Work Paper SCE17MI005

Revision 0

**Southern California Edison**

Energy Upgrade California – Prescriptive Whole Home Upgrade

**For Work Paper Reviewer Use Only**

**List all major comments that occurred during the review. This table may only be removed during management review.**

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| --- | --- | --- | --- |
| **Major Comment** | **Reviewer Name** | **Date** | **Outcome/Resolution** |
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# At-a-Glance Summary

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| --- | --- |
| **Measure Codes** | 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 |
| **Units** | per home |
| **Energy Savings** | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment |
| **Effective Useful Life** | Varies by measure package from 11 to 20 years; measure EULs averaged to determine package EULs. |
| **Measure Installation Type** | Retrofit Add-On (REA) or Accelerated Replacement(AR) |
| **Net-to-Gross Ratio** | 0.7 (DEER NTGR ID: EUC-Default, DEER2016) |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

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| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 10/09/2017 | James Russell, Thomas Anreise/CLEAResult  Andres Fergadiotti/SCE | * Updated to latest statewide work paper template * Updated Duct leakage measure requirements to align with Title 24 (2016) * Updated High Performance Windows measure to use existing baseline, in conformance with D.13-11-008. * Updated Thermostatic Shut-Off Valve and Low Flow Showerhead measure per updates to work paper SCGWP100303B Rev6 * Updated Thermostatic Shut-Off Valve (work paper SCGWP100303B Rev6) * Added Auto-Diverting Tub Spout measure (work paper SWWH001v00) * Specified EER requirement for AC Replacement measure * Reviewed and updated cost data sources * Updated package EUL and GSIA values using simplified measure weighting method * Updated natural gas water heating measures per the June 2017 DEER update, which reflects an adjustment of the baseline conditions and efficient case conditions. * Updated the Efficient Air Conditioner measure per the June 2017 DEER update, which modified the Existing Condition from SEER 10 to SEER 11.4. * See Log tab in calculator (Attachment 4) for modifications |

# Commission Staff and Cal TF Comments

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| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
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Cal TF website: <http://www.caltf.org/>

# 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, all Program Administrators (PAs). 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 Description & Background

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 1.1.2).

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 a complementary Ex Ante Database data set. Measure implementation tables describing the 146 measure packages offered by the PAs that, based on an analysis conducted in early 2017, together account for 80% of the energy savings and 88% of all projects reported by the PAs for 2015 and 2016 – See Attachment 1 [AA]. 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.

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 Measures and Codes table below.

Due to the large potential number of measures, the package measure codes will be updated on a quarterly basis as claims arise, using the methodologies defined within this work paper.

Measures and Codes

|  |  |
| --- | --- |
| **Measure Code** | **Measure Name** |
| L15 | Reduce Building Leakage (15%) |
| L30 | Reduce Building Leakage (30%) |
| iD8 | Insulate Duct (R8) |
| DL10 | Reduce Duct Leakage (10%) |
| DL5 | Reduce Duct Leakage (5%) |
| iA30/iA38 | Insulate Attic (R30/R38) |
| iA44 | Insulate Attic (R44) |
| iF19 | Insulate Floor (R19) |
| iW13 | Insulate Wall (R13) |
| hPW | High Performance Windows (U0.30, SHGC0.25) |
| eAC15 | Efficient Air Conditioner (SEER 15) |
| eF92 | Efficient Furnace (AFUE 92%) |
| eF95 | Efficient Furnace (AFUE 95%) |
| wF70 | Efficient Wall Furnace (AFUE 70%) |
| eH200 | Efficient Electric Water Heater (EF) |
| H67 | Efficient Gas Water Heater (67 EF) |
| H70 | Efficient Gas Water Heater (70 EF) |
| tH82 | Tankless Gas Water Heater (82 EF) |
| WRAP | Hot Water Pipe Wrap (1.0 Inch) |
| STV | Thermostatic Shut-Off Valve |
| STFLF | Thermostatic Shut-Off Valve & Low-Flow Showerhead |
| ADTV | Auto Diverting Tub Spout with Thermostatic Shut-Off Valve |

### Base Case Description

The base case in this work paper 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 the Climate Zone Regions table below.

These climate regions and the proxy climate zone for each region were selected based on two main considerations:

* An analysis of the eQUEST simulation results from Revision 0 and 1 of this work paper indicated only modest differences in kWh, kW and therm impacts across many similar climates, and
* Where the program delivery has been greatest and where it is expected to grow in the future.

Climate Zone 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 later in Section 2.3. 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.

Existing conditions are field verified by program implementers. Data collection process includes all home characteristics and parameters needed to support the evaluation of measure savings potential using companion calculator. These include the following:

* Climate zone (zip code)
* Vintage
* Floor Construction
* Air Conditioning
* Heating Type
* Water Heating Type
* Number of Stories

Other home characteristics including envelope insulation levels and HVAC vintage are based on latest DEER documentation given SFM vintage.

### Eligibility and Implementation 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 participating 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, and the remaining two measures may be from either Group A or Group B.

Fourteen 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 eight measures interact with the domestic hot water (DHW) system. Further, the interaction between the DHW system and heating and cooling system is assumed to be negligible. The system for interactions for each measure is described in the table below.

The group assigned to each measure as well as the system for interactions is described in the table below.

Individual Measure Group Assignment and System for Interactions

|  |  |  |
| --- | --- | --- |
| **Measure Name** | **Group Assignment** | **System for Interactions** |
| Reduce Building Leakage (15%) | Group A (Base Measure) | Heating & Cooling |
| Reduce Building Leakage (30%) |
| Insulate Duct (R8) | Group B |
| Reduce Duct Leakage (10%) | Group A (Base Measure) |
| Reduce Duct Leakage (5%) |
| Insulate Attic (R30/R38) | Group A (Base Measure) |
| Insulate Attic (R44) |
| Insulate Floor (R19) | Group B |
| Insulate Wall (R13) | Group B |
| High Performance Windows (U0.30, SHGC0.25) | Group B |
| Efficient Air Conditioner (SEER 15) | Group B |
| Efficient Furnace (AFUE 92%) | Group B |
| Efficient Furnace (AFUE 95%) |
| Efficient Wall Furnace (AFUE 70%) | Group B |
| Efficient Electric Water Heater (200 EF) | Group B | Domestic Hot Water |
| Efficient Gas Water Heater (67 EF) |
| Efficient Gas Water Heater (70 EF) |
| Tankless Gas Water Heater (82 EF) |
| Hot Water Pipe Wrap (1.0 Inch) | Group B |
| Thermostatic Shut-Off Valve | Group B |
| Thermostatic Shut-Off Valve & Low-Flow Showerhead | Group B |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | Group B |

Given the nature of the measures, most participating homes are expected to be from one of the three modeled vintages: pre-1978 (“pre78”), 1978-1992 (“78-92”), and 1993-2001 (“93-01”). Older homes are targeted and home age is a program requirement. Newer homes can be served through the Advanced Home Upgrade program.

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

## 1.2 Technical Description

The characteristics of participant homes within each vintage and climate region were estimated using data from the home energy audits conducted in the Advanced Home Upgrade (previously referred to as EUC Advanced Path) program from 2011 through 2013. 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

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.

Base, Standard, and Measure Cases

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Name** | **Vintage** | **Infiltration Level (ACHn)** | | |
| Existing Condition | Code/Standard† | Measure |
| Reduce Building Leakage (15%) | pre78 | 0.66 | Not applicable | 0.56 |
| 78-92 | 0.48 | 0.41 |
| 93-01 | 0.43 | 0.36 |
| Reduce Building Leakage (30%) | pre78 | 0.66 | Not applicable | 0.46 |
| 78-92 | 0.48 | 0.35 |
| 93-01 | 0.43 | ineligible |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The Title 24 (2016) requirement in Section 110.7 is that “All joints, penetrations and other openings in the building envelope that are potential sources of air leakage shall be

caulked, gasketed, weather stripped, or otherwise sealed to limit infiltration and exfiltration.” The measure levels do not exceed this requirement.

The base case infiltration was determined by measuring the leak fraction of floor area from program participants and shown in the table below.

Program Participant Infiltration

|  |  |  |  |
| --- | --- | --- | --- |
| **Vintage** | **Infiltration - program participants** | | **DEER 2011 for**  **comparison** |
| 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

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. The existing condition is based on program participants. This measure is not applicable if there is no existing heating or cooling equipment including air duct distribution systems. It is highly recommended for program participants to implement this measure (insulate ducts) only after the reduce duct leakage measure has been implemented.

Base, Standard, and Measure Cases

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Name** | **Vintage** | **Duct R-Value** | | | |
| Existing Condition | Code/Standard† | Measure | DEER 2011 for  Comparison |
| Insulate Duct (R8) | pre78 | 3.32 | Not applicable | 8 | 2.8 |
| 78-92 | 3.67 | 2.8 |
| 93-01 | 4.26 | 4.9 |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The measure level is equal to the Title 24 (2016) requirement for climate zones 11 and 14-16 and above the requirement of R-6 for climate zones 1-10,12 and 13.

Reduce Duct Leakage

There are two eligible measures to reduce duct leakage. Duct replacement can be applied to reduce total duct leakage to 5% of system airflow. Alternatively, duct sealing can be applied to reduce total duct leakage to 10% of system airflow. The existing condition is based on program participants. This measure is not applicable if there is no existing heating or cooling equipment.

Base, Standard, and Measure Cases

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Name** | **Vintage** | **Percent Total Duct Leakage** | | | |
| Existing Condition | Code/Standard† | Measure | DEER 2011 for  comparison |
| Reduce Duct Leakage (10%) | pre78 | 33% | Not applicable | 10% | 28% |
| 78-92 | 26% | 21% |
| 93-01 | 22% | 14% |
| Reduce Duct Leakage (5%) | pre78 | 33% | Not applicable | 5% | 28% |
| 78-92 | 26% | 21% |
| 93-01 | 22% | 14% |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The measure levels are more stringent than the Title 24 (2016) requirement for alterations (see Section 1.4.2).

Insulate Attic

The level of attic insulation on the attic floor (also referred to as ceiling insulation) is increased to either R-30 or R-38 depending on the climate zone or R-44. The existing condition is based on program participants and additionally summarized by Climate Region and applies to all attic insulation measure levels. The measure case is summarized in a separate table by Climate Zone.

Base and Standard Cases

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Region** | **Vintage** | **Attic R-Value** | | |
| Existing Condition | Code/Standard† | DEER 2011 for  comparison |
| NC (3) | pre78 | 6.68 | Not applicable | 6.71 |
| 78-92 | 10.31 | 24.13 |
| 93-01 | 10.31 | 38.13 |
| SC (7) | pre78 | 9.12 | 7.39 |
| 78-92 | 11.48 | 18.53 |
| 93-01 | 16.55 | 30.13 |
| IS (9) | pre78 | 11.12 | 6.88 |
| 78-92 | 14.28 | 18.13 |
| 93-01 | 17.33 | 30.13 |
| CR (4) | pre78 | 11.05 | 6.71 |
| 78-92 | 13.87 | 24.13 |
| 93-01 | 19.33 | 38.13 |
| CVS (12) | pre78 | 11.93 | 6.88 |
| 78-92 | 15.9 | 19.73 |
| 93-01 | 17.74 | 38.13 |
| CVD (13) | pre78 | 15.41 | 6.88 |
| 78-92 | 18.17 | 19.73 |
| 93-01 | 22.91 | 38.13 |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The R-30/R-38 measure level is equal to the T24 (2016) code requirement per 150.1-A and the R-44 measure exceeds the requirement.

Measure Case

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Climate Region** | **Climate Zone** | **Attic R-Value** |
| Measure |
| Attic Insulation (R-30/R-38) | NC (3) | 1 | 38 |
| 3 | 30 |
| 5 | 30 |
| SC (7) | 6 | 30 |
| 7 | 30 |
| 8 | 30 |
| IS (9) | 9 | 30 |
| 10 | 30 |
| CR (4) | 2 | 30 |
| 4 | 30 |
| CVS (12) | 12 | 38 |
| 16 | 38 |
| CVD (13) | 11 | 38 |
| 13 | 38 |
| 14 | 38 |
| 15 | 38 |
| 16 | 38 |
| Attic Insulation (R-44) | All | All | 44 |

Insulate Wall

The level of wall insulation is increased to R-13. The existing condition is based on program participants and additionally summarized by Climate Region.

Base and Standard Cases

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Name** | **Climate Region** | **Vintage** | **Wall R-Value** | | | |
| Existing  Condition | Code/Standard† | Measure | DEER 2011 for  comparison |
| Insulate Wall (R-13) | NC (3) | pre78 | 0.96 | Not applicable | 13 | 5.18 |
| 78-92 | 10.25 | 15.38 |
| 93-01 | 10.25 | 18.23 |
| SC (7) | pre78 | 0.96 | 7.82 |
| 78-92 | 10.25 | 11.91 |
| 93-01 | 10.25 | 12.42 |
| IS (9) | pre78 | 0.96 | 6.68 |
| 78-92 | 10.25 | 12.19 |
| 93-01 | 10.25 | 12.41 |
| CR (4) | pre78 | 3.1 | 5.18 |
| 78-92 | 10.25 | 15.38 |
| 93-01 | 10.25 | 18.23 |
| CVS (12) | pre78 | 3.1 | 6.68 |
| 78-92 | 10.25 | 11.73 |
| 93-01 | 10.25 | 16.85 |
| CVD (13) | pre78 | 3.1 | 6.68 |
| 78-92 | 10.25 | 11.73 |
| 93-01 | 10.25 | 16.85 |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The measure level is equal to the Title 24 (2016) requirement equivalent to R-13 insulation in 2x4 framing per Section 150.0(b).

Insulate Floor

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

Base, Standard, and Measure Cases

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Name** | **Vintage** | **Floor R-Value** | | | |
| Existing Condition | Code/Standard† | Measure | DEER 2011 for  comparison |
| Insulate Floor (R-19) | pre78 | 1.34 | Not applicable | 19 | 5.51 |
| 78-92 | 5.96 | N/A |
| 93-01 | 5.96 | N/A |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The measure level is equal to the Title 24 (2016) requirement equivalent to R-19 insulation in a wood framed assembly per Section 150.0(d).

Among the DEER 2011 prototypes, 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

New high performance windows are installed in place of all existing windows. The new windows shall have NFRC-certified ratings at levels which meet or exceed the minimum ENERGY STAR criteria, which are a U-factor of 0.30 and Solar Heat Gain Coefficient (SHGC) of 0.25 [X]. Air Leakage ratings on all new windows shall be less than 0.3 cfm/sqft of window area when tested according to NFRC-400 or ASTM E283 at a pressure differential of 75 pascals. The existing condition is based on program participants and additionally summarized by Climate Region.

The total surface area of glazing replaced and varies by vintage and number of stories, as shown below.

Window Glazing

|  |  |  |  |
| --- | --- | --- | --- |
| **Number of Stories** | **Vintage** | **Window Glazing** | |
| Surface Area(ft2) | % Wall Area |
| 1-Story | pre78 | 171 | 17.10% |
| 78-92 | 158 | 13.80% |
| 93-01 | 308 | 25.50% |
| 2-Story | pre78 | 226 | 15.30% |
| 78-92 | 223 | 12.80% |
| 93-01 | 472 | 24.20% |

Base and Standard, and Measure Cases

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure Name** | **Climate**  **Region** | **Vintage** | **Window U-Factors and SHGC** | | | | | |
| Existing Condition | | Code/Standard† | | Measure | |
| U-Factor | SHGC | U-Factor | SHGC | U-Factor | SHGC |
| High Performance Windows (U0.30, SHGC0.25) | NC (3) | pre78 | 1.23 | 0.87 | Not applicable | | 0.30 | 0.25 |
| 78-92 | 0.82 | 0.79 |
| 93-01 | 0.67 | 0.79 |
| SC (7) | pre78 | 1.23 | 0.87 |
| 78-92 | 1.15 | 0.87 |
| 93-01 | 0.67 | 0.79 |
| IS (9) | pre78 | 1.23 | 0.87 |
| 78-92 | 1.18 | 0.87 |
| 93-01 | 0.67 | 0.61 |
| CR (4) | pre78 | 1.23 | 0.87 |
| 78-92 | 0.82 | 0.79 |
| 93-01 | 0.67 | 0.79 |
| CVS (12) | pre78 | 1.23 | 0.87 |
| 78-92 | 0.935 | 0.83 |
| 93-01 | 0.62 | 0.7 |
| CVD (13) | pre78 | 1.23 | 0.87 |
| 78-92 | 1.14 | 0.87 |
| 93-01 | 0.57 | 0.55 |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The measure level is slightly better than the Title 24 (2016) requirement of a maximum U-factor of 0.32 and maximum SHGC of 0.25 per 150.1-A.

Efficient Air Conditioner

A new central air conditioner is installed. The new unit must replace an existing unit (or units) and serve as the primary cooling equipment for the home. The new unit has a seasonal energy efficiency ratio (SEER) of 15 and an Energy Efficiency Ratio (EER) of 12.72 [D]. The existing AC unit has a SEER of 11.4 based on a DEER2017 analysis of the CLASS database and did not specify an associated EER [Z]. This measure is not applicable if the existing cooling equipment is a heat pump.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Air Conditioner SEER Value** | | |
| Existing Condition | Code/Standard | Measure |
| Efficient Air Conditioner (SEER 15) | 11.4 | 14 | 15 |

Efficient Gas Furnace

A new gas furnace is installed. The new unit must replace an existing unit (or units) and serve as the primary heating equipment for the home. The new unit has an annual fuel utilization efficiency (AFUE) of either 92% or 95%. The existing gas furnace has an AFUE of 80% [A; 62, page 2-74]. The Title 20 (2017) code/standard gas furnace also has an AFUE of 80%. This measure is not applicable if the existing heating equipment is not a gas furnace.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Gas Furnace AFUE** | | |
| Existing Condition | Code/Standard | Measure |
| Efficient Gas Furnace (AFUE 92%) | 80% | 80% | 92% |
| Efficient Gas Furnace (AFUE 95%) | 80% | 80% | 95% |

Efficient Wall Furnace

A new, natural gas, gravity wall furnace is installed. The new unit has an AFUE of 70%. The existing wall furnace has an AFUE of 62%, which is the required efficiency after 1990 from National Appliance Energy Conservation Act of 1987 [O]. The Title 20 (2017) code/standard wall furnace has an AFUE of 66%. This measure is not applicable if the existing heating equipment is not a wall furnace.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Wall Furnace AFUE** | | |
| Existing Condition | Code/Standard | Measure |
| Efficient Wall Furnace (AFUE 70%) | 62% | 66% | 70% |

Efficient Electric Water Heater

A new electric storage water heater with an energy factor (EF) The revised existing electric storage water heater has an EF of 0.92 [E] as opposed to the previous DEER 2015 measure that had an EF 0f 0.86. This measure is provided by DEER READI, as described later in Section 2.5. This measure is not applicable for replacing existing gas water heating equipment. The storage tank capacity is limited to what is considered a “small tank” under the Title 20 and federal standard regulations. Products in this category are considered residential products and are currently manufactured to a maximum capacity in the efficient case at 80 gallons. The standard sizes used in the savings analysis remained under 55 gallons due to an increase in efficiency requirements above 55 gallons, therefore the maximum capacity tank water heater should be limited to 55 gallons.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Electric Water Heater EF Value** | | |
| Existing Condition | Code/Standard | Measure |
| Efficient Electric Water Heater (EF 3.24) | 0.92 | 0.95 | 3.24 |
| Efficient Electric Water Heater (EF 3.50) | 0.92 | 0.95 | 3.50 |

Efficient Gas Water Heater

A new natural gas storage water heater with an EF of either 0.67 or 0.70. The existing natural gas storage water heater has an EF of 0.59 [E]. This measure is provided by DEER READI, as described later in Section 2.5. This measure is not applicable for replacing existing electric water heating equipment.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Gas Water Heater EF Value** | | |
| Existing Condition | Code/Standard | Measure |
| Efficient Gas Water Heater (EF 67) | 0.59 | 0.60 | 0.67 |
| Efficient Gas Water Heater (EF 70) | 0.59 | 0.60 | 0.70 |

Tankless Gas Water Heater

A new natural gas tankless water heater with an EF of 0.82. The existing natural gas storage water heater has an EF of 0.52 [E]. This measure is provided by DEER READI, as described later in Section 2.5. This measure is not applicable for replacing existing electric water heating equipment.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Tankless Gas Water Heater EF Value** | | |
| Existing Condition | Code/Standard | Measure |
| Tankless Gas Water Heater (EF 82) | 0.52 | 0.74 | 0.82 |

Hot Water Pipe Wrap

5 feet of pipe are insulated with R-4.7 pipe wrap. Pipe (thermal) insulation shall have a minimum insulation thickness of 1.0 inch. The existing conditions assume a bare ¾ inch copper piping in unconditioned space. This measure calculation is provided in Section 2.5.

Base, Standard, and Measure Cases

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Name** | **Hot Water Pipe Wrap** | | |  |
| Existing Condition | Code/Standard† | Measure | Insulation Thickness |
| Hot Water Pipe Wrap (5ft of R-4.7) | None | Not applicable | 5ft of R-4.7 | 1.0 inch |

† Per the adopted Default Baseline Policy for All Sectors (Resolution E-4818), the code/standard level does not apply to this measure. The measure level is similar to the Title 24 (2016) requirement for application of 1 inch of insulation to accessible piping per 150.2(b) and 120.3-A.

Shower Thermostatic Shut-Off Valve

Temperature-initiated flow-restriction valves (TSV) 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. The existing condition assumes a conventional showerhead, with a flow of 2.25 gallons per minute (gpm), without thermostatic shut-off valve. This measure is provided by DEER READI, as described later in Section 2.5.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Shower Thermostatic Shut-Off Valve** | | |
| Existing Condition | Code/Standard | Measure |
| Shower Thermostatic Shut-Off Valve | No TSV, 2.25gpm | None | TSV, 2.25 GPM |

Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead

A low-flow showerhead, with flow of 1.6 gpm or less, is installed with the Shower Thermostatic Shut-Off Valve, as described in the Shower Thermostatic Shut-Off Valve measure. The existing condition assumes a conventional showerhead, with flow of 2.25 gpm. This measure is provided by DEER READI, as described later in Section 2.5.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Shower Thermostatic Shut-Off Valve** | | |
| Existing Condition | Code/Standard | Measure |
| Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead | No TSV, 2.25 gpm | 2.25 gpm showerhead | TSV, 1.6 GPM |

Auto Diverting Tub Spout with Thermostatic Shut-Off Valve

The Auto-diverting tub spout (5.0 gpm) with thermostatic shut-off valve purges cold water through tub spout until the water raises to 95° F. The water is then diverted to the showerhead at a trickle until full flow (1.5 gpm) is activated via the pull cord. The existing condition assumes a 5.0 gpm tub spout with 1.8 gpm showerhead combination. This measure calculation is based on a prior work paper. Further details are provided in Section 2.5.

Base, Standard, and Measure Cases

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **Shower Thermostatic Shut-Off Valve** | | |
| Existing Condition | Code/Standard | Measure |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | No TSV, 5.0 gpm Tub Spout, 1.8 gpm Showerhead | 5.0 gpm tub spout with a 2.0 gpm showerhead | TSV, 5.0 gpm Tub Spout, 1.5 gpm Showerhead |

## 1.3 Installation Types and Delivery Mechanisms

The Installation Type varies by each individual measure and is summarized in the Installation Type by Measure table below. Refer to the Installation Type Descriptions table for further explanation of the installation types.

Installation Type Descriptions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Retrofit or Accelerated Replacement (AR) | Above Customer Existing | Above Code or Standard | RUL | EUL-RUL |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | EUL | N/A |

Installation Type by Measure

|  |  |
| --- | --- |
| **Measure Name** | **Installation Type** |
| Reduce Building Leakage (15%) | REA |
| Reduce Building Leakage (30%) | REA |
| Insulate Duct (R-8) | REA |
| Reduce Duct Leakage (10%) | REA |
| Reduce Duct Leakage (5%) | REA |
| Insulate Attic (R-30/R-38) | REA |
| Insulate Attic (R-44) | REA |
| Insulate Floor (R-19) | REA |
| Insulate Wall (R-13) | REA |
| High Performance Windows (U0. 30, SHGC0.25) | REA |
| Efficient Air Conditioner (SEER 15) | AR |
| Efficient Furnace (AFUE 92%) | AR |
| Efficient Furnace (AFUE 95%) | AR |
| Efficient Wall Furnace (AFUE 70%) | AR |
| Efficient Electric Water Heater (200 EF) | AR |
| Efficient Gas Water Heater (67 EF) | AR |
| Efficient Gas Water Heater (70 EF) | AR |
| Tankless Gas Water Heater (82 EF) | AR |
| Hot Water Pipe Wrap (1.0 Inch) | REA |
| Shower Thermostatic Shut-Off Valve | REA |
| Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead | REA |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | REA |

The installation type for a package of measures will be REA unless an AR measure is included in the package.

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings. The delivery mechanism is Financial Support - Down-Stream Incentive.

Delivery Method Descriptions

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized.  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. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

DEER 2017 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.

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Work paper** |
| Modified DEER methodology | Yes |
| Scaled DEER measure | No |
| DEER Base Case | Yes for measure savings from DEER, No for simulated measures |
| DEER Measure Case | Yes for measure savings from DEER, No for simulated measures |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | Yes, with baseline characteristics adjusted and energy use calibrated to match that of past program participants |
| DEER Version | DEER 2017 |
| Reason for Deviation from DEER | DEER does not combine measures to account for their interactive effects |
| DEER Measure IDs Used | 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 2017. 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 described further in Section 2.5.

**Net-to-Gross Ratio**

The Net-to-Gross (NTG) Ratio is used to estimate and describe free-ridership. The NTG values were obtained using the DEER 2017, READI tool [E]. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| EUC-Default | Energy Upgrade California | Res | Any | Any | 0.70 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The Installation Rate (IR) addresses the percentage of units that are claimed but not installed. The IR values were obtained using the DEER 2017, READI tool [E]. Where no IR was specified by DEER 2017, the Def-GSIA ID was used. The relevant IR values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |
| Res-Ins-All | Residential Insulation; Annual Installation Rate | Res | SFm | NonUpStrm | 0.865 |
| Res-DuctSeal-All | Residential Duct Sealing; Annual Installation Rate | Res | Any | NonUpStrm | 0.463 |
| Res-AtticIns-All | Residential Attic Insulation; Annual Installation Rate | Res | SFm | NonUpStrm | 0.782 |
| Res-WallIns-All | Residential Wall Insulation; Annual Installation Rate | Res | SFm | NonUpStrm | 0.946 |
| Res-LowF-SH-All | Residential low-flow Showerhead; Annual Installation Rate | Res | Any | NonUpStrm | 0.737 |

To determine package IRs, the individual measure IRs within each package were combined as a weighted average. The weighting used for each measure was previously the total, 1st baseline energy savings of each individual measure, which varied by climate zone and with home characteristics. However, the method was simplified in Rev4 of the work paper by using one set of measure weights that, based on analysis of the 2015-2016 program data, produced lifecycle savings with less than 2 percent difference from the more complex prior method. The form of this calculation is shown below, followed by the measure weights.

Where:

Package IR is the weighted average IR for a package including n measures

Mi,IR is the IR associated with individual measure, i

Mi,ES is the applied measure weight according to the following table:

Individual Measure Weight and Installation Rate

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **GSIA ID** | **GSIAValue**  **(Mi,IR)** | **Measure**  **Weight**  **(Mi,ES)** |
| Reduce Building Leakage (15%) | Def-GSIA | 1 | 16 |
| Reduce Building Leakage (30%) | Def-GSIA | 1 | 32 |
| Insulate Duct (R-8) | Res-Ins-All | 0.865 | 20 |
| Reduce Duct Leakage (10%) | Res-DuctSeal-All | 0.463 | 40 |
| Reduce Duct Leakage (5%) | Res-DuctSeal-All | 0.463 | 47 |
| Insulate Attic (R-30/R-38) | Res-AtticIns-All | 0.782 | 8 |
| Insulate Attic (R-44) | Res-AtticIns-All | 0.782 | 12 |
| Insulate Floor (R-19) | Res-Ins-All | 0.865 | 35 |
| Insulate Wall (R-13) | Res-WallIns-All | 0.946 | 76 |
| High Performance Windows (U0.30, SHGC0.25) | Def-GSIA | 1 | 89 |
| Efficient Air Conditioner (SEER 15) | Def-GSIA | 1 | 26 |
| Efficient Furnace (AFUE 92%) | Def-GSIA | 1 | 56 |
| Efficient Furnace (AFUE 95%) | Def-GSIA | 1 | 69 |
| Efficient Wall Furnace (AFUE 70%) | Def-GSIA | 1 | 34 |
| Efficient Electric Water Heater (200 EF) | Def-GSIA | 1 | 17 |
| Efficient Gas Water Heater (67 EF) | Def-GSIA | 1 | 54 |
| Efficient Gas Water Heater (70 EF) | Def-GSIA | 1 | 21 |
| Tankless Gas Water Heater (82 EF) | Def-GSIA | 1 | 90 |
| Hot Water Pipe Wrap (1.0 Inch) | Res-Ins-All | 0.865 | 7 |
| Shower Thermostatic Shut-Off Valve | Res-LowF-SH-All | 0.737 | 3 |
| Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead | Res-LowF-SH-All | 0.737 | 35 |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | Def-GSIA | 1 | 3 |

The calculation tool (Attachment 4) provides the weighted IR for each package created.

**Effective and Remaining Useful Life**

The Effective Useful Life (EUL) is an estimate of the median number of years that an installed measure will remain in place and is operational. The EUL and Remaining Useful Life (RUL) values were obtained using the DEER 2017 READI tool [E]. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an AR measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| BS-Wthr | Low-Income Weatherization | Res | Service | 11 | 3.7 |
| HVAC-DuctInsul | Duct Insulation Material | Com | HVAC | 20 | 6.7 |
| HV-DuctSeal | Duct Sealing | Res | HVAC | 18 | 6 |
| BS-CeilIns | Roof/Ceiling Insulation - Residential | Res | BldgEnv | 20 | 6.7 |
| BS-FlrIns | Floor Insulation - Residential | Res | BldgEnv | 20 | 6.7 |
| BS-BlowInIns | Wall Insulation (blown-in) | Res | BldgEnv | 20 | 6.7 |
| BS-Win | High Performance Windows | Res | BldgEnv | 20 | 6.7 |
| HV-ResAC | High Efficiency Air Conditioner (package and split systems) | Res | HVAC | 15 | 5 |
| HV-EffFurn | HV-EffFurn | Res | HVAC | 20 | 6.7 |
| WtrHt-Res-Elec | Residential Electric Water Heater | Res | SHW | 13 | 4.33 |
| WtrHt-Res-Gas | Residential Gas Water Heater | Res | SHW | 11 | 3.67 |
| WtrHt-Instant-Res | Residential Instantaneous Water Heater | Res | SHW | 20 | 6.67 |
| WtrHt-WH-R4PipeIns-Gas | Pipe Insulation - Gas Water Heater - Residential | Res | SHW | 11 | 3.7 |
| WtrHt-WH-Aertr | Faucet Aerators | Any | SHW | 10 | 3.3 |
| WtrHt-WH-Shrhd | Low-Flow Showerhead | Res | SHW | 10 | 3.3 |

To determine package EUL, the individual measure EULs within each package were combined as a weighted average, using the same method described above for determining package IR. The form of this calculation is shown below, followed by the measure weights.

Where:

Package EUL is the weighted average IR for a package including n measures

Mi,EUL is the EUL associated with individual measure, i

Mi,ES is the applied measure weight according to the following table:

Individual Measure Weight and EUL

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Name** | **EUL ID** | **EUL**  **(Mi,EUL)** | **Measure**  **Weight**  **(Mi,ES)** |
| Reduce Building Leakage (15%) | BS-Wthr | 11 | 16 |
| Reduce Building Leakage (30%) | BS-Wthr | 11 | 32 |
| Insulate Duct (R-8) | HVAC-DuctInsul | 20 | 20 |
| Reduce Duct Leakage (10%) | HV-DuctSeal | 18 | 40 |
| Reduce Duct Leakage (5%) | HV-DuctSeal | 18 | 47 |
| Insulate Attic (R-30/R-38) | BS-CeilIns | 20 | 8 |
| Insulate Attic (R-44) | BS-CeilIns | 20 | 12 |
| Insulate Floor (R-19) | BS-FlrIns | 20 | 35 |
| Insulate Wall (R-13) | BS-BlowInIns | 20 | 76 |
| High Performance Windows (U0.30, SHGC0.25) | BS-Win | 20 | 89 |
| Efficient Air Conditioner (SEER 15) | HV-ResAC | 15 | 26 |
| Efficient Furnace (AFUE 92%) | HV-EffFurn | 20 | 56 |
| Efficient Furnace (AFUE 95%) | HV-EffFurn | 20 | 69 |
| Efficient Wall Furnace (AFUE 70%) | HV-EffFurn | 20 | 34 |
| Efficient Electric Water Heater (200 EF) | WtrHt-Res-Elec | 13 | 17 |
| Efficient Gas Water Heater (67 EF) | WtrHt-Res-Gas | 11 | 54 |
| Efficient Gas Water Heater (70 EF) | WtrHt-Res-Gas | 11 | 21 |
| Tankless Gas Water Heater (82 EF) | WtrHt-Instant-Res | 20 | 90 |
| Hot Water Pipe Wrap (1.0 Inch) | WtrHt-WH-R4PipeIns-Gas | 11 | 7 |
| Shower Thermostatic Shut-Off Valve | WtrHt-WH-Aertr | 10 | 3 |
| Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead | WtrHt-WH-Aertr | 10 | 35 |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | WtrHt-WH-Shrhd | 10 | 3 |

The calculation tool (Attachment 4) provides the weighted EUL for each package created.

### 1.4.2 Codes and Standards Analysis

Most of the measures in this work paper are subject to provisions of either California’s Title 24 (2016) or Title 20 (2017) which incorporates both California-specific appliance regulations and the federal standard. The table below summarizes the relevant code requirements.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | “Entirely New or Complete Replacement Duct System.  If the new ducts form an entirely new or replacement duct system directly connected to the air handler, the measured duct leakage shall be equal to or less than 5 percent of the system air handler airflow…” [150.2(b)1D].  “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]. | January 1, 2017  July 1, 2014 |
| Title 24 (2016) | “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.” [150.2(b)1B]. | January 1, 2017 |
| Title 20 (2017) | Section 1605.1, Table E-6 describes standards for central gas furnaces. The minimum AFUE for a non-weatherized gas-fired central furnace less than 225,000 Btu/hr is 80. | November 19, 2015 |
| Title 20 (2017) | Section 1605.1, Table E-2 describes standards for gas wall furnaces. The minimum AFUE for a gravity type gas wall furnace over 27000 Btu/h and under 46000 Btu/h is 66. | April 16, 2013 |
| Title 20 (2017) | Section 1605.1, Table C-3 describes standards for air-cooled air conditioners with a cooling capacity less than 65,000 Btu/hr. The minimums for a split system air conditioner between 45,000 and 65,000 Btu/hr cooling capacity are: SEER of 14, EER of 11.7, and off-mode power consumption of 30 Watts. | January 1, 2015 |
| Title 20 (2017) | Section 1605.1, Table F-3, referencing federal regulations, describes the following minimum Energy Factors for water heaters:   * Gas-fired storage <55 gallons = 0.675-(0.0015xV) * Gas-fired instantaneous = 0.82-(0.0019xV) * Heat pump water heaters = 0.97-(0.00132xV) | April 16, 2015 |

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

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 in 2009 through 2012 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 is also described in Section 2.5.

**FINAL REPORT: 2015 HOME UPGRADE PROGRAM IMPACT EVALUATION, dated June, 2017.**

Program year 2015 is the third evaluation of the Home Upgrade Program and includes HUP and AHUP. Three impact evaluations over five years have reported similar average differences in household usage from before the upgrade to after the upgrade. In all evaluations, for all PAs evaluated, the percent of electric savings (kWh) consistently are in the single digits.

For this program, the evaluated savings were far below the PA reported savings and the overall average realization rate was -11% for kWh, 8% for kW and 91% for therms. Realization rates for kWh and kW were low across the PAs. For therm savings SDG&E (97%) and SoCalREN (96%) had the highest realization rates. The current model for HUP savings is the Energy Upgrade California (EUCA) model. This calculator is designed specifically for HUP projects and uses simulation savings estimations for prototype buildings. Savings for each individual home is imputed using these prototypes.

**At a later time (per Policy/Rolling Portfolio requirements), recommendations from this study are expected to be evaluated and adopted by each IOU in coordination/guidance from Commission Staff.**

## 1.6 Data Quality and Future Data Needs

A subsequent work paper update will address recent findings from the 2015 statewide impact evaluation.

# Section 2. Calculation Methodology

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. The following table summarizes each step in the procedure, and additional detail is provided in Sections 2.1 through 2.6.

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. |

## 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 3,376 homes was obtained. The data was summarized according to three home vintages and six climate regions (described in Section 1.1.1) when sufficient data was available. The following table shows the overall counts of home audit data provided across utilities summarized by the home vintages and climate regions.

Summary of Participant Home Audit Data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Climate Zone Region** | **Vintage** | **PG&E** | **SCG** | **SCE** | **SDG&E** | **Grand Total** |
| **Central Valley & Desert (CVD)** | **pre78** | 98 | 0 | 26 | 0 | **124** |
| **78-92** | 103 | 0 | 12 | 0 | **115** |
| **93-01** | 34 | 0 | 2 | 0 | **36** |
| **Central Valley & Sierra (CVS)** | **pre78** | 912 | 0 | 19 | 0 | **931** |
| **78-92** | 345 | 0 | 0 | 0 | **345** |
| **93-01** | 70 | 0 | 0 | 0 | **70** |
| **Coast Ranges (CR)** | **pre78** | 271 | 0 | 0 | 0 | **271** |
| **78-92** | 42 | 0 | 0 | 0 | **42** |
| **93-01** | 16 | 0 | 0 | 0 | **16** |
| **Inland Southwest (IS)** | **pre78** | 0 | 0 | 335 | 71 | **406** |
| **78-92** | 0 | 0 | 17 | 38 | **55** |
| **93-01** | 0 | 0 | 2 | 1 | **3** |
| **North Coast (NC)** | **pre78** | 574 | 0 | 0 | 0 | **574** |
| **78-92** | 37 | 0 | 0 | 0 | **37** |
| **93-01** | 18 | 0 | 0 | 0 | **18** |
| **South Coast (SC)** | **pre78** | 1 | 0 | 72 | 212 | **285** |
| **78-92** | 0 | 0 | 4 | 32 | **36** |
| **93-01** | 0 | 0 | 0 | 12 | **12** |
| **Grand Total** |  | **2,521** | **0** | **489** | **366** | **3,376** |

When a participant characteristic had smaller sample sizes across home vintages and climate regions, a partition analysis was performed using JMP®12 statistical software to optimally split and combine groups in order to achieve an adequate sample size. A partition analysis was performed for Building Leakage, Attic Insulation, Duct Leakage, Duct Insulation, Floor Insulation, Wall Insulation, base case construction characteristics. 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]. The resulting measure-specific participant characteristics are detailed within each measure technical description in Section 1.2. A summarized table of the participant characteristics is available in Attachment 18.

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. The table below shows the number of audit results and billing histories that were included in this analysis.

Summary of Participant Data for Base Case Construction

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Section** | **PG&E** | **SCG** | **SCE** | **SDG&E** | **Total** |
| Pre-upgrade assessments | 2,521 |  | 489 | 366 | 3,376 |
| 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 (see Attachment 19). 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 setpoints. 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.

Calibration Targets for Models Representing Participant Homes

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **No. Stories** | **Climate Region** | **Homes with AC** | | | | **Homes without AC** | | | |
| **Baseline** | | **Heating** | **Cooling** | **Baseline** | | **Heating** | **Cooling** |
| therm/ft2 | kWh/ft2 | therm/ft2 | kWh/ft2 | therm/ft2 | kWh/ft2 | therm/ft2 | kWh/ft2 |
| 1 | CVD | 0.089 | 4.85 | 0.246 | 1.53 | 0.014 | 4.22 | 0.026 | 0.089 |
| CVS | 0.105 | 4.11 | 0.245 | 0.81 | 0.009 | 3.35 | 0.06 | 0.105 |
| CR | 0.11 | 3.84 | 0.232 | 0.62 | 0.01 | 3.04 | 0.044 | 0.11 |
| IS | 0.125 | 4.36 | 0.179 | 0.91 | 0.014 | 3.28 | 0.03 | 0.125 |
| NC | 0.161 | 3.69 | 0.295 | 0.57 | 0.015 | 3.13 | 0.041 | 0.161 |
| SC | 0.125 | 3.97 | 0.207 | 0.57 | 0.012 | 3.65 | 0.037 | 0.125 |
| 2 | CVD | 0.083 | 4.82 | 0.146 | 1.04 | N/A | N/A | N/A | 0.083 |
| CVS | 0.091 | 3.09 | 0.222 | 0.58 | 0.009 | 1.96 | 0.051 | 0.091 |
| CR | 0.083 | 3.12 | 0.207 | 0.47 | 0.008 | 3.21 | 0.027 | 0.083 |
| IS | 0.084 | 3 | 0.129 | 0.56 | N/A | N/A | N/A | 0.084 |
| NC | 0.07 | 2.81 | 0.216 | 0.31 | 0.013 | 2.76 | 0.032 | 0.07 |
| SC | 0.093 | 3.13 | 0.214 | 0.65 | 0.009 | 2.9 | 0.036 | 0.093 |

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.

Conditioned Area of Home Prototypes

|  |  |  |
| --- | --- | --- |
| **Model Size** | **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 |

## 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. 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. The full set of factors and the ranges used in the analysis are shown in the table below.

DoEx Factors and Ranges

|  |  |  |
| --- | --- | --- |
| **Factor** | **Value Range** | |
| **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.

## 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.

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 2.

Reduce Building Leakage

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% reduction in leakage measured by the blower door test.

Insulate Duct

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 [R].

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

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

Total Duct Leakage Base and Measure Case

|  |  |  |  |
| --- | --- | --- | --- |
| **Vintage** | **Measured Leakage, program participants** | **1-Story Base case Supply Duct Air Loss Fraction** | **2-Story Base case Supply Duct Air Loss Fraction** |
| 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 5% (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

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%), in DEER.[[1]](#footnote-1)

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.[[2]](#footnote-2) 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. Demand reduction estimates utilized latest CPUC’s DEER2014 peak demand definition.

## 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 below.

Summary of Required Regression Models

|  |  |
| --- | --- |
| **Characteristic** | **Number of 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 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.

## 2.5 Domestic Hot Water Measure Additions

There are eight 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.

Summary of Domestic Hot Water Calculation Methodologies

|  |  |
| --- | --- |
| **Measure Name** | **Calculation Methodology** |
| Efficient Electric Water Heater (200 EF) | DEER2015 Water Heater Calculator v1.1 [Y]  (see Attachment 6) |
| Efficient Gas Water Heater (67 EF) | DEER READI Tool [E]  (see READI Data Used table below) |
| Efficient Gas Water Heater (70 EF) |
| Tankless Gas Water Heater (82 EF) |
| Hot Water Pipe Wrap | Manual calculation.  (see Attachment 7) |
| Shower Thermostatic Shut-Off Valve | DEER READI Tool [E]  (see READI Data Used table below) |
| Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | Energy Impacts were obtained from the Southern California Gas Company (2016) Work Paper, “Auto-Diverting Tub Spout with Thermostatic Valve” [W]  (see Attachment 8 and Attachment 9) |

The following table indicates which measures are taken directly from or created with the DEER READI tool [E].

READI Data Used

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Code** | **Measure Name** | **READI Data** | **DEER Version** |
| Res-ShwrFlowRes-Elec  Res-ShwrFlowRes-Gas | Shower Thermostatic Shut-Off Valve | See Attachment 10 and Attachment 11 | 2015 |
| Res-ShowerHdFlowRes-Elec-1.6  Res-ShowerHdFlowRes-Gas-1.6 | Shower Thermostatic Shut-Off Valve & Low-Flow Showerhead | See Attachment 12 and Attachment 13 | 2015 |
| RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-0p67EF | Efficient Gas Water Heater (67 EF) | See Attachment 14 | 2017 |
| RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-0p70EF | Efficient Gas Water Heater (70 EF) | See Attachment 15 | 2017 |
| RG-WtrHt-SmlInst-Gas-150kBtuh-lt2G-0p82EF | Tankless Gas Water Heater (82 EF) | See Attachment 16 | 2017 |

## 2.6 Total Impact Calculator

A calculator tool (Attachment 4) 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 general 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.

**Home Upgrade Calculator Testing Procedure**

A testing procedure is followed when major revisions are made to the impact calculator to ensure that the calculator is functioning on a technical level and that outputs meet expectations. Through the procedure, technical inaccuracies indicated during the procedure will be identified and corrected. When unexpected results not due to a technical inaccuracy, these scenarios will be identified as ongoing limitations of the calculator within the log. The testing procedure is documented within Attachment 20.

# Section 3. Load Shapes

Load shapes are used for portfolio lifecycle cost analysis. A load shape indicates the distribution of a measure’s energy savings over one year. A load shape is a set of fractions summing to unity, with one fraction per hour (or other time period). Multiplying a savings value by the load shape value for any particular hour yields the energy savings for that particular hour.

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Residential Single Family | DEER:HVAC\_Eff\_AC | RES |

# Section 4. Costs

Packages’ costs are estimated as the sum of the costs of the measures they include. Some measures use a single cost for all homes. Others measures, such as furnace and AC costs, have costs that vary decidedly with climate and vintage. Those variable measure costs are calculated uniquely for each home vintage and climate zone combination. The Full and Incremental Cost table below shows, for each measure, which parameters drive any cost variations. The individual measure costs were derived from various sources to provide the most up to date data collection and best fit for efficiency measure upgrade as defined within this workpaper.

## 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 (AR) there exists a theoretical base case that the measure can be compared to in cost. The base case costs of individual measures are summarized in the Full and Incremental Costs table.

## 4.2 Measure Case Cost

Estimated full measure costs are based on the Work Order 17 (WO017) Ex Ante Measure Cost Study whenever available, and then on other industry sources as documented below. For REA measures, there exists no base case to compare the measure, making incremental measure cost equal to the gross measure cost. Below is a summary of the gross measure cost estimation methodology used for each measure:

* Attic Insulation: 2017 Regional Technical Forum (RTF) incremental measure cost, per square foot basis, multiplied by DEER prototype attic surface area for appropriate vintage. Adjustment to CA cost using 2014 RS Mean City Cost Index [U, V].
* Floor Insulation: 2017 RTF incremental measure cost, per square foot, multiplied by DEER prototype floor surface area for appropriate vintage. Adjustment to CA cost using 2014 RS Mean City Cost Index [U, V].
* Wall Insulation: 2017 RTF incremental measure cost, per square foot, multiplied by DEER prototype exterior wall surface area for appropriate vintage. Adjustment to CA cost using 2014 RS Mean City Cost Index [U, V].
* Reduce 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].
* Reduce Duct Leakage (Duct Sealing): For duct sealing, the cost is adopted from the WO017 Measure Cost Study [T]. 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) [S].
* Domestic Hot Water Heater measures: Measure cost reflects full installed cost of equipment as reported the WO017 Measure Cost Study [T].
* Efficient Furnace measures: Measure cost reflects full installed cost of equipment as reported in the WO017 Measure Cost Study [T].
* Efficient Air Conditioner: Measure cost reflects full installed cost of equipment as reported in the WO017 Measure Cost Study [T], AC size informed by market availability and DEER prototypes for appropriate vintage and climate zone.
* Duct Insulation: Measure cost per square foot was obtained from RSMeans Green Building Cost Data 2014 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 RSMeans Green Building Cost Data 2014 and one-half the average duct area.
* High Performance Windows: Measure cost per square foot was obtained from the 2017 RTF Standard Information Workbook [U]. 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). Adjustment to CA cost using 2014 RS Mean City Cost Index [V].
* Hot Water Pipe wrap: Measure cost per foot was obtained from RSMeans Green Building Cost Data 2014, using a closed cell polyethylene foam insulation cost installed on a ¾” pipe. The material cost per linear foot is listed as $0.49 with $3.53 of labor.
* Shower thermostatic valve, and shower thermostatic valve with low flow showerhead: Costs were adopted from the 2014 SoCal Gas work paper SCGWP100303B [M].
* Auto-Diverting Tub Spout with Thermostatic Shut-Off Valve: Costs were adopted from the 2016 SoCal Gas work paper SWWH001v00 [W].

For AR measures, the estimated incremental measure costs are based on WO017, the DEER Measure Cost table, work papers and market research. Below is a summary of the incremental cost estimation methodology used for each applicable measure:

* Domestic Hot Water Heater measures: Incremental measure cost is the additional cost of the measure case above the cost of meeting the minimum code/standard requirement, as reported in the WO017 Measure Cost Study [T].
* Efficient Furnace measures: Incremental measure cost is the additional cost of the measure case above the cost of meeting the minimum code/standard requirement, as reported in the WO017 Measure Cost Study [T].
* Efficient Air Conditioner: Incremental measure cost is the additional cost of the measure case above the cost of meeting the minimum code/standard requirement, as reported in the WO017 Measure Cost Study [T].
* Shower thermostatic valve, and shower thermostatic valve with low flow showerhead: Costs were adopted from the 2014 SoCal Gas work paper SCGWP100303B [M].
* Auto-Diverting Tub Spout with Thermostatic Shut-Off Valve: Costs were adopted from the 2016 SoCal Gas work paper SWWH001v00 [W].

## 4.3 Full and Incremental Measure Cost

Full and Incremental Measure Cost Equations

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| AR | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

Full and Incremental individual measure costs are summarized below. Note that these costs are not in the same units as they can vary depending on home characteristics. The full cost table with detailed references is available in the provided Cost Analysis (Attachment 5). Depending on the baseline condition or whether the measure is AR or REA, the costs assumed for the efficient measure condition may differ from one another.

Full and Incremental Costs

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Installation**  **Type** | **Unit** | **Incremental**  **Measure**  **Cost** | **Full Measure Cost** | | **Varies by**  **Parameter** | **Cost**  **Source**  **Year** |
| **1st**  **Baseline** | **2nd**  **Baseline** |
| Reduce Building Leakage (15%) | REA | Home | $350.00 | $350.00 | N/A | None | 2010 |
| Reduce Building Leakage (30%) | REA | Home | $525.00 | $525.00 | N/A | None | 2010 |
| Insulate Duct (R-8) | REA | sqft. | $3.21 | $3.21 | N/A | None | 2014 |
| Reduce Duct Leakage (10%) | REA | Home | $270.75 | $270.75 | N/A | Climate | 2013 |
| Reduce Duct Leakage (5%) | REA | Home | $1,744.00 | $1,744.00 | N/A | Climate | 2013 |
| Insulate Attic (R-30/R-38) | REA | sqft. | $1.01 | $1.01 | N/A | Vintage | 2012 |
| Insulate Attic (R-44) | REA | sqft. | $1.17 | $1.17 | N/A | Vintage | 2012 |
| Insulate Floor (R-19) | REA | sqft. | $1.66 | $1.66 | N/A | Vintage | 2012 |
| Insulate Wall (R-13) | REA | sqft. | $1.47 | $1.47 | N/A | Vintage | 2012 |
| High Performance Windows (U0.30, SHGC0.25) | REA | sqft. | $43.66 | $43.66 | N/A | Vintage | 2012 |
| Efficient Air Conditioner (SEER 15) | AR | Ton | $92.13 | $828.03 | $92.13 | Vintage &  Climate | 2013 |
| Efficient Furnace (AFUE 92%) | AR | kBtuh | $7.43 | $22.96 | $7.43 | Vintage &  Climate | 2013 |
| Efficient Furnace (AFUE 95%) | AR | kBtuh | $8.78 | $24.31 | $8.78 | Vintage &  Climate | 2013 |
| Efficient Wall Furnace (AFUE 70%) | AR | kBtuh | $1.52 | $30.48 | $1.52 | Vintage &  Climate | 2013 |
| Efficient Electric Water Heater (200 EF) | AR | Home | $1,170.03 | $2,228.92 | $1,170.03 | None | 2013 |
| Efficient Gas Water Heater (67 EF) | AR | Home | $1,220.82 | $1,408.59 | $1,220.82 | None | 2013 |
| Efficient Gas Water Heater (70 EF) | AR | Home | $1,220.83 | $1,489.07 | $1,220.83 | None | 2013 |
| Tankless Gas Water Heater (82 EF) | AR | Home | $1,145.57 | $1,999.53 | $1,145.57 | None | 2013 |
| Hot Water Pipe Wrap (1.0 Inch) | REA | Ft | $4.02 | $4.02 | N/A | None | 2014 |
| Shower Thermostatic Shut-Off Valve | REA | Install | $7.00 | $44.95 | N/A | None | 2016 |
| Shower Thermostatic Shut-Off Valve and Low-Flow Showerhead | REA | Install | $17.00 | $54.95 | N/A | None | 2016 |
| Auto Diverting Tub Spout with Thermostatic Shut-Off Valve | REA | Install | $91.38 | $191.99 | N/A | None | 2016 |

# Attachments

1. SCE17MI005.0 A1 - IOU Measure Implementation Tables

2. SCE17MI005.0 A2 - Simulation Inputs.xlsx

3. SCE17MI005.0 A3 – Regression Model Statistics.xlsx

4. SCE17MI005.0 A4 – Home Upgrade WP Calc Tool v7.xlsm

5. SCE17MI005.0 A5 - Home Upgrade Costs 20170719.xlsm

6. SCE17MI005.0 A6 - DEER2015-Water-Heater-Calculator-v1.1xlsm

7. SCE17MI005.0 A7 - PHWERP Pipe Wrap Calculation.xls

8. SCE17MI005.0 A8 - SWWH001v00\_Auto-Diverting\_Tub\_Spout\_with\_Thermostatic\_Shut-off\_Valve.docx

9. SCE17MI005.0 A9 - Tub\_Spout\_Calculations\_Rev0.xlsx

10. SCE17MI005.0 A10 - EnergyImpacts\_Res-ShwrFlowRes-Elec.CSV

11. SCE17MI005.0 A11 - EnergyImpacts\_Res-ShwrFlowRes-Gas.CSV

12. SCE17MI005.0 A12 - EnergyImpacts\_Res-ShowerHdFlowRes-Elec-1.6.CSV

13. SCE17MI005.0 A13 - EnergyImpacts\_Res-ShowerHdFlowRes-Gas-1.6.CSV

14. SCE17MI005.0 A14 - EnergyImpacts\_RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-0p67EF.CSV

15. SCE17MI005.0 A15 - EnergyImpacts\_RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-0p70EF.CSV

16. SCE17MI005.0 A16 - EnergyImpacts\_RG-WtrHt-SmlInst-Gas-150kBtuh-lt2G-0p82EF.CSV

17. SCE17MI005.0 A17 – Reference List 2014-01-21.xlsx

18. SCE17MI005.0 A18 – EUC Participant Default Table v4 20131018.xlsx

19. SCE17MI005.0 A19 – HUWP eQuest Simulation Model Calibration Procedure.docx

20. SCE17MI005.0 A20 - Home Upgrade Calculator Testing Procedure.docx

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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)
2. The U-value modeled was 0.32. Program implementers have since changed the requirement to 0.30 to match Energy Star criteria, but the energy savings remain based on the modeling at 0.32. [↑](#footnote-ref-2)