**Work Paper WPSDGEREMI0005**

**Revision 0**

**San Diego Gas & Electric**

**Energy Efficiency Engineering**

**Energy Upgrade California – Prescriptive Whole Home Upgrade**

**At-a-Glance Summary**

|  |  |
| --- | --- |
| Applicable Measure Codes: | Due to the large potential number of measures. The Measure codes will be updated on a quarterly basis as claims arise, using the methodologies defined within this work paper. |
| Measure Description: | There are 22 measures that can be implemented in various packages under the Home Upgrade program. These measures improve the efficiency of the building shell, the heating and cooling system, as well as the domestic hot water system. |
| Base Case Description: | Existing customer equipment; average derived from base case measurements of past program participants |
| Energy Impact Common Units: | per home |
| Energy Savings : | Refer to Ex-Ante Database |
| Gross Measure Cost ($/unit) | Refer to Ex-Ante Database |
| Measure Incremental Cost ($/unit): | Refer to Ex-Ante Database |
| Effective Useful Life (ID): | NDEUCAWB |
| Measure Application Type: | Early Retirement |
| Net-to-Gross Ratios (ID): | EUC-Default |
| Important Comments: | This work paper document does contain a data set in conformance with the 4/1/14 CPUC Ex Ante Database Specification. |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision # | MM/DD/YY | Author/Affiliation | Summary of Changes |
| 0 | 08/27/2014 | Martin Vu/RMS Energy Consulting, LLC | Original work paper template for 2013-2014 Program Cycle |

# Section 1. General Measure & Baseline Data

This work paper was developed through a collaborative effort of PG&E, SCE, SoCal Gas, SDG&E, Bay REN, and SoCal REN. Many other program stakeholders provided review and input throughout development and implementation of the technical approach. The Energy Division was invited to provide upfront consultation on the development of this work paper. Many recommendations of the Energy Division’s staff and consultants were incorporated in the technical approach; examples include use of the Sherman-Grimsrud infiltration model and creation of eQUEST home prototypes with different floor areas. This work paper describes the results of this highly collaborative effort.

## 1.1 Measure & Delivery Description

The whole house upgrade program, now known as Energy Upgrade California Home Upgrade, is a downstream program targeting Single Family Homes. Participating homeowners work with a qualified contractor to select and install a package of eligible measures. These packages must include at least three measures, one of which must be defined as a base measure (see Section 1.3b). This work paper describes the approach used to estimate the energy savings for those packages. The savings values for a subset of the many thousands of eligible packages are presented in ex-ante database tables. If other eligible packages are implemented that are not included in that table, the regression models that are described in the work paper and incorporated in the attached calculation tool can be used to directly calculate savings for any package, within each climate and for various home characteristics.

### 1.1a Measure Description

There are 22 measures that can be implemented in various combinations under the Home Upgrade program following the Program rules. These measures are listed in Table 1 below. Fifteen of the measures interact with the heating and cooling system; for example, an insulation measure reduces furnace energy use and hence the total energy savings of an insulation measure and a furnace efficiency measure is not a simple sum of the individual energy savings of each measure. The remaining seven measures interact with the domestic hot water (DHW) system. The interaction between the DHW system and heating and cooling system is assumed to be negligible.

**Table 1 Individual Home Upgrade Measures**

|  |  |  |
| --- | --- | --- |
|  | Measure name | System for Interactions |
| 1 | Reduce Building Leakage 30% | Heating & Cooling |
| 2 | Reduce Building Leakage 15% | Heating & Cooling |
| 3 | Insulate Duct to R-8 | Heating & Cooling |
| 4 | Reduce Total Duct Leakage to 10% (duct sealing) | Heating & Cooling |
| 5 | Reduce Total Duct Leakage to 6% (duct replacement) |  |
| 6 | Insulate Attic to R-30 (climate zones 2-10) or to R-38 (climate zones 1 and 11-16) | Heating & Cooling |
| 7 | Insulate Attic to R-44 | Heating & Cooling |
| 8 | Insulate Wall to R-13 | Heating & Cooling |
| 9 | Insulate Floor to R-19 | Heating & Cooling |
| 10 | High Performance Windows (U=0.32,SHGC=0.25) | Heating & Cooling |
| 11 | Efficient Air Conditioner (SEER 14) | Heating & Cooling |
| 12 | Efficient Air Conditioner (SEER 15) | Heating & Cooling |
| 13 | Efficient Gas Furnace (AFUE 92%) | Heating & Cooling |
| 14 | Efficient Gas Furnace (AFUE 95%) | Heating & Cooling |
| 15 | Efficient Gas Wall Heater (AFUE 70%) | Heating & Cooling |
| 16 | Efficient Electric Water Heater (93 EF) | Domestic Hot Water |
| 17 | Efficient Gas Water Heater (62 EF) | Domestic Hot Water |
| 18 | Efficient Gas Water Heater (67 EF) | Domestic Hot Water |
| 19 | Tankless Gas Water Heater | Domestic Hot Water |
| 20 | Hot Water Pipe Wrap | Domestic Hot Water |
| 21 | Thermostatic Shut-Off Valve | Domestic Hot Water |
| 22 | Low Flow Showerhead with Thermostatic Shut-Off Valve | Domestic Hot Water |

**1.1b Base Case Description**

The base case is a typical Energy Upgrade California participant home in the pre-1978, 1978-1992, or 1993-2001 vintage and in one of six climate regions. The six climate regions and corresponding DEER climate zones are shown in Table 2. These climate regions and the proxy climate zone for each region were selected based on two main considerations: 1) an analysis of the eQUEST simulation results indicated only modest differences in kWh, kW and therm impacts across many similar climates, and 2) where the program delivery has been greatest and where it is expected to grow in the future.

Table 2 Climate Regions

|  |  |  |
| --- | --- | --- |
| Climate Region | DEER Climate Zones | Primary DEER Climate Zone |
| North Coast (NC) | 1,3,5 | 3 |
| Coast Ranges (CR) | 2,4 | 4 |
| Central Valley & Sierra (CVS) | 12,16 | 12 |
| Central Valley & Desert (CVD) | 11,13,14,15 | 13 |
| South Coast (SC) | 6,7,8 | 7 |
| Inland Southwest (IS) | 9,10 | 9 |

The use of six Climate Regions reduced the total number of home prototypes and simulations required, as illustrated in Table 15. This allowed additional effort to be applied in customizing the models to represent program participants. This trade-off was evaluated by the project collaborators, including representatives of the Energy Division, and judged to be an effective use of project resources.

### 1.1c Delivery and Incentive Mechanism

The Delivery Mechanism is Financial Support / Down-Stream Incentive – Deemed. As shown in Table 3 below, the install type varies by measure. Some measures are retrofit (RET) and others are retrofit add-on (REA). However, packages often contain both retrofit and retrofit add-on measures. For consistency, all packages have been assigned the install type RET. However, as discussed in subsequent sections, the cost and EUL for each package is a blend of the individual measures’ costs and EULs.

Table 3 Install Type, by Measure

|  |  |
| --- | --- |
| **Measure Type** | **Install Type** |
| Reduce Building Leakage | RET – Add-on |
| Reduce Duct Leakage | RET |
| Insulate duct, attic, wall, or floor | RET – Add-on |
| High Performance Windows | RET |
| Efficient Air Conditioner or Furnace | RET |
| Efficient Water Heater | RET |
| Hot Water Pipe Wrap | RET – Add-on |
| Thermostatic Shut-Off Valve | RET – Add-on |
| All Measure Packages | RET |

### 1.1d Measure Requirements

Applicant must be a current SCE, SoCal Gas, SDG&E, or PG&E residential customer. Each utility will only participate in program delivery and claim energy savings from its own customers. Fuel switching measures are not allowed, and the program is not available for new construction. Work must be performed by a licensed contractor in accordance with applicable building codes. The program will be available for a detached single family residence. To qualify for the program, customers must select at least three measures. One of the measures must be a base measure from Group A below, and the remaining two measures may be from either Group A or Group B.

Group A

* Attic Insulation
* Reduce Duct Leakage
* Reduce Building Leakage

Group B

* Wall Insulation
* Floor Insulation
* Duct Insulation
* High Performance Windows
* AC retrofit
* Furnace retrofit
* Water heater retrofit
* Thermostatic control valve

Given the nature of the measures, most participating homes are expected to be from one of the three modeled vintages: pre-1978, 1978-1992, and 1993-2001. Older homes are targeted, but home age is not a program requirement.

If a home has a unique set of requirements that cannot be fulfilled by the packages in this work paper, it can be eligible for the EUC Advanced Path.

### 1.1e TECHNICAL DESCRIPTION

The characteristics of participant homes within each vintage and climate region were estimated using data from the home energy audits that precede upgrades through the program. Brief descriptions of each individual measure case and the base case, that resulted from the analysis of participant data follow. Further discussion of the adjustments to prototypes and the calibration procedure are provided in Section 2.

**Reduce Building Leakage 15% or 30%**

*Measure*

There are two eligible whole home air sealing measures. The exchange of air between the interior and exterior of the home can be reduced by either 15% or 30%. In practice, this is accomplished by sealing gaps in the building envelope, including those that often occur around penetrations for windows, exterior doors, attic access doors, electrical outlets, plumbing, and light fixtures. The methods for achieving the reduction are the same for both the 15% and 30% measures, with the difference being the level of air-tightness that the implementer achieves, as measured by a post-sealing blower door test (“Test Out”). The vintage-specific levels required at Test Out are shown in the table below.

|  |  |  |
| --- | --- | --- |
| Vintage | 15% Reduction Level, ACHn | 30% Reduction Level, ACHn |
| pre78 | 0.56 | 0.46 |
| 78-92 | 0.41 | 0.35 |
| 93-01 | 0.36 | ineligible |

*Base case*

The base case for this measure varies with the vintage of the home:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Infiltration - program participants | | DEER 2011 ACH for comparison |
| Vintage | Leak fraction of floor area | Roughly equivalent ACHn |
| pre78 | 0.00071 | 0.66 | 0.35 |
| 78-92 | 0.00052 | 0.48 | 0.35 |
| 93-01 | 0.00046 | 0.43 | 0.35 |

**Insulate Duct to R-8**

*Measure*

The insulation of ducts in unconditioned space is increased to an effective value of R-8. This may be achieved by adding blown in insulation to fully bury a duct or by increasing duct wrap. For duct wrap, the thickness used to determine the R value is assumed to be 75% the nominal thickness to account for compression.

*Base case*

|  |  |  |
| --- | --- | --- |
| Vintage | Duct R value – program participants | DEER 2011 R value for comparison |
| pre78 | 3.32 | 2.80 |
| 78-92 | 3.67 | 2.80 |
| 93-01 | 4.26 | 4.90 |

**Reduce Duct Leakage to 10% or 6%**

*Measure*

There are two eligible measures to reduce duct leakage. Duct replacement can be applied to reduce total duct leakage to 6% of system airflow. Alternatively, duct sealing can be applied to reduce total duct leakage to 10% of system airflow.

*Base case*

|  |  |  |
| --- | --- | --- |
| Vintage | Percent total duct leakage – program participants | DEER 2011 total duct leakage for comparison |
| pre78 | 33% | 28% |
| 78-92 | 26% | 21% |
| 93-01 | 22% | 14% |

**Insulate Attic to R-30 (climate zones 2-10) or R-38 (climate zones 1 and 11-16)**

*Measure*

The level of attic insulation on the attic floor (also referred to as ceiling insulation) is increased to R-30 in climate zones 2-10. The level of attic insulation on the attic floor (also referred to as ceiling insulation) is increased to R-38 in climate zones 1 and 11-16.

*Base case*

|  |  |  |  |
| --- | --- | --- | --- |
| Vintage | Climate region | Ceiling R value | DEER 2011 ceiling R value for comparison |
| pre78 | NC | 6.68 | 6.71 |
| 78-92 | NC | 10.31 | 24.13 |
| 93-01 | NC | 10.31 | 38.13 |
| pre78 | SC | 9.12 | 7.39 |
| 78-92 | SC | 11.48 | 18.53 |
| 93-01 | SC | 16.55 | 30.13 |
| pre78 | IS | 11.12 | 6.88 |
| 78-92 | IS | 14.28 | 18.13 |
| 93-01 | IS | 17.33 | 30.13 |
| pre78 | CR | 11.05 | 6.71 |
| 78-92 | CR | 13.87 | 24.13 |
| 93-01 | CR | 19.33 | 38.13 |
| pre78 | CVS | 11.93 | 6.88 |
| 78-92 | CVS | 15.90 | 19.73 |
| 93-01 | CVS | 17.74 | 38.13 |
| pre78 | CVD | 15.41 | 6.88 |
| 78-92 | CVD | 18.17 | 19.73 |
| 93-01 | CVD | 22.91 | 38.13 |

**Insulate Attic to R-44**

*Measure*

The level of attic insulation on the attic floor (also referred to as ceiling insulation) is increased to R-44.

*Base case*

Same as previous Insulate Attic measure.

**Insulate Wall to R-13**

*Measure*

The level of wall insulation is increased to R-13.

*Base case*

|  |  |  |  |
| --- | --- | --- | --- |
| Vintage | Climate | Wall R value | DEER 2011 wall insulation R value for comparison |
| 78-92 | NC | 10.25 | 15.38 |
| 93-01 | NC | 10.25 | 18.23 |
| pre78 | NC | 0.96 | 5.18 |
| 78-92 | SC | 10.25 | 11.91 |
| 93-01 | SC | 10.25 | 12.42 |
| pre78 | SC | 0.96 | 7.82 |
| 78-92 | IS | 10.25 | 12.19 |
| 93-01 | IS | 10.25 | 12.41 |
| pre78 | IS | 0.96 | 6.68 |
| 78-92 | CR | 10.25 | 15.38 |
| 93-01 | CR | 10.25 | 18.23 |
| pre78 | CR | 3.10 | 5.18 |
| 78-92 | CVS | 10.25 | 11.73 |
| 93-01 | CVS | 10.25 | 16.85 |
| pre78 | CVS | 3.10 | 6.68 |
| 78-92 | CVD | 10.25 | 11.73 |
| 93-01 | CVD | 10.25 | 16.85 |
| pre78 | CVD | 3.10 | 6.68 |

**Insulate Floor to R-19**

*Measure*

The level of insulation under a floor above a crawl space is increased to R-19.

*Base case*

|  |  |  |
| --- | --- | --- |
| Vintage | Floor R Value | DEER 2011 floor R value for comparison |
| pre78 | 1.34 | 5.51 |
| 78-92 | 5.96 | - n/a - |
| 93-01 | 5.96 | - n/a - |

Among the DEER 2011 prototypes, which have been updated with the latest DEER weather files, only the pre78 vintage homes have a crawlspace. To perform the energy savings analysis for later vintage homes it was necessary to develop new versions of the 78-92 and 93-01 prototypes with crawlspaces added.

**High Performance Windows**

*Measure*

New high performance windows are installed in place of all existing windows. The new windows have a U-factor of 0.32 and a Solar Heat Gain Coefficient of 0.25. This is equal to the level required by Title 24 (2013) and therefore above code savings only exist during the assumed remaining useful life. The total surface area of glazing replaced varies by vintage and number of stories, as shown below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Vintage | 1-story glazing (ft2) | 1-story glazing (%wall area) | 2-story glazing (ft2) | 2-story glazing (%wall area) |
| Pre78 | 171 | 17.1% | 226 | 15.3% |
| 78-92 | 158 | 13.8% | 223 | 12.8% |
| 93-01 | 308 | 25.5% | 472 | 24.2% |

*Base case*

|  |  |  |  |
| --- | --- | --- | --- |
| Vintage | Climate | U-Factor | SHGC |
| 78-92 | NC | 0.820 | 0.790 |
| 93-01 | NC | 0.670 | 0.790 |
| pre78 | NC | 1.230 | 0.870 |
| 78-92 | SC | 1.150 | 0.870 |
| 93-01 | SC | 0.670 | 0.790 |
| pre78 | SC | 1.230 | 0.870 |
| 78-92 | IS | 1.180 | 0.870 |
| 93-01 | IS | 0.670 | 0.610 |
| pre78 | IS | 1.230 | 0.870 |
| 78-92 | CR | 0.820 | 0.790 |
| 93-01 | CR | 0.670 | 0.790 |
| pre78 | CR | 1.230 | 0.870 |
| 78-92 | CVS | 0.935 | 0.830 |
| 93-01 | CVS | 0.620 | 0.700 |
| pre78 | CVS | 1.230 | 0.870 |
| 78-92 | CVD | 1.140 | 0.870 |
| 93-01 | CVD | 0.570 | 0.550 |
| pre78 | CVD | 1.230 | 0.870 |

Insufficient program data was available for base case window performance, so the DEER 2011 prototype’s values were used without modification.

**Efficient Air Conditioner (SEER 14)**

*Measure*

A new air conditioner is installed. The new unit has a seasonal energy efficiency ratio (SEER) of 14 and an Energy Efficiency Ratio (EER) of 12.04.

*Base case*

The existing AC unit has a SEER of 10 and an EER of 9.17 [A; D].

**Efficient Air Conditioner (SEER 15)**

*Measure*

A new air conditioner is installed. The new unit has a seasonal energy efficiency ratio (SEER) of 15.

*Base case*

The existing AC unit has a SEER of 10 and an EER of 9.17 [A; D].

**Efficient Gas Furnace (AFUE 92%)**

*Measure*

A new gas furnace is installed. The new unit has an annual fuel utilization efficiency (AFUE) of 92%.

*Base case*

The existing gas furnace has an AFUE of 78% [A; 62, page 2-74].

**Efficient Gas Furnace (AFUE 95%)**

*Measure*

A new gas furnace is installed. The new unit has an AFUE of 95%.

*Base case*

The existing gas furnace has an AFUE of 78% [A; 62, page 2-74].

**Efficient Wall Furnace (AFUE 70%)**

*Measure*

A new, natural gas, gravity wall furnace is installed. The new unit has an AFUE of 70%.

*Base case*

The existing gas furnace has an AFUE of 62%, which is the required efficiency after 1990 from National Appliance Energy Conservation Act of 1987 [O].

**Efficient Electric Water Heater (93 EF)**

*Measure*

A new electric storage water heater with an energy factor (EF) of 0.93.

*Base case*

An existing electric storage water heater with an EF of 0.88 [E].

**Efficient Gas Water Heater (62 EF)**

*Measure*

A new natural gas storage water heater with an EF of 0.62.

*Base case*

An existing natural gas storage water heater with an EF of 0.57 [E].

**Efficient Gas Water Heater (67 EF)**

*Measure*

A new natural gas storage water heater with an EF of 0.67.

*Base case*

An existing natural gas storage water heater with an EF of 0.57 [E].

**Tankless Gas Water Heater**

*Measure*

A new natural gas tankless water heater with an EF of 0.82.

*Base case*

An existing natural gas storage water heater with an EF of 0.57 [E].

**Hot Water Pipe Wrap**

*Measure*

5 feet of pipe are insulated with R-4.7 pipe wrap.

*Base case*

Existing bare ¾ inch copper piping in unconditioned space.

**Shower Thermostatic Shut-Off Valve**

*Measure*

Temperature-initiated flow-restriction valves are installed at the showerhead. The valve is initially open and allows cold water that has been sitting in the pipes to flow through the showerhead. When the water temperature reaches approximately 95 ºF, the valve restricts the water flow to a trickle until the user enters the shower and switches the valve open again to restore full flow.

*Base case*

A low-flow showerhead, with a flow of 1.7 gallons per minute (gpm), without thermostatic shut-off valve.

**Low-flow Showerhead with Thermostatic Shuff-Off Valve**

*Measure*

A low-flow showerhead, with flow of 1.7 gpm or less, is installed with the Shower Thermostatic Shut-Off Valve.

*Base case*

A conventional showerhead, with flow of 2.25 gpm.

## 1.2 DEER Differences Analysis

DEER 2014 includes many of the individual measures that are included in the home upgrade packages. However, the DEER values do not capture the interactions that occur when multiple measures are delivered together as a package. In order to account for those interactive effects, it was necessary to simulate entire packages of measures. Thus, eQUEST models were developed to estimate the whole home energy savings from packages of measures. Regression models were then built on those simulation results to extend the results and allow estimation of energy impacts for the large number of possible measure packages.

Table 4 DEER Difference Summary

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | Yes |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | Yes, with baseline characteristics adjusted to match the characteristics of program participants’ homes |
| Deviation from DEER | DEER does not combine measures to account for their interactive effects |
| DEER Version | DEER for 2014 Code Update |
| DEER Run ID and Measure Name (Sample) | RB-BS-CeilIns-R0-R30, Ceiling R-0 to R-30 Insulation-Batts  RB-BS-CeilIns-R0-R38, Ceiling R-0 to R-38 Insulation-Batts  RB-BS-CeilIns-VintR-AddR11, Ceiling - Add R-11 batts on top of vintage-specific existing insulation  RB-BS-CeilIns-VintR-AddR19, Ceiling - Add R-19 batts on top of vintage-specific existing insulation  RB-BS-CeilIns-VintR-AddR30, Ceiling - Add R-30 batts on top of vintage-specific existing insulation  RB-BS-BlowInIns-R0-R13, Wall Blow-In R-0 to R-13 Insulation  D03-426, Floor R-0 to R-19 Insulation Batts  Res-DuctSeal-HighToLow-wtd, Residential: Duct Sealing (Total Leakage Reduced from High (40/35%) to Low (15/12%)  Res-DuctSeal-MedToLow-wtd, Residential: Duct Sealing (Total Leakage Reduced from High (25/24%) to Low (15/12%)  RE-HV-ResAC-14S, 14 SEER (12.15 EER) Split-System Air Conditioner  RG-HV-EffFurn-92AFUE, High Efficiency Furnace 92 AFUE(1.08 HIR) |

The storage water heater measures are the only measures adopted directly from DEER 2014. Assuming that most water heaters are located in the garage, they have little if any interaction with the other simulated measures. Therefore, it was possible to simply adopt the DEER measures, which can be added into any of the measure packages. The DEER water heater measures incorporated in this way are as follows:

* RE-WtrHt-SmlStrg-Elec-lte12kW-50G-0p93EF, High Efficiency Small Electric Storage Water Heater - 50 Gal , 0.93 EF
* RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-0p62EF, High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.62 EF
* RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-0p67EF, High Efficiency Small Gas Storage Water Heater - 50 Gal , 0.67 EF

### Non-DEER Study Review

The principal Non-DEER source used in this work paper is the program itself. Data collected by the program on the baseline characteristics of past Energy Upgrade California participant homes has been used to construct the base case. This procedure is described in Section 2. The use of other Non-DEER studies of individual measure impacts are also described in Section 2.5.

## 1.3 Code Analysis

All of the retrofit measures in this work paper are subject to provisions of either California’s Title 24 (2013) [355] or Title 20 (2014) [422]. The table below summarizes the relevant code requirements.

**Table 5 Code Summary**

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | “In all climate zones, when a space-conditioning system is altered… the duct system… shall be sealed…The measured duct leakage shall be equal to or less than 15 percent of system air handler airflow…” [150.2(b)1E]. | July 1, 2014 |
| Title 24 (2013) | “Replacement of fenestration, where existing fenestration area in an existing wall or roof is replaced with a new manufactured fenestration product and up to the total fenestration area removed in the existing wall or roof, the replaced fenestration shall meet the U-factor and Solar Heat Gain Coefficient requirements of Sections 150.1(c)3A, and 150.1(c)4.” [105.2(b)1B. | July 1, 2014 |
| Title 20 (2014) | “The current Appliance Efficiency Regulations require that the Annual Fuel Utilization Efficiency (AFUE) of all new central furnaces be at least 78 percent for equipment with output capacity less than 225,000 Btu/hr.” …” [422, Table E-8]. | January 23, 2006 |
| 10 CFR 430.32 | Federal standards require AFUE 66 percent for gravity type gas wall furnaces over 27,000 Btu/h up to 46,000 Btu/h | April 16, 2013 |
| Title 20 (2014) | SEER 13.0 is the minimum allowable cooling efficiency for, “new central, single phase air conditioners and air source heat pumps with output less than 65,000 Btu/h.” [422, Table C-2]. | January 23, 2006 |
| 10 CFR 430.32 | Federal standards require SEER 13 for split systems and SEER 14 for packaged units starting in 2015. | January 1, 2015 |

The energy savings for each retrofit (RET) type measure, and the packages including those measures, are estimated using dual baselines. For the first baseline, energy savings are calculated as the difference between the measure case and the customer average base case represented by the adjusted DEER prototypes. For the second baseline, energy savings are calculated as the difference between the measure case and a hypothetical case where the system impacted by the measure is brought up to the code compliant level. For example, the first baseline energy savings of the SEER 14 AC measure compare the SEER 14 AC to the existing SEER 10 AC. In the second baseline, the SEER 14 AC is compared to a Title 20 (2014) compliant SEER 13 AC unit. The table below summarizes the comparison for each individual measure in the 2nd baseline.

**Table 6 Definition of the 2nd Baseline**

|  |  |
| --- | --- |
| Measure | 2nd Baseline |
| Reduce Building Leakage 30% | Existing vs measure, same as 1st Baseline |
| Reduce Building Leakage 15% | Existing vs measure, same as 1st Baseline |
| Insulate Duct to R-8 | Existing vs measure, same as 1st Baseline |
| Reduce Total Duct Leakage to 10% (duct sealing) | Existing vs code required duct sealing to 15% total duct leakage |
| Reduce Total Duct Leakage to 6% (duct replacement) | Existing vs code required duct sealing to 15% total duct leakage |
| Insulate Attic to R-30 (climate zones 2-10) or to R-38 (climate zones 1 and 11-16) | Existing vs measure, same as 1st Baseline |
| Insulate Attic to R-44 | Existing vs measure, same as 1st Baseline |
| Insulate Wall to R-13 | Existing vs measure, same as 1st Baseline |
| Insulate Floor to R-19 | Existing vs measure, same as 1st Baseline |
| High Performance Windows | Existing vs code-required U=0.32, SHGC=0.25 |
| Efficient Air Conditioner (SEER 14) | Existing vs code-required SEER 13 |
| Efficient Air Conditioner (SEER 15) | Existing vs code-required SEER 13 |
| Efficient Gas Furnace (AFUE 92%) | Existing vs measure, same as 1st Baseline (existing is compliant with code) |
| Efficient Gas Furnace (AFUE 95%) | Existing vs measure, same as 1st Baseline (existing is compliant with code) |
| Efficient Gas Wall Heater (AFUE 70%) | Existing vs code-required AFUE 66 |
| Efficient Electric Water Heater (93 EF) | Existing vs measure, same as 1st Baseline (existing is compliant with code) |
| Efficient Gas Water Heater (62 EF) | Existing vs code-required EF .59 |
| Efficient Gas Water Heater (67 EF) | Existing vs code-required EF .59 |
| Tankless Gas Water Heater | Existing vs code-required EF .59 |
| Hot Water Pipe Wrap | Existing vs measure, same as 1st Baseline |
| Thermostatic Shut-Off Valve | Existing vs measure, same as 1st Baseline |
| Low Flow Showerhead with Thermostatic Shut-Off Valve | Existing vs measure, same as 1st Baseline |

## 1.4 Measure Effective Useful Life

Refer to the Ex-Ante Database for the EUL values.

Table 7 DEER08 EUL Value/Methodology

|  |  |
| --- | --- |
| EUL\_ID | Market |
| NDEUCAWB | Residential |

## 1.5 Net-to-Gross Ratios for Different Program Strategies

Refer to the Ex-Ante Database for the NTG values.

Table 8 Net-to-Gross Ratio

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID |
| EUC-Default | Energy Upgrade California | Res | Any | All |

\*Denotes that the column is taken from the DEER NTG Table.

## 1.6 Time-of-Use Adjustment Factor

As directed by the CPUC in decision 06-06-063 dated June 29, 2006, time-of-use (TOU) adjustment factors are to be applied for residential A/C and commercial A/C (packaged and split-system direct-expansion cooling) measures only. Since this is not an A/C measure, the TOU adjustment factor is 0. Additionally, if a measure is assigned a DEER08 load shape, i.e. the load shape starts with “DEER:” the TOU assigned to that measure should also be zero.

Table 9 TOU Summary Table

|  |  |
| --- | --- |
| Measure | % |
| Energy Upgrade California | 0 |

# Section 2. Energy Savings & Demand Reduction Calculations

## 2.1 Energy Savings & Demand Reduction Calculations

The estimation of energy savings for the home upgrade packages is complicated by the number of possible measure packages and the complexity of accounting for the interactions between measures. To address this complexity we applied a six step procedure. Table 10 summarizes each step in the procedure, and additional detail is provided in Sections 2.1 through 2.6.

Table 10 Summary of Energy Saving & Demand Reduction Calculation Procedure

|  |  |
| --- | --- |
| Section | Summary Description |
| 2.1 | Create eQUEST home prototypes that have similar characteristics as program participants |
| 2.2 | Use design of experiments methodology to create a sample of measure packages representing the range of possible packages for various groups of participant homes. |
| 2.3 | Simulate the sample measure packages in eQUEST to estimate the energy performance of different measure packages. |
| 2.4 | Use the simulation results to construct regression models that estimate the energy performance for the home group across all possible measure packages. |
| 2.5 | Incorporate additional energy savings estimates for measures that do not interact with the heating and cooling system. |
| 2.6 | Create a spreadsheet calculator that combines all the results into a single tool to estimate energy savings for all possible measure packages. |

## Section 2.1 Creation of Home Upgrade Participant Models

In the first version of this work paper, energy savings were estimated using DEER prototypes that represent typical California homes. This was believed to underestimate the energy savings of the program’s measure packages because the energy performance of program participants’ homes is likely to be worse than the California average. Therefore, a major effort was made in the latest analysis to update the baseline models to better represent program participants.

The first step in updating the baseline models was to obtain pre-upgrade home audit data from the program implementers. Audit data representing nearly 3,000 homes was obtained. The data was summarized according to three home vintages and six climate regions (described in Table 2). Once summarized, those participant characteristics were used to adjust the characteristics of the DEER 2011 Single Family Home eQUEST prototypes extracted from the MASControl tool, v2.00.10 [A].

After adjusting the characteristics, the eQUEST prototypes were calibrated to the energy use of the actual participant homes for that vintage and climate region using anonymous billing data provided by the utilities. Table 11 below shows the number of audit results and billing histories that were included in this analysis.

Table 11 Number of participant audits and billing histories used to construct the base case

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | PG&E | SoCal Gas | SCE | SDG&E | Total |
| Pre-upgrade assessments | 2,481 |  | 500 | 369 | 2,981 |
| Pre-upgrade bill histories | 2,500 | 1,010 | 1,356 | 348 | 5,214 |

The models were calibrated by matching the end use energy performance of the prototypes, now with participants’ characteristics, to the actual billed consumption of the participants. The actual billed consumption was for the years 2010 and 2011, so we obtained weather data for this same period, for each of the climate regions, and formatted the data for use in eQUEST. After running a simulation using this actual weather data for a particular prototype, representing a specific home vintage and climate, we then compared the model’s performance to the billing results. Several eQUEST parameters were iteratively adjusted until the model’s end use energy performance was within 15% of the target suggested by the billing data.

To make the calibration comparison on an end use level (heating, cooling, DHW and other), we first disaggregated the billing data using the following steps:

1. Assume usage during months with the fewest HDD/CDD (spring/fall) represents the base load (lighting, plug loads, cooking and DHW),
2. Adjust this base load for longer/shorter lighting hours and warmer/cooler source water in summer/winter,
3. Calculate heating use as natural gas use in the winter, less the adjusted winter base load
4. Calculate cooling use as electricity use in the summer, less the adjusted summer base load.

The key parameters adjusted to achieve calibration were the prototype homes’ electric equipment loads and the heating and cooling set points. Only homes with billing histories for both electricity and natural gas were used for the calibration. Separate calibration targets were created for homes that were indicated as having air conditioning and for homes without air conditioning. The calibration targets for all the home groups are shown in the table below.

Table 12 Calibration targets for models representing participant homes

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Homes w/ AC | | | | Homes w/out AC | | |
|  |  | Baseline | | Heating | Cooling | Baseline | | Heating |
| Climate Region | No. Stories | therm/ ft2 | kWh/ ft2 | therm/ ft2 | kWh/ ft2 | therm/ ft2. | kWh/ ft2 | therm/ft2 |
| CVD | 1 | 0.089 | 4.85 | 0.246 | 1.53 | 0.014 | 4.22 | 0.026 |
| CVS | 1 | 0.105 | 4.11 | 0.245 | 0.81 | 0.009 | 3.35 | 0.060 |
| CR | 1 | 0.110 | 3.84 | 0.232 | 0.62 | 0.010 | 3.04 | 0.044 |
| IS | 1 | 0.125 | 4.36 | 0.179 | 0.91 | 0.014 | 3.28 | 0.030 |
| NC | 1 | 0.161 | 3.69 | 0.295 | 0.57 | 0.015 | 3.13 | 0.041 |
| SC | 1 | 0.125 | 3.97 | 0.207 | 0.57 | 0.012 | 3.65 | 0.037 |
| CVD | 2 | 0.083 | 4.82 | 0.146 | 1.04 | na | na | na |
| CVS | 2 | 0.091 | 3.09 | 0.222 | 0.58 | 0.009 | 1.96 | 0.051 |
| CR | 2 | 0.083 | 3.12 | 0.207 | 0.47 | 0.008 | 3.21 | 0.027 |
| IS | 2 | 0.084 | 3.00 | 0.129 | 0.56 | na | na | na |
| NC | 2 | 0.070 | 2.81 | 0.216 | 0.31 | 0.013 | 2.76 | 0.032 |
| SC | 2 | 0.093 | 3.13 | 0.214 | 0.65 | 0.009 | 2.90 | 0.036 |

The size of participant homes was expected to be a strong predictor of energy use. Therefore, the majority of the energy saving calculation methodology dealt with energy intensity; energy savings per square foot. But even here, the size of the home has a large influence on the energy intensity. To estimate the influence of home size, we took the calibrated average sized home and next created a range of sizes of the home prototypes. The full range of sizes of home prototypes is shown in below. Though it would have been preferable to calibrate each size of home, neither time nor data allowed for that approach.

Table 13 Conditioned area of home prototypes

|  |  |  |
| --- | --- | --- |
| Model | 1-story home area (ft2) | 2-story home area (ft2) |
| Size 1 | 645 | 1,290 |
| Size 2 | 860 | 1,720 |
| Size 3, average | 1,075 | 2,150 |
| Size 4 | 1,340 | 2,690 |
| Size 5 | 1,610 | 3,220 |

## Section 2.2 Design of Experiment

Design of Experiments (DOEx) is a branch of applied statistics that plans, conducts, and analyzes controlled tests to measure the effect factors (such as efficiency, insulation level, or leakage) have on a response (such as energy use). In the DOEx approach, economy is achieved by selecting energy simulations in which each simulation run provides information on all the factors of interest in the analysis. This allows evaluation of all factors and combinations of interactions that might affect a response while minimizing the number of needed runs and maintaining statistical significance.

The key inputs to the design were selection of the analysis method (such as fractional factorial or response surface) and the factors to include in the analysis. For the analysis, we selected the response surface method (RSM). RSM is a type of statistical optimization that generates a surface map for the various conditions of your factors. It allows for non-linear responses. In contrast, a factorial analysis would be limited to linear responses. Initial testing of this approach indicated nonlinear responses would be present in the analysis, and thus the RSM method was most appropriate.

The factors chosen were those needed to represent the different home upgrade measures. Home size and window area were also selected as factors so that the results of the analysis could be interpreted in light of those important influences of home energy use. The full set of factors and the ranges used in the analysis are shown in Table 14. Since results are only valid within the factor ranges, the factor ranges were typically set wider than the baseline and measure levels to allow for future extension of the results.

Table 14 DoEx Factors and Ranges

|  |  |  |
| --- | --- | --- |
|  | Low | High |
| Floor Area, 1-story | 645 | 1613 |
| Floor Area, 2-story | 1290 | 3225 |
| Window:Floor Area Ratio | 11.5 | 20 |
| Building leakage fraction of floor area | 0.00032 | 0.001 |
| Duct insulation R-value | 0.1 | 8 |
| Total duct leakage | 6 | 35 |
| Attic insulation R-value | 0.1 | 44 |
| Floor insulation R-value | 0.1 | 19 |
| Wall insulation R-value | 0.1 | 14 |
| Window U and SHGC | 1.28, 0.80 | 0.3, 0.25 |
| AC SEER | 10 | 16 |
| Furnace AFUE | 78 | 95 |
| Wall furnace AFUE | 62 | 70 |

Using the response surface method and the above variables, a unique design was created for 8 different groups of homes, representing homes with and without air conditioning, with slab-on-grade and crawlspace construction, and with central gas furnace or gas wall furnace. Each of the resulting designs was in effect a specification for a different set of building energy simulations to execute. The designs were created using Design-Expert® v8 software produced by Stat-Ease.

## Section 2.3 Building Energy Simulations

The building energy simulations were conducted using the calibrated prototypes and batch processing in eQUEST v3.64. The runs used the latest CZ2010 weather data. The number of simulations conducted for each of the eight designs is shown in the table below. The different number of runs is due to different measure applicability across the home groups – for example, the slab-on-grade homes do not allow for application of the under floor insulation measure. Each design must be simulated for all six climate regions and each simulation delivers results for both one and two story homes, and for kWh, kW, and therm impacts, giving the total of 85,212 results.

Table 15 Number of simulations by home characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| **Cooling** | **Heating** | **Floor** | **Number of Runs** |
| AC | Central Furnace | Crawlspace | 472 |
| AC | Wall Furnace | Crawlspace | 472 |
| AC | Central Furnace | Slab-on-grade | 296 |
| AC | Wall Furnace | Slab-on-grade | 296 |
| No AC | Central Furnace | Crawlspace | 296 |
| No AC | Wall Furnace | Crawlspace | 175 |
| No AC | Central Furnace | Slab-on-grade | 230 |
| No AC | Wall Furnace | Slab-on-grade | 130 |
|  |  | **Subtotal** | **2,367** |
|  | Climate Regions | x6 |  |
|  |  | **Simulations** | **14,202** |
|  | 1 and 2 Story | x2 |  |
|  | kWh, kW and therm | x3 |  |
|  |  | **Total Results** | **85,212** |

Before modeling the measures in eQUEST, they had to first be specified in DOE2 keywords and as they specifically applied to the home prototypes. The analyses used to arrive at those inputs for each measure are described below. The full set of eQUEST inputs is provided as Attachment 1.

*Reduce Building Leakage to 30% and 15%*

Building leakage was simulated in eQUEST using the Sherman-Grimsrud infiltration model (INF-METHOD = S-G) with the following inputs:

HOR-LEAK-FRAC = 0.4 (default)

NEUTRAL LEVEL = 0.5 (default)

FRAC-LEAK AREA = Determined from analysis of program data

The FRAC-LEAK AREA for the baseline was derived from contractor measurements of leakage using blower door tests at 50 Pascals. The results from those tests were converted to fractional leakage area as follows:

AL = Q1\*SQRT(ρ/(2Δp2)) \* (Δp2/Δp1)n

[alternatively, using IP units, AL = 0.186\*Q1\*SQRT(ρ/(2Δp2)) \* (Δp2/Δp1)n]

Where:

AL is the leakage area in m2 [or in IP, in2]

Q1 is the measured leakage rate in m3/s [or in IP, in2]

ρ is air density 1.2 kg/m3 [or in IP, 0.075 lbm/ft3]

Δp1 is the pressure difference during the blower door test (50 Pa) [or in IP, 0.2 inH2O]

Δp2 is the natural pressure difference (4 Pa) [or in IP, 0.016 inH2O]

n is the pressure exponent, assumed to be 0.65

Calculate Leak Fraction of Floor Area, LF = AL / FA

Where:

FA is the floor area of the home (m2) [or in IP, in2]

The measure case infiltration rate was then calculated using the same procedure but assuming a 30% and 15% reduction in leakage measured by the blower door test.

*Insulate Duct to R-8*

The insulation of ducts in unconditioned space is increased to an effective value of R-8. To simulate this in eQUEST, the R-value is converted to a UA value following the approach described beginning on page 31 of the T24 2013 Residential ACM Manual [Q].

Supply Duct UA = CFA \* 0.27 \* (1.35 - 0.35\*N) / EDR

Return Duct UA = CFA \* 0.05 \* N / EDR

Where:

CFA = Conditioned floor area of home

N = Number of floors in home

EDR = Effective duct insulation R-value

*Reduce Duct Leakage to 6% (duct replacement) and 10% (duct seal)*

Duct leakage is modeled in eQUEST by manipulating the supply duct air loss fraction. Total duct leakage in the base case is estimated using total duct leakage tests performed at participant homes. These duct leakage tests, performed at 25 Pa, are assumed to represent the actual total leakage when the system is operating. Following the DEER methodology, we assume that in single story homes 75% of that leakage is to unconditioned space and in two story homes 67% is to unconditioned space [26]. Base case leakage from the supply duct is then determined as follows:

Base case Supply Duct Air Loss Fraction (1-story) = Measured Leakage \* 0.5 \* 0.75

Base case Supply Duct Air Loss Fraction (2-story) = Measured Leakage \* 0.5 \* 0.67

Table 16 Base case total duct leakage

|  |  |  |  |
| --- | --- | --- | --- |
| Vintage | Measured Leakage, program participants | Base case Supply Duct Air Loss Fraction (1-story) | Base case Supply Duct Air Loss Fraction (2-story) |
| pre78 | 0.33 | 0.124 | 0.111 |
| 78-92 | 0.26 | 0.098 | 0.087 |
| 93-01 | 0.22 | 0.083 | 0.074 |

In the duct seal and duct replacement measure cases, 10% (duct seal) and 6% (duct replacement) are the post-upgrade total duct leakage. Calculation of the supply duct air loss fraction is done the same way as in the base case.

*Insulation Measures*

The effective resistance of insulation is calculated by combining the resistances of the framing members and the insulation, which may be both in parallel (insulation alongside stud) and in series (insulation over stud). This is done as follows:

Re = 1 / (As / Rs + Ai / Ri,s) + Ri,a

Where:

Re = Effective combined R-value

As = Fractional area of studs in the attic, wall or floor plane

Rs = R-value of stud (3.465 for a 3.5 inch stud and 5.445 for a 5.5 inch stud)

Ai = 1 - As, the area of insulation that is coplanar with studs

Ri,s = the R-value of insulation to the depth of the stud

Ri,a = the R-value of insulation above the stud

*Efficient Air Conditioner (SEER 14 and SEER 15)*

For the purpose of simulations, the new and existing air conditioning units’ performance characteristics are the same as those developed for the DEER 2005 update, which are described in the references documents incorporated in the DEER 2005 Final Report [26].

*Efficient Gas Furnace (AFUE 92% and 95%)*

For simulation in eQUEST, AFUE is converted to a Heat Input Ratio using the conversion documented in the Title 24 Nonresidential Alternative Compliance Manual [62, page 2-74].

Furnace-HIR = 1 / ( 0.011116 \* AFUE - 0.098185 )

This results in a measure case HIR of 1.082 (AFUE 92%) and 1.044 (AFUE 95%). The base case HIR is 1.242 (AFUE 78%), as in DEER.[[1]](#footnote-1)

Efficient Wall Furnace

The efficient wall furnace was simulated using the same procedure as in the existing SoCal Gas work paper for that measure. In this approach, the central heat source is eliminated and wall gas furnaces are required to meet all demand for heat [N]. This is accomplished using the following eQUEST inputs:

HEAT-SOURCE = NONE

BASEBOARD-SOURCE=FURNACE

With heating thus provided by a wall furnace, we then adjust the wall furnace efficiency using the FURNACE-HIR keyword. Calculation of this heat input ratio is done in the same way as for the efficient gas furnace measure, but in this case the efficiency levels are AFUE 62% (base case) and AFUE 70% (efficient case).

High Performance Windows

The base case window efficiency levels reported by the program implementers were provided as Solar Heat Gain Coefficient (SHGC) and U-Value, as are the measure case levels. These were modeled in eQUEST using the same approach used in the DEER 2011 prototypes. SHGC and U-values were converted to shading coefficient and glass conductance using the following formulas:

SHADING COEFFICIENT = SHGC / 0.87 = 0.345

GLASS CONDUCTANCE = 1/(1/U-Factor - 0.2) = 0.43

The preceding discussion illustrates the calculation of base case and measure case inputs to eQUEST. In reality, additional levels were calculated to provide all the samples needed for the design of experiment. After the input levels were calculated for each design, the simulations were conducted using the eQUEST batch processor. The annual energy use (kWh and therm) results from all simulations were combined in a database, as were the peak demand (kW) values. The peak demand (kW) was obtained by extracting the energy use during the defined peak period from the eQUEST hourly output files. The peak period hours, shown in the table below, are those used in DEER 2014.

Table 17 2014 peak demand period, by climate zone

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| CZ | start month | start day | end month | end day | start hour | end hour | CZ |
| 1 | 9 | 16 | 9 | 18 | 15 | 17 | 1 |
| 2 | 7 | 8 | 7 | 10 | 15 | 17 | 2 |
| 3 | 7 | 8 | 7 | 10 | 15 | 17 | 3 |
| 4 | 9 | 1 | 9 | 3 | 15 | 17 | 4 |
| 5 | 9 | 8 | 9 | 10 | 15 | 17 | 5 |
| 6 | 9 | 1 | 9 | 3 | 15 | 17 | 6 |
| 7 | 9 | 1 | 9 | 3 | 15 | 17 | 7 |
| 8 | 9 | 1 | 9 | 3 | 15 | 17 | 8 |
| 9 | 9 | 1 | 9 | 3 | 15 | 17 | 9 |
| 10 | 9 | 1 | 9 | 3 | 15 | 17 | 10 |
| 11 | 7 | 8 | 7 | 10 | 15 | 17 | 11 |
| 12 | 7 | 8 | 7 | 10 | 15 | 17 | 12 |
| 13 | 7 | 8 | 7 | 10 | 15 | 17 | 13 |
| 14 | 8 | 26 | 8 | 28 | 15 | 17 | 14 |
| 15 | 8 | 25 | 8 | 27 | 15 | 17 | 15 |
| 16 | 7 | 8 | 7 | 10 | 15 | 17 | 16 |

## Section 2.4 Regression Models

Once the results were obtained from the building simulations, they were used to create regression models that can be used to estimate the energy performance of a home using inputs for each of the factors used in the DoEx. A separate regression model was needed for each home type, climate region and energy impact. Hence, a total of 288 regressions were required, as shown in the Table 18.

Table 18 Required regression models

|  |  |
| --- | --- |
| Home construction variations | 8 |
| Climate regions | 6 |
| 1 and 2 story | 2 |
| Impact (kWh, kW, therm) | 3 |
| **Total regression models** | **288** |

Design-Expert® was again used to create the regressions. As expected, the response (kWh, therms, or kW) was often non-linear, thus the software recommended appropriate transformations of the response. Several criteria were used in selecting the most appropriate model. These criteria included measures of how well the model fit the data (adjusted R2 and RMSE), the distribution of residuals of the predictions, and appearance of Box-Cox plots for transformations. The resulting regression models include the factors themselves, any terms representing interactions between the factors, and any significant quadratic or cubic terms (depending on the transformation). In some cases, this results in more than 60 terms in the regression model. However, the final energy savings calculator reduces this complexity for users, such that only the measures applied to the home must be chosen.

The resulting regression models have been tested by comparing their energy impact predictions against eQUEST simulations. Specifically, the 20 most common measure packages from the home upgrade program were simulated in eQUEST and the results were compared to the regression models’ predictions for all six climate regions. The results were within five percent, indicating that the regression models are providing a close approximation to the energy consumption that would be estimated by direct simulation of the packages in eQUEST.

## Section 2.5 Domestic Hot Water Measure Additions

There are seven additional measures, not simulated as part of a package, that can be added to packages as individual measures. Those additional measures and their calculation methodologies are summarized in the table below.

Table 19 Summary of calculation methodologies for individual measures

|  |  |
| --- | --- |
| **Measures** | **Calculation Methodology** |
| Efficient Electric Water Heater (93 EF) | Energy impacts for storage hot water heaters were obtained from DEER11 v4.0. See DEER Differences Analysis, above, for details. |
| Efficient Gas Water Heater (62 EF) |
| Efficient Gas Water Heater (67 EF) |
| Tankless Gas Water Heater | Simulated measure in eQUEST with an Energy Factor of 0.82 per the EnergyStar requirement for whole-home tankless gas water heaters [G]. This increase is represented by the following inputs:   * HEAT-INPUT-RATIO equal to 1.3256 * TANK-UA equal to 0 * TANK-VOLUME equal to 1   HEAT-INPUT-RATIO was derived using the following formula, which is based on the methodology for determining hourly fuel energy use of small gas or oil instantaneous hot water heaters presented in the Title 24 2008 Residential Alternative Calculation Manual Appendix E[H]:  HIR = 1/(EF\*0.92)  The formula is derived based on research performed by Davis Energy Group[I] and takes into account minor standby losses incurred from the small volume of water that remains in the heat exchanger, eliminating the need to approximate these losses using the TANK-UA keyword. TANK-VOLUME was set to the eQuest minimum allowed value of 1 gallon. |
| Hot Water Pipe Wrap | Manual calculation. |
| Thermostatic Shut-Off Valve | Energy impacts were obtained from the Southern California Gas Company (2010) Work Paper, “Temperature-Initiated Shower Flow Restriction Valve with and without an Integrated Low-Flow Showerhead.” |
| Low Flow Showerheat with Thermostatic Shut-Off Valve |

## Section 2.6 Total Impact Calculator

A calculator tool, Attachment 3, was created to simplify use of the regression models and to combine the results of the regression models with those of the domestic hot water measures. The calculation tool requires a user to input the basic home characteristics and then to select the efficiency measures that will be applied to the home. Based on these inputs, the tool automatically selects the appropriate regression model to use and the appropriate base case, code case, and measure case inputs to the model. The energy savings are then estimated as the difference between the base case (customer average or code) and measure case.

*1st Baseline: Savings = Customer Average Baseline - Measure Case*

*2nd Baseline: Savings = Code Compliant Baseline - Measure Case*

Energy savings for domestic hot water measures are looked up from a database of energy savings for those measures that is included in the tool. Interactions between multiple measures applied to the domestic hot water system are accounted for in a simplified fashion. If a hot water supply efficiency measure is selected, then the savings of any additional hot water measures are discounted by the percentage savings achieved by the hot water supply measure. This calculation is shown below.

*Total DWH Savings = DHW Supply Measure Savings + (1 - DHW Supply Measure % Savings)\*Additional DHW Measure Savings*

The final energy impacts are then estimated as the sum of the heating and cooling interactive measure impacts and the DHW measure impacts. The calculator tool also estimates the combined cost, EUL, and IR for the measure package.

**2.7 Installation Rate**

The installation rate (IR) is identified in ex-ante database. This value is obtained from the support table available in READi. Currently there is no versioning on the installation rate table. To address appropriate selection of the installation rate the date of the work paper will serve as the last date checked for updated IR values. The installation rate varies by end use, sector, technology, application, and delivery method. The relevant IR values for this measure are shown below.

**Table 20 Installation Rate**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSIA\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID |
| Def-GSIA | Default GSIA values | Any | Any | Any |
| Res-RCA-All | Residential Duct Sealing; Annual Installation Rate | Res | Any | NonUpStrm |
| Res-AC-SCE,  Res-AC-SDG,  Def-GSIA | Res AC Replacement; Annual Installation Rate,  Default GSIA values | Res,  Any | Any | NonUpStrm,  Any |
| Res-WallIns-All | Residential Wall Insulation; Annual Installation Rate | Res | SFm | NonUpStrm |
| Res-Ins-All | Residential Insulation; Annual Installation Rate | Res | SFm | NonUpStrm |
| Res-LowF-SH-All | Residential low-flow Showerhead; Annual Installation Rate | Res | Any | NonUpStrm |
| Def-GSIA | Default GSIA values | Any | Any | Any |

**2.8 Spillage Rate**

Spillage rate will also be applied to measures however the values will not be tracked in the work papers. The spillage rate will be tracked in an external table to be supplied to the Energy Division.

## 2.5 READi Technology Fields

To support the development of the ED ex ante tables, select fields from the ex-ante database will be identified in the work paper. However, for a full set of values associated with the measures in the work paper please refer to the ex-ante database tables.

Table 21 READi Tech IDs

|  |  |
| --- | --- |
| READi Field Name | Values included in this work paper |
| Measure Case UseCategory | Non-DEER |
| Measure Case UseSubCats | Non-DEER |
| Measure Case TechGroups | Non-DEER |
| Measure Case TechTypes | Non-DEER |
| Base Case TechGroups | Non-DEER |
| Base Case TechTypes | Non-DEER |

# Section 3. 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:HVAC\_Eff\_AC load shape. See Table X for a list of all Building Types and Load Shapes. See the KEMA report [31] for a more thorough discussion regarding the load shapes for this measure.

Table 22 Building Types and Load Shapes

|  |  |
| --- | --- |
| Building Type | Load Shape |
| Residential Single Family | DEER:HVAC\_Eff\_AC |

# Section 4. Base Case & Measure Costs

Packages’ costs are estimated as the sum of the costs of the measures they include. Some measure costs, such as furnace and AC costs, depend on the size of the unit, which is in turn influenced by climate zone and vintage. Those variable measure costs are calculated uniquely for each home vintage and climate zone combination, then averaged. Measures with fixed-costs are distributed across applicable vintages and climate zones.

Table 23 Individual Measure Costs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Measure Name | DEER Cost Measure IDa or Source | Unit | Gross Measure Cost | Base case Cost | Incremental Cost |
| Attic Insulation – R30/38 | D08-NE-BldgEnv-RoofIns-CodeRVal | Sq. Ft. | $1.36 | $0 | $1.36 |
| Attic Insulation – R44 | D08-NE-BldgEnv-RoofIns-CodeRVal, ClgIns-AddR11 | Sq. Ft. | $1.76 | $0 | $1.76 |
| Wall Insulation | D08-RB-BS-BlowInIns-R0-R13 | Sq. Ft. | $0.94 | $0 | $0.94 |
| Floor Insulation | D08-RB-BS-FlrIns-R0-R19 | Sq. Ft. | $1.04 | $0 | $1.04 |
| Duct Leakage-Reduce to 10% | DuctSeal-high | Home | $497.62 | $0 | $497.62 (CZ1,3-8)  $0 (CZ2, 9-16) |
| Duct Leakage-Reduce to 6% | [R] | Home | $1,744 | $0 | $1,744 (CZ1,3-8)  $1,247 (CZ2, 9-16) |
| Building Leakage-Reduce by 30% | [G,H,I,J] | Home | $525.00 | $0 | $525.00 |
| Building Leakage-Reduce by 15% | [G,H,I,J] | Home | $350.00 | $0 | $350.00 |
| Hot Water Heater, EF=0.62 | [215] | Unit | $631.30 | $564.06 | $67.24 |
| Hot Water Heater, EF=0.67 | [L] | Unit | $1,656.00 | $564.06 | $1,091.94 |
| Hot Water Heater, EF=0.93 | [215] | Unit | $529.30 | $480.47 | $48.83 |
| Furnace Replacement, AFUE 92% | EffFurn-cond-92AFUE | kBtuh | $20.30 | $14.50 | $5.80 |
| Furnace Replacement, AFUE 95% | EffFurn-cond-94AFUE, EffFurn-cond-96AFUE | kBtuh | $23.07 | $14.50 | $8.57 |
| Wall Furnace | [N] | kBtuh | $30.48 | $29.96 | $1.52 |
| AC Replacement SEER14 | D08-RE-HV-ResAC-S14 | Ton | $1,179 | $1,060 | $119 |
| AC Replacement SEER15 | D08-RE-HV-ResAC-S15 | Ton | $1,298 | $1,060 | $238 |
| Duct Insulation Replacement | D03-075 | Sq. Ft. | $3.08 | $0 | $3.08 |
| Tankless Hot Water Heater, EF=0.87 | D03-940 | Unit | $1,114.50 | $474.18 | $640.32 |
| Pipe Wrap | D03-936 | Ft | $2.80 | $0 | $2.80 |
| Shower thermostatic valve | [M] | Valve | $44.95 | $0 | $44.95 |
| Shower thermostatic valve with low flow showerhead | [M] | Valve and  showerhead | $54.95 | $0 | $54.95 |
| High Performance Windows | Win-tint-0p35U-0p32S | Sq. Ft. | $21.69 | $21.69 | $0b |

a Measure IDs are as listed in [18] and [215]. b Deviates from DEER due to measure equivalence with T24 (2013) requirement.

## 4.1 Base Case Cost

For most measures, the base case cost is assumed to be zero because they are discretionary modifications to the customers’ existing equipment (REA). Their alternative is to make no changes to their existing system. However, for the retrofit measures (RET) there exists a theoretical base case that the measure can be compared to in cost. The base case costs of individual measures are shown in Table 23.

## 4.2 Gross Measure Cost

Wherever possible, the individual measure costs are adopted from DEER. Alternative sources are used as necessary, and are described in the following sections. Individual measure costs are summed to arrive at total measure package costs. This summation is shown in the attached calculation tool.

## 4.3 Incremental Measure Cost

### 4.3.1 Gross Measure Cost

Estimated Gross Measure costs are based on DEER whenever available, and other industry sources. Below is a summary of the cost estimation methodology used for each measure.

* Attic Insulation: DEER Material plus labor, per ft2 basis, multiplied by DEER prototype attic surface area for appropriate vintage.
* Floor Insulation: DEER Material plus labor, per ft2 basis, multiplied by DEER prototype floor surface area for appropriate vintage.
* Wall Insulation: DEER Material plus labor, per ft2 basis, multiplied by DEER prototype exterior wall surface area for appropriate vintage.
* Building Leakage (Air Sealing): Per building cost based on estimated costs and reported costs from weatherization programs in the Northwest and Midwest, adjusted to 2008 California costs using RSMeans 2010 city cost indices and inflation estimates from US Bureau of Labor Statistics [G, H]. The Northwest’s estimated cost for air sealing is $250 per home (year=2000) [I]. Air sealing costs (labor and materials) from the Iowa Weatherization Program were $395 per home, on average (year=2008) [J].
* Duct Leakage (Duct Sealing): For duct sealing, the cost is adopted from DEER [215]. For duct replacement, an assumed 86 linear feet of duct replaced, derived from the duct area of the DEER prototypes, combines with an installed cost of $10.90 per linear foot from RS Means 2013. Additional costs of fittings are estimated as four connections ($21.50ea), four elbows ($73.00ea), and three tees ($143ea) [R].
* Domestic Hot Water Heater- 0.62 EF: Measure cost reflects full cost of equipment as reported in DEER.
* Domestic Hot Water Heater- 0.67 EF: Measure cost based on DOE estimated incremental cost of a EF 0.67 gas water heater [L]. Incremental cost is added to the DEER 0.62 EF base case cost to obtain the gross measure cost.
* Domestic Hot Water Heater-0 .93 EF: Measure cost reflects full cost of equipment as reported in DEER.
* Furnace Replacement: Measure cost on a per kBtu/h basis reflects full cost of equipment plus labor. Furnace size informed by market availability and DEER prototypes for appropriate vintage and climate zone.
* AC Replacement: Measure cost on a per kBtu/h basis reflects full cost of equipment plus labor. AC size informed by market availability and DEER prototypes for appropriate vintage and climate zone.
* Duct Insulation: Measure cost on a per ft2 basis was obtained from DEER for a measure that increases existing duct insulation levels in older vintage buildings to achieve R-8. The average total duct area is estimated using the DEER prototypes’ floor area and the procedure in the Title 24 Residential Alternative Calculation Manual [B, 63]. Only half the total duct area is assumed to be accessible. Therefore the total cost per home is estimated as the product of the DEER measure cost and one-half the average duct area.
* High Performance Windows: Measure cost on a per ft2 basis was obtained from DEER. The assumed area of windows upgraded for each vintage is the average window area of the vintage-specific home prototypes: 251 ft2 (pre78), 242 ft2 (78-92), 464 ft2 (93-01).
* Pipe wrap: Measure cost on a per ft basis was obtained from DEER and multiplied by 5 ft [215].
* Shower thermostatic valve, and shower thermostatic valve with low flow showerhead: Costs were adopted from the SoCal Gas work paper SCGWP100303B [M].

### 4.3.2 Incremental Measure Cost

For RET measures, the estimated Incremental Measure costs are based on the DEER Measure Cost table, work papers and market research. Below is a summary of the cost estimation methodology used for each measure.

* Duct Leakage (Duct Sealing): Title 24 (2008) requires duct sealing in climate zones 2, and 9-16 when heating or cooling equipment is upgraded [66]. Therefore, in those climate zones the incremental cost is zero (10% measure level), or the cost premium for replacing instead of sealing ducts (6% measure level). In other climate zones, where duct sealing is not required, the incremental measure cost is the same as the gross measure cost.
* Domestic Hot Water Heater-0 .62 EF: Measure cost on a per unit basis reflects incremental equipment cost reported in DEER. Labor is assumed to be the same for installation of the measure case and a standard efficiency unit.
* Domestic Hot Water Heater-0 .67 EF: Measure cost based on DOE estimated incremental cost of a EF 0.67 gas water heater [L].
* Domestic Hot Water Heater-0 .93 EF: Measure cost on a per unit basis reflects incremental equipment cost reported in DEER. Labor is assumed to be the same for installation of the measure case and a standard efficiency unit.
* Furnace Replacement: Measure cost on a per kBtu/h basis reflects incremental equipment cost reported in DEER. Labor is assumed to be the same for installation of the measure case and a standard efficiency unit. Furnace size informed by market availability and DEER prototypes for appropriate vintage and climate zone.
* AC Replacement: Measure cost on a per kBtu/h basis reflects incremental equipment cost reported in DEER. Labor is assumed to be the same for installation of the measure case and that of a standard efficiency unit. AC size informed by market availability and DEER prototypes for appropriate vintage and climate zone.
* High Performance Windows: Measure case is equal to the Title 24 (2013) requirement, so the incremental cost is assumed to be zero.

# Attachments

1. Simulation inputs



2. Regression results



3. Calc tool



# References



[18]

[26]

[31]

[62]

[63]

[66]

[131]

[215]

[355]

[422]

[436]

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[C] “2005DEERResidentialMeasuresList\_05-08-15,” in “DEER 2005 Final Report in MS Word format with references,” prepared by Itron and available at deeresources.com.

[D] “UnitSelectionAndEnergySavingsForResidentialSplitSystems-V10C,” in “DEER 2005 Final Report in MS Word format with references,” prepared by Itron and available at deeresources.com.

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[L] DOE (2010), “Residential Heating Products Final Rule Technical Support Document, available at www1.eere.energy.gov/buildings/appliance\_standards/residential/heating\_products\_fr\_tsd.html.

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[O] US Congress (1987), National Appliance Energy Conservation Act of 1987, www.gpo.gov/fdsys/pkg/STATUTE-101/pdf/STATUTE-101-Pg103.pdf

[P] CPUC (2013), “DEER for 2014 Code Update” SupportTable GSIA (csv), READI v.1.0.4.

[Q] CEC (2013), “2013 Residential Alternative Calculation Method” California Energy Commission, CEC-400-2013-003-SD-REV.

[R] R.S. Means Company (2013). RSMeans Building Construction Cost Data 2013.

1. The base case HIR does not result from an input of 78 AFUE into the above equation, because the Title 24 Nonresidential Alternative Compliance Manual uses a different equation for systems with AFUE < 83.5. [↑](#footnote-ref-1)