimation Methodologies in order to conform to the DEER methodology for determining peak demand.

Table 16 : Savings from Blower Motor Replacement

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Total Annual Savings (per home)** | | | **Total Annual Savings (Per Ton)** | | |
| **Demand** | **Energy** | **Gas** | **Demand** | **Energy** | **Gas** |
| **CZ** | **Capacity Tonnage** | **kW/yr** | **kWh/yr** | **therms/yr** | **kW/ton** | **kWh/ton** | **therms/ton** |
| **One-Story** | | | | | | | |
| **1** | **1.40** | 0.005691 | 238 | -11.00 | 0.004053 | 169.4865 | -7.83341 |
| **2** | **2.31** | 0.186809 | 182 | -5.50 | 0.081062 | 73.76841 | -2.38663 |
| **3** | **1.98** | 0.059073 | 144 | -6.50 | 0.029874 | 72.56954 | -3.28712 |
| **4** | **1.86** | 0.150194 | 192.5 | -5.00 | 0.080923 | 97.25099 | -2.69393 |
| **5** | **2.10** | 0.063532 | 153.5 | -6.50 | 0.030321 | 72.0663 | -3.10219 |
| **11** | **2.74** | 0.338498 | 419 | -5.50 | 0.123615 | 132.9283 | -2.00853 |
| **12** | **2.60** | 0.240205 | 267 | -5.50 | 0.092335 | 93.60119 | -2.1142 |
| **13** | **2.60** | 0.276121 | 412.5 | -4.50 | 0.106379 | 133.879 | -1.73369 |
| **16** | **2.24** | 0.122931 | 293.5 | -12.00 | 0.054814 | 128.1942 | -5.35071 |
| **Two-Story** | | | | | | | |
| **1** | **2.81** | 0.037826 | 399 | -18.00 | 0.013468 | 141.7135 | -6.40915 |
| **2** | **4.61** | 0.464711 | 421.5 | -10.50 | 0.100826 | 83.31492 | -2.27814 |
| **3** | **3.96** | 0.189918 | 454 | -19.50 | 0.048022 | 113.4057 | -4.93068 |
| **4** | **3.71** | 0.315515 | 401 | -9.50 | 0.084998 | 97.25099 | -2.55924 |
| **5** | **4.19** | 0.148812 | 433 | -19.00 | 0.035511 | 102.253 | -4.53397 |
| **11** | **5.48** | 0.67267 | 851 | -8.50 | 0.122825 | 132.837 | -1.55205 |
| **12** | **5.20** | 0.531101 | 577.5 | -8.50 | 0.102077 | 98.02178 | -1.6337 |
| **13** | **5.19** | 0.551202 | 852.5 | -8.00 | 0.106179 | 141.0064 | -1.54105 |
| **16** | **4.49** | 0.222693 | 527 | -22.50 | 0.049649 | 114.1486 | -5.01629 |
| **Weighted Average Home** | | | | | | | |
| **1** | **2.13** | 0.022337 | 321.398 | -14.63 | 0.010479 | 150.775 | -6.86139 |
| **2** | **3.35** | 0.311865 | 289.775 | -7.75 | 0.09333 | 86.71904 | -2.31929 |
| **3** | **2.95** | 0.123056 | 295.59 | -12.86 | 0.041794 | 100.3916 | -4.36664 |
| **4** | **2.74** | 0.228721 | 291.5375 | -7.14 | 0.083547 | 106.4926 | -2.60718 |
| **5** | **3.10** | 0.104296 | 287.101 | -12.47 | 0.033678 | 92.70765 | -4.0283 |
| **11** | **3.50** | 0.435408 | 544.28 | -6.37 | 0.12326 | 154.0809 | -1.80329 |
| **12** | **3.32** | 0.323692 | 356.1135 | -6.36 | 0.09668 | 106.3634 | -1.89989 |
| **13** | **3.33** | 0.356995 | 541.86 | -5.53 | 0.106288 | 161.3283 | -1.64615 |
| **16** | **3.30** | 0.16952 | 402.5445 | -16.90 | 0.051525 | 122.3529 | -5.1378 |

# Glossary of Terms and Acronyms

The following definitions will be used throughout this workpaper.

1. ANSI/AHRI Standard 210/240-2008 – The purpose of this standard is to establish, for Unitary Air-Conditioners and Air-Source Unitary Heat Pumps: definitions, classifications, test requirements, rating requirements, minimum data requirements for published ratings, operating requirements, marking and nameplate, and conformance conditions. This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors, and users.

1. Air Conditioning Contractors of America, Standard 4 (ACCA 4) – The ANSI/ACCA Standard 4 Maintenance of Residential HVAC Systems-2008. The purpose of this standard is to establish minimum inspection requirements in the maintenance of HVAC equipment found in one-family and two-family dwellings of three stories or less.
2. Base case cost - The cost for base case equipment/treatment per common unit.
3. CPUC Energy Division (ED) - The California Public Utilities Commission (CPUC) regulates privately owned electric communications, electric, natural gas, water, railroad, rail transit, and passenger transportation companies. The CPUC's Energy Division develops and administers energy policy and programs “to serve the public interest”, advise the Commission, and ensure compliance with the Commission decisions and statutory mandates.
4. eQUEST (DOE2) – Software to perform detailed comparative analysis of building designs and technologies by applying sophisticated building energy use simulation techniques. PG&E requires that eQUEST version 3.64 or newer shall be used for this work.

<http://doe2.com/eQUEST/>

1. Databases for Energy Efficient Resources (DEER) - The DEER provides estimates of the energy-savings potential for a variety of technologies of measures in residential and nonresidential applications. <http://www.deeresources.com/>
2. DEER Single Family Prototype - The DEER Single Family Prototype describes a single site configuration, including one or multiple building shells served by one or more HVAC system types. Prototype characteristics correspond to eQUEST building “creation wizard” inputs, where the characteristics were developed specifically for DEER analysis. <http://www.doe2.com/download/DEER/MAStool/>
3. HVAC - The heating, ventilation and air conditioning system(s) in a home used for heating, cooling, and maintaining the home at a controlled temperature, surrounded by fresh air, at a humidity level that is safe and comfortable for the building and its contents.
4. Incremental Measure Cost (IMC) - The value of the incremental cost of the measure (measure equipment cost less base equipment cost) per common unit.
5. Labor cost – The cost of labor to perform the work of specific measures/treatments.
6. Measure Case Cost – The cost for measure case equipment/treatment per common unit.
7. PG&E – Pacific Gas and Electric Company.
8. QM Implementer - A QM Implementer is a company that provides documented verification of work performed by licensed HVAC contractors performing a specified type of work or service. In the context of the Program, the service which the QM Implementer is to follow a program performance specification, market, recruit, and train licensed HVAC contractors and their technicians to offer the comprehensive quality maintenance service to the customers.
9. Quality Maintenance (QM) – ACCA Standard 4 defines what must be done to implement Quality Maintenance on residential HVAC systems. Using multiple treatments/measures the HVAC system and its elements are maintained on a regular interval to provide the intended thermal comfort and energy efficiency.
10. Workpaper (WP) - A document developed by the utility that documents the product description, savings methodology, measure costs, effective useful life, and net-to-gross ratios.

# References and Endnotes

1. ACCA, “Maintenance of Residential HVAC Systems” - ANSI/ACCA Standard 4, 2008.

   <https://www.acca.org/industry/ansi-standards> [↑](#endnote-ref-2)
2. Database for Energy Efficiency Resources (DEER) Single Family Prototype Input File from MASControl.

   <http://www.doe2.com/download/DEER/MAStool/> [↑](#endnote-ref-3)
3. Itron, Inc. DEER 2011 v2011 4.01. “DEER2011-NTGR\_2012-05-16.xls” spreadsheet, May 2012.

   <http://www.deeresources.com/index.php?option=com_content&view=article&id=68&Itemid=60> [↑](#endnote-ref-4)
4. Itron, Inc. “DEER EUL/RUL (Effective/Remaining Useful Life) Values, Updated February 5, 2014.

   <http://www.deeresources.com/> [↑](#endnote-ref-5)
5. California Energy Commission (CEC). “California Code of Regulations, Title 20. Public Utilities and Energy.” CEC-140-2014-002. March 2014.

   <http://www.energy.ca.gov/2014publications/CEC-140-2014-002/CEC-140-2014-002.pdf> [↑](#endnote-ref-6)
6. California Energy Commission (CEC). “Title 24: Building Energy Efficiency Standards.” CEC-400-2012-004-CMF-REV2. May 2012.

   <http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf> [↑](#endnote-ref-7)
7. Robert Mowris & Associates, Anne Blankenship, and Ean Jones. “Field Measurements of Air Conditioners With and Without TXVs”, paper for 2004 ACEE Summer Study Proceedings, 2004.

   <http://aceee.org/proceedings-paper/ss04/panel01/paper19> [↑](#endnote-ref-8)
8. PG&E Performance Testing and Analysis Unit Technical and Ecological Services, “Influence of the Expansion Device on the Performance of a residential split system air conditioner”, Report # 491-01.4, January 2001. [↑](#endnote-ref-9)
9. 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-10)
10. Itron, Inc. “2014 Database for Energy Efficiency Resources (DEER)”, v.1.0.5 , November 2013.

    <http://www.deeresources.com/> [↑](#endnote-ref-11)
11. CEC 2013 Title 24 Weather Data (CZ2010)

    <http://bees.archenergy.com/weather.html> [↑](#endnote-ref-12)
12. KEMA, The Cadmus Group, and Summit Blue Consulting. “Evaluation Measurement and Verification of the California Public Utilities Commission HVAC High Impact Measures and Specialized Commercial Contract Group Programs.” CPUC. February 10, 2010.

    <http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/> [↑](#endnote-ref-13)
13. Itron, Inc. DEER 2008 Cost data, “Revised DEER Measure Cost Summary 05302008 Revised 06022008\_ResHVAC.xlsx”, November 2011.

    <http://www.deeresources.com/> [↑](#endnote-ref-14)
14. 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-15)
15. DEER Single Family Prototypes with adjusted inputs. Adapted from 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, prepared for Southern California Edison by Itron, Inc. with support from J. J. Hirsch and Associates, December 2005. (“Starting Prototypes for Fresno.zip”)

    <http://www.deeresources.com/index.php?option=com_content&view=category&layout=blog&id=36&Itemid=53> [↑](#endnote-ref-16)
16. California Energy Commission (CEC). “2008 Nonresidential Alternative Calculation Method (ACM) Approval Manual.” CEC-400-2008-003-CMF. Section 2.5.2.10, Page 2-74. December 2008.

    <http://www.energy.ca.gov/2008publications/CEC-400-2008-003/CEC-400-2008-003-CMF.PDF> [↑](#endnote-ref-17)
17. James J. Hirsch and Associates, “EER & SEER as Predictors of Seasonal Cooling Performance.” Figure 5 – Performance Characteristics of SEER-rated Cooling Systems Selected for this Analysis Rated SEER (at 82°F) versus Rated EER (at 95°F), page 13. October 2004.

    <http://doe2.com/Download/DEER/SEER%2BProgThermostats/EER-SEER_CASE_ProjectSummary_Oct2004_V6a.pdf> [↑](#endnote-ref-18)
18. Pigg, Scott, “Central Air Conditioning in Wisconsin: A Compilation of Recent Field Research”, ECW Report Number 241-1, May 2008. [↑](#endnote-ref-19)
19. 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. [↑](#endnote-ref-20)
20. *SEER RASS by Climate Zone, June 2011*

    ** [↑](#endnote-ref-21)