**Work Paper PGECODHW126**

**Demand Control for Centralized Water Heater Multi Family**

**Revision #0**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Demand Control for Centralized Water Heater Recirculation Pump**

**Measure Code: BW009- BW014**

**At-a-Glance Summary**

|  |  |
| --- | --- |
| Applicable Measure Codes |  |
| **Measure Description** | Demand Control Recirculation Pump for multi-family building types with central gas, electric, or heat pump water heating. The control activates the hot water circulation pump when temperature and flow sensors indicate the need for the pump to run in order to maintain delivered hot water temperature. Both pumping and water heating savings are realized. |
| **Energy Impact Common Units** | Therms/kWh |
| **Base Case Description** | Base case is considered to be a system with a functioning recirculation pump. |
|  |  |
| **Measure Energy Consumption** | kWh/ Therm |
| **Energy Savings**  **(Base Case – Measure)** | Varies |
| **Costs Common Units** | $ per measure unit |
| **Base Case Equipment Cost ($/unit)** | $0 |
| **Measure Equipment Cost ($/unit)** | $10.65 per unit measure Low Rise building types  $10.11 per unit measure High Rise building types |
| **Gross Measure Cost ($/unit)** | $37.10 Low Rise Building Types/ $18.55 High Rise Building Types |
| **Measure Incremental Cost ($/unit)** | $27.00 Low Rise Building Types/ $8.00 High Rise Building Types |
| **Effective Useful Life (years)** | 15 years for HVAC - EMS, from 2014 DEER Version 2.0.1 READI Tool[[1]](#endnote-1) |
| **Measure Application Type** | Retrofit Add On (REA) |
| **Net-to-Gross Ratios** | 0.55 for Residential Default, from 2014 DEER READI Version 2.0.1 Tool1 |
| **Important Comments** | Savings based on SCE approved work paper SCE13WP002 R1, savings added for PG&E climate zones |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **PG&E Measure Code** | **Measure Description** | **BldgType** | **CZ** | **Vintage** | **IMC** | **NTG** | **EUL** |
| BW009 | Electric Low Rise | mfm | All | Any | $27 | 0.55 | 15 |
| BW010 | Gas Low Rise | mfm | All | Any | $27 | 0.55 | 15 |
| BW011 | Heat Pump Low Rise | mfm | All | Any | $27 | 0.55 | 15 |
| BW012 | Electric High Rise | mfm | All | Any | $8 | 0.55 | 15 |
| BW013 | Gas High Rise | mfm | All | Any | $8 | 0.55 | 15 |
| BW014 | Heat Pump High Rise | mfm | All | Any | $8 | 0.55 | 15 |

**Work Paper Approvals**

|  |  |
| --- | --- |
|  |  |
| **Grant Brohard**  Manager, Technical Product Support | Date |
| **Carolyn Weiner**  Manager, Products | Date |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Revision Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| Revision 0 | 01/12/2015 | PGECODHW126 Rev. 0  New for PG&E 2015 using approved wp from SCE | Southern California Edison Company SCE13WP002R1 |
|  |  |  |  |
|  |  |  |  |

**Southern California Edison Company**

**Demand Control for Centralized Water Heater Recirculation Pump**

**Core Measure Summary Table**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| General Measure Information | | | | | | | | PT | | 1st Baseline Period | | | | 2nd Baseline Period | | | | TOU |
| Measure Name | Measure RunID | Solution Code | CZ | Building Type | Load Shape | EUL | Unit Definition | Program Type (NEW, ROB, RET) | Applicable Code | Gross Unit Annual Electricity Savings (kWh/unit) | User Entered kW Savings per unit (kW/unit) | Gas Savings (Therms) | 1st Baseline Useful Life | kWh Saving per unit (kWh/unit) | kW Savings per unit (kW/unit) | Gas Savings (Therms) | 2nd Baseline Useful Life | % TOU |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | To be Exported from the MMDB | PM-35626 | 06 | Residential Multi-family | HeatPump\_WtrHt-RC | 15.0 | Dwelling Unit | REA | No | 27.91 | 0.00309 | 22.886 | 15.0 | 0.00 | 0.00000 | 0.000 | 0.0 | 0.00 |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | To be Exported from the MMDB | PM-35626 | 08 | Residential Multi-family | HeatPump\_WtrHt-RC | 15.0 | Dwelling Unit | REA | No | 27.91 | 0.00309 | 22.545 | 15.0 | 0.00 | 0.00000 | 0.000 | 0.0 | 0.00 |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | To be Exported from the MMDB | PM-35626 | 09 | Residential Multi-family | HeatPump\_WtrHt-RC | 15.0 | Dwelling Unit | REA | No | 27.91 | 0.00309 | 22.545 | 15.0 | 0.00 | 0.00000 | 0.000 | 0.0 | 0.00 |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | To be Exported from the MMDB | PM-35626 | 10 | Residential Multi-family | HeatPump\_WtrHt-RC | 15.0 | Dwelling Unit | REA | No | 27.91 | 0.00309 | 22.545 | 15.0 | 0.00 | 0.00000 | 0.000 | 0.0 | 0.00 |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | To be Exported from the MMDB | PM-35626 | 13 | Residential Multi-family | HeatPump\_WtrHt-RC | 15.0 | Dwelling Unit | REA | No | 27.91 | 0.00309 | 22.523 | 15.0 | 0.00 | 0.00000 | 0.000 | 0.0 | 0.00 |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | To be Exported from the MMDB | PM-35626 | 14 | Residential Multi-family | HeatPump\_WtrHt-RC | 15.0 | Dwelling Unit | REA | No | 27.91 | 0.00309 | 22.795 | 15.0 | 0.00 | 0.00000 | 0.000 | 0.0 | 0.00 |

*Note:* ***For the complete list of Measures, refer to the attached calculation spreadsheet***

**Costing and NTG Summary Table**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| General Measure Information | | | | PT | | NTG | | | IR | 1st Baseline Period | 2nd Baseline Period | IMC | DIM |
| Measure Name | Solution Code | CZ | Unit Definition | Program Type (NEW, ROB, RET) | Applicable Code | NTG Non-Res. | NTG Res. | NTG Multi Family | Installation Rate | Gross Measure Cost per unit | Gross Measure Cost per unit | Incremental Measure Cost per unit | Delivery & Incentive Method |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | PM-35626 | 06 | Dwelling Unit | REA | No | N/A | N/A | 0.85 | 1 | From Program | $0.00 | $23.48 | Financial Support / Direct Install |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | PM-35626 | 08 | Dwelling Unit | REA | No | N/A | N/A | 0.85 | 1 | From Program | $0.00 | $25.26 | Financial Support / Direct Install |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | PM-35626 | 09 | Dwelling Unit | REA | No | N/A | N/A | 0.85 | 1 | From Program | $0.00 | $25.99 | Financial Support / Direct Install |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | PM-35626 | 10 | Dwelling Unit | REA | No | N/A | N/A | 0.85 | 1 | From Program | $0.00 | $24.40 | Financial Support / Direct Install |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | PM-35626 | 13 | Dwelling Unit | REA | No | N/A | N/A | 0.85 | 1 | From Program | $0.00 | $24.13 | Financial Support / Direct Install |
| Demand Control Recirculation Pump Gas Water Heater Low Rise Building | PM-35626 | 14 | Dwelling Unit | REA | No | N/A | N/A | 0.85 | 1 | From Program | $0.00 | $23.72 | Financial Support / Direct Install |

*Note:* ***For the complete list of Measures, refer to the attached calculation spreadsheet***

**Document Revision History**

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **MM/DD/YY** | **Author/Affiliation** | **Summary of Changes** |
| 0 | 04/09/12 | Brian James/SCE | * Original WP from WPSCREWP0002.0 * Changed the energy savings calculations to scale by recovery efficiency instead of energy factor. Updated template and references. |
| 1 | 06/20/13 | Devin Rauss/SCE | * Modified per unit basis to be per dwelling unit * Incorporated Energy Division 13-14 workpaper disposition. * Savings for PGE, SDGE, and SCG added to the workpaper. |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **PG&E Measure Code** | **Measure Description** | **BldgType** | **CZ** | **Vintage** | **IMC** | **NTG** | **EUL** |
| BW009 | Electric Low Rise | mfm | All | Any | $27 | 0.70 | 15 |
| BW010 | Gas Low Rise | mfm | All | Any | $27 | 0.70 | 15 |
| BW011 | Heat Pump Low Rise | mfm | All | Any | $27 | 0.70 | 15 |
| BW012 | Electric High Rise | mfm | All | Any | $8 | 0.70 | 15 |
| BW013 | Gas High Rise | mfm | All | Any | $8 | 0.70 | 15 |
| BW014 | Heat Pump High Rise | mfm | All | Any | $8 | 0.70 | 15 |

**Section 1. General Measure & Baseline Data**

**1.1 Measure & Delivery Description**

This work paper details the installation of a recirculation pump with demand controls for a central gas, electrical resistance, and heat pump water heater in a multi-family residential dwelling. The savings are provided on a per dwelling unit basis and classified by building size. The “low rise” building is up to 3 floors and the “high rise” is 3 stories and above.

**1.1a Measure Description**

The measure is a demand control recirculation pump for a multi-family central gas, electric, or heat pump water heater. The controls only activate the hot water circulation pump when temperature and flow sensors indicate the need for the pump to run in order to maintain delivered hot water temperature. This saves both pumping and water heating energy.

There are a total of 6 base cases for this measure, all of which assume there is a continuously operating (24/7) recirculation pump installed. The base cases are divided into two categories: low rise building’s pump and high rise building’s pump. Finally, the base cases are further defined based on whether the central water heater is gas, electric, or a heat pump.

Here is a list of the 6 base cases:

* low rise building’s pump
  + Continuously operating recirculation pump for a gas central water heater
  + Continuously operating recirculation pump for an electric central water heater
  + Continuously operating recirculation pump for a central heat pump water heater
* high rise building’s pump
  + Continuously operating recirculation pump for a gas central water heater
  + Continuously operating recirculation pump for an electric central water heater
  + Continuously operating recirculation pump for a central heat pump water heater

**Table 1 Measure Names**

|  |  |
| --- | --- |
| Solution Code - SCE | Measure name |
| PM-35626 | Demand Control Recirculation Pump Gas Water Heater Low Rise Building |
| PM-22452 | Demand Control Recirculation Pump Electric Water Heater Low Rise Building |
| PM-48756 | Demand Control Recirculation Pump Heat Pump Water Heater Low Rise Building |
| PM-59789 | Demand Control Recirculation Pump Gas Water Heater High Rise Building |
| PM-64745 | Demand Control Recirculation Pump Electric Water Heater High Rise Building |
| PM-76564 | Demand Control Recirculation Pump Heat Pump Water Heater High Rise Building |

\*PGE Savings values are derived directly from the SCE values since PGE savings values were not addressed in the 13-14 ED workpaper disposition

\*SDGE and SCG savings values were extracted directly from the 13-14 ED workpaper disposition

**1.1b Delivery and Incentive Mechanism**

The delivery mechanism is Financial Support-Direct Install and Financial Support – Downstream Incentive Deemed.

The measure install type is Retrofit Add On (REA).

**1.1c Measure Requirements**

This measure is eligible for all climate zones and multi-family residential building types with a hot water recirculation pump installed on a central water heater.

**1.2 DEER Differences Analysis**

This specific measure is not included in the Database for Energy Efficient Resources (DEER) Version 2005.2.01 [49].

The DEER 2011 READI tool does contain a similar measure (D03-095 – Circulation Pump Timeclock Retrofit) which adds a time clock to the existing circulation pump that turns the pump off when the building is unoccupied. The measures within this work paper, however, use controls which are demand based and only activate the hot water circulation pump when temperature and flow sensors indicate that there is a need for hot water.

This specific measure is not included in DEER Version 2008.3.02. The database only contains related data for a 40 gallon electric water heater with EF = 0.88 and EF = 0.94. The recovery efficiencies are not provided. This data is only available for Residential Single Family building types. Since this measure is considered only with regards to central multi-family water heating equipment, it was determined the DEER data could not be used.

Baseline data for this measure was obtained from a third party source due to the lack of data available in DEER. Heschong Mahone Group performed field and modeling analysis on recirculation pumps with temperature modulation and demand control in multi-family central water heaters to support a Public Interest Energy Research (PIER) project for the California Energy Commission [[[2]](#endnote-2)]. Research from the latter was used to develop the 2013 Codes and Standards Enhancement (CASE) study conducted by the California Utilities Statewide Codes and Standards Team [[[3]](#endnote-3)].

**Table 2 DEER Difference Summary**

|  |  |
| --- | --- |
| DEER Difference Summary Table | |
| Modified DEER Methodology | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | No |
| Deviation from DEER | DEER does not contain this type of measure. |
| DEER Version | N/A |
| DEER Run ID and Measure Name (Sample) | N/A |

**1.3 Code Analysis**

**Table 3 Code Summary**

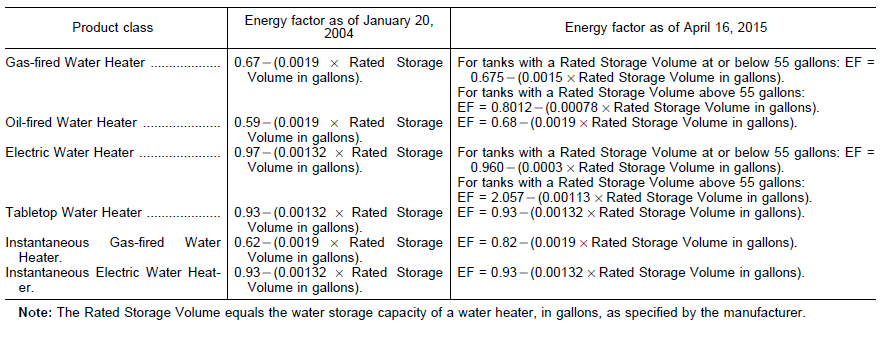
|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Dates |
| Title 24 (2013) | 2013 Building Energy Efficiency Standards | January 1, 2014 |
| Title 24 (2008) | 2008 Building Energy Efficiency Standards | January 1, 2014 |
| 10 CFR Part 430. Vol. 75, No. 73, Page 20234 | Federal Code Standards | January 20, 2004 |
| Title 20 (2010) | N/A | N/A |

This measure is being proposed for inclusion in California’s Title 24 Building Energy Efficiency Standards for 2013. Methodologies from the research conducted in the CASE study were used to estimate demand reduction and energy savings for this measure as mentioned in the previous section.

**Federal Code Analysis**

There are currently no federal regulations for recirculation pumps. However, water heaters are regulated and must meet the minimum efficiency requirements as given in Table 2 [[[4]](#endnote-4)].

**Table 4 Federal Standards for Water Heaters**



**State Code Analysis**

This measure is not included in California’s Title 20 Appliance Efficiency Regulations 2010 [277].

In California’s Title 24 Building Energy Efficiency Standards for 2008 [208], demand controls for recirculation pumps are not included, but mandatory requirements for recirculation loops are included. The mandatory requirements for recirculation loops are listed in Section 113 (c) 5, and are included below for reference.

**SECTION 113 – MANDATORY REQUIREMENTS FOR SERVICE WATER-HEATING SYSTEMS AND EQUIPMENT**

(c) **Installation**. Any service water-heating system or equipment may be installed only if the system or equipment complies with all of the applicable requirements of this subsection for the system or equipment.

5. **Water Heating Recirculation Loops Serving Multiple Dwelling Units, High-Rise Residential, Hotel/Motel and Nonresidential Occupancies.** A water heating recirculation loop is a type of hot water distribution systemthat reduces the time needed to deliver hot water to fixtures that are distant from the water heater, boiler or otherwater heating equipment. The recirculation loop is comprised of a supply portion, connected to branches thatserve multiple dwelling units, guest rooms, or fixtures and a return portion that completes the loop back to thewater heating equipment. A water heating recirculation loop shall meet the following requirements:

A. **Air release valve or vertical pump installation**. An automatic air release valve shall be installed on the recirculation loop piping on the inlet side of the recirculation pump and no more than 4 feet from the pump. This valve shall be mounted on top of a vertical riser at least 12” in length and shall be accessible for replacement and repair. Alternatively, the pump shall be installed on a vertical section of the return line.

B. **Recirculation loop backflow prevention**. A check valve or similar device shall be located between the recirculation pump and the water heating equipment to prevent water from flowing backwards though the recirculation loop.

C. **Equipment for pump priming**. A hose bibb shall be installed between the pump and the water heating equipment. An isolation valve shall be installed between the hose bibb and the water heating equipment. This hose bibb is used for bleeding air out of the pump after pump replacement.

D. **Pump isolation valves**. Isolation valves shall be installed on both sides of the pump. These valves may be part of the flange that attaches the pump to the pipe. One of the isolation valves may be the same isolation valve as in item C.

E. **Cold water supply and recirculation loop connection to hot water storage tank**. Storage water heaters and boilers shall be plumbed in accordance with the boiler manufacturer’s specifications. The cold water piping and the recirculation loop piping shall not be connected to the hot water storage tank drain port.

F. **Cold water supply backflow prevention**. A check valve shall be installed on the cold water supply line between the hot water system and the next closest tee on the cold water supply line. The system shall comply with the expansion tank requirements as described in the California Plumbing Code Section 608.3.

**1.4 Measure Effective Useful Life**

The 2013 CASE study estimates demand control equipment to have an effective useful life of 15 years. In addition, DEER 2011 [213] contains a measure “Circulation Pump Timeclock Retrofit.” This measure is similar to demand controls and has a EUL of 15 years. The DEER documentation “Summary of EUL-RUL Analysis for the April 2008 Update to DEER” provides the RUL value as a flat 1/3 of the EUL value. The RUL value will only be applied to the first baseline period for retrofit measures that have applicable code that will affect the energy savings. In all other installation types and retrofit with no applicable code that affects the energy savings, the RUL is not applicable to either the first or second baseline period.

To obtain the EUL value the DEER11 documentation, EUL\_Summary\_10-1-08.xls [213], was consulted. Table 5 below identifies the value used for the measures in this work paper.

This workpaper uses DEER EUL\_ID WtrHt-Timeclock.

**Table 5 EUL Value**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Market | End Use | Measure | EUL (Years) | RUL (Years) |
| Non-Residential | Water Heating | Circulation Pump Timeclock Retrofit | 15 | N/A |

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

The NTG value was obtained from the “DEER2011\_NTGR\_2012-05-16.xls” on the DEER website as required by Version 4 of the California Public Utilities Commission (CPUC) Energy Efficiency Policy Manual [132]. The relevant NTGR for this measure is shown in Table 6 below. Note this measure is brand new to the portfolio for 2013 and is targeted to multifamily direct install applications which are considered “hard-to-reach.” by CPUC policy. These two NTG values are reflected below.

**Table 6 Net-to-Gross Ratio**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID | NTG\* |
| All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | All | Any | All | 0.70 |
| Res-Default-HTG-di | All other EEM with no evaluated NTGR; direct install hard-to-reach only. | Res | Any | DirInstall | 0.85 |

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

The installation rate (IR) is identified in the calculation attachment. This value is obtained from a spreadsheet created by the DEER team titled “GrossSavingsAdjustments.xlsx”. The installation rate varies by end use, sector, technology, application, and delivery method.

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

**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 7 TOU Summary Table**

|  |  |
| --- | --- |
| Measure | % |
| Demand Control Recirculation Pump | 0 |

\*Note: Check Section 3 if a measure appears to require a non-zero percentage but is assigned zero. If the load shape is a DEER08 load shape, a TOU of 0 is correct.

**Section 2. Energy Savings & Demand Reduction Calculations**

Energy savings were calculated in two steps. First, this work paper considers the energy savings from decreased pump run time. Second, this work paper considers the energy savings from decreased water heater run time. Energy savings are reported for ¼ hp and ½ hp recirculation pumps in the 2013 CASE study [[[5]](#endnote-5)] and reported in Attachment 1 [[[6]](#endnote-6)]. The CASE study bases all calculations on two building prototypes that were developed for the 2005 Title 24 code changes; low rise and high rise. The building prototypes consist of one small multi-family dwelling with 44 units (low rise) and one large multi-family dwelling with 88 units (high rise). The data in the CASE study is calculated using a model that was validated using field measured data. Details of the assumptions can be found in the CASE report.

The savings calculations from the 2013 CASE study are for central gas water heaters only. Savings calculations for electric and heat pump water heaters were calculated by converting units and adjusting for changes in efficiency by multiplying by a ratio of recovery efficiencies (ƞr) for the electric water heater and coefficient of performance (COP) for the heat pump. The per dwelling unit savings are captured by dividing the savings values by the number of dwelling units for the appropriate building type.

Demand reduction was calculated under the assumption that a demand controlled recirculation pump operates approximately 2 hours a day compared to the 24-hour baseline. The CASE study assumed a 24-hour baseline as a result of data collected in the PIER report [A, B]. Climate zone sensitivity was considered, but it was determined negligible since the model used to determine energy savings in the 2013 CASE study assumed all pipes were in a conditioned space. Again, the per dwelling unit savings were calculated using the number of units from the building prototypes.

This work paper does not factor in any existing hot water heater control schemes into the baseline. There are two predominant control strategies on the market: timers and temperature modulation. Timers are used to shut off water heaters during times when demand is anticipated to be low. Temperature modulation is a control scheme that lowers the setpoint temperature of the tank by 10 to 15°F when demand is anticipated to be low. More complicated temperature modulation schemes exist where a sensor continuously monitors hot water demand on the tank, and reduces the setpoint when demand is known to be low. It is assumed that these control strategies are relatively rare in this market.

1. **Gas Water Heater Energy Savings Calculation**

Installation of a demand control recirculation pump for central gas water heaters results in electric energy savings for the pump only. Electric energy savings for the recirculation pump are calculated in the 2013 CASE study and reported in Attachment 2 [G]. Demand control savings are derived based on the demand controls schedule developed for the 2013 CASE study model, which assumed the pump switches on and off once each hour in two uneven time steps. The pump is on during the first time step, which is usually short. The exact duration of the time step depended on return pipe volume and recirculation flow rate. The second time step lasts the remainder of the hour when the pump is off. Pump on and off cycles were assumed to be the same throughout a 24-hour period. From the model, pump run time would range from 1.48 to 2.96 hours in small multi-family dwellings and 2.26 to 4.52 hours in large multi-family dwellings. This model was validated using field monitored data. Additionally, while standby losses may vary between summer and winter months, the 2013 CASE study calculated energy savings using the assumption that pipes were in a conditioned space. Therefore, climatic affects were assumed to be negligible.

1. **Electric Water Heater Energy Savings Calculation**

Installation of a demand control recirculation pump for central electric water heaters results in electric energy savings for both the water heater and recirculation pump. The savings measured in field studies and energy simulations were based solely on a gas water heater [B]. The CASE report identifies water heater savings (gas), temperature modulation savings (gas), and demand control savings (electric). Therefore, total energy savings were determined by converting units from gas to electric and factoring in the assumed energy factor of the gas and electric water heaters with the following equation:

**Equation 1**

**

where 29.3 is the conversion factor between kWh and therms.

The recovery efficiencies used to calculate electric water heater energy savings were ƞr,gas = 80% and ƞr,electric = 98%.

For example, an electric central water heating system in Climate Zone 6 will result in the following energy savings:

**Equation 2**

**

This value is then added to the energy savings from the value reported for the gas water heater, which reports only electric energy savings from pump operation. This is represented in the following equation:

**Equation 3**

**

For example, for the same central water heating system described in Equation 2, in a low rise building, the energy savings can be calculated in the following equation:

**Equation 4**

**

1. **Heat Pump Water Heater Energy Savings Calculation**

Heat pump water heaters are rarely, if ever, used in central domestic hot water applications due to their limited capacity. Energy savings calculations for a heat pump water heater are the same as the calculations performed for an electric water heater, with the exception of the efficiency metric used. Through discussions with the Energy Division [[[7]](#endnote-7)], it was decided that COP is the most viable metric to use to capture heat pump performance. In these discussions, it was agreed upon that the COP of a gas water heater would be equivalent to the recovery efficiency (0.8) and the COP for a heat pump would be significantly higher (2.5) to reflect the improved efficiency of these systems. The following equation details a calculation:

**Equation 5**

**

For example, a central water heating system in Climate Zone 6 will result in the following energy savings:

**Equation 6**

**

Equation 3 is then applied to determine the overall energy savings for the system, which would result in a total energy savings of 242.492 kWh/dwelling unit in the example above.

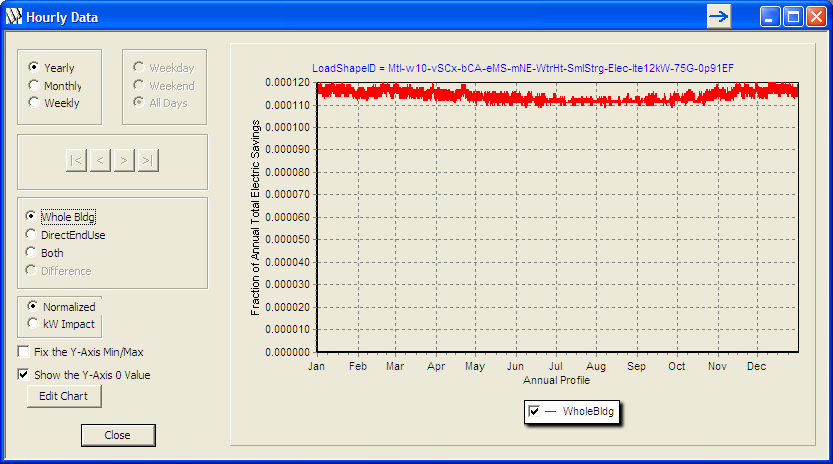
**Demand Reduction Calculations**

Demand Reduction was investigated based on the estimated energy consumed during the hottest nine hours of the year. However, hourly data is not available, so the demand reduction was determined based on the annual energy savings. Since the reduction in operating time is already factored into the annual savings numbers, the demand reduction can be calculated by first calculating the energy savings over the hottest nine hours of the year. This is assumed to be the same as the energy savings for any other set of nine hours in the year. This assumption is consistent with the demand controls schedule developed for the 2013 CASE study model, which was described in the “Gas Water Heater Energy Savings Calculations” section above.

The simplest way to determine demand reduction is by multiplying the annual energy savings by the ratio of 9 hours over 8760 hours. Finally, you divide by 9 hours in order to get the demand reduction in kW. This method assumes a flat yearly load; however, it is likely that the load during the 9 hottest days will be lower than the winter months due to seasonal variation creating a cosine type wave starting with the beginning of the year.

Investigation into the load shape used by DEER08 (figure below) for electric water heaters confirms there is a dip, however slight. To accommodate this dip the peak load value, instead of 1/8760 or (0.000114) simulating a flat load, the DEER value will be used. The DEER value can be seen in the figure below and is calculable by dividing the kW by kWh for an electric water heater from DEER08. The number comes out to 0.000110677. Since the energy savings are already calculated on a per dwelling unit basis, the demand savings derived are also per dwelling unit.

**Figure 1. Yearly load profile for High Efficiency Small Electric Water Heater – 75 Gal, 0.91 EF**



**Equation 7**

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This equation is the same for gas, electric, and heat pump water heaters. An example calculation is shown for a gas water heater with a demand control recirculation pump in a low rise building. Since the gas water heater only has savings from the pump, it is the same for all climate zones.

**Equation 8**

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The full set of calculations is detailed in Attachment 2 [[[8]](#endnote-8)].

**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: HeatPump\_WtrHt-RC. This was chosen because the pump operates when there is hot water demand. See Table 8 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 8 Building Types and Load Shapes**

|  |  |  |
| --- | --- | --- |
| Building Type | E3 Alt. Building Type | Load Shape |
| Residential Multi-family | Residential | DEER: HeatPump\_WtrHt-RC |

**Section 4. Base Case & Measure Costs**

**4.1 Base Case Cost**

Base case cost was determined by a web-based search of local distributor’s prices for commercially available water recirculating pumps. A variety of size and material of pumps were chosen to reflect the range of options that may be currently installed as the base case. The cost and source of each unit used to determine the average base case cost can be found in Attachment 3 [[[9]](#endnote-9)].

The base case cost was determined to be $10.65/dwelling unit for a high rise building.

The base case cost was determined to be $10.11/dwelling unit for a low rise building.

**4.2 Gross Measure Cost**

Measure equipment cost was determined by calling the manufacturer who makes the demand control recirculation pump. Currently, only a 1/6 hp pump is commercially available by the manufacturer Enovative Kontrols Systems. The price quoted for equipment cost was $1,595.00 for a basic “T” size and $1,670 for larger “T” size. The average of these two costs, $1,632.50, was taken to be the measure cost. This translates to $37.10/dwelling unit and $18.55/dwelling unit for the low and high rise buildings, respectively.

Labor required to install the measure is estimated to be between one and two hours (per manufacturer conversations). Therefore, this work paper assumes two hours of labor will be required at the Labor Base Wage Rate from DEER Measure Cost Summary [215] for NR-DHW-SWH of $59 per hour, regardless of building size. This gives a total labor of $2.68/dwelling unit and $1.34/dwelling unit for the low and high rise buildings, respectively. This labor cost is based on incremental labor only, and assumes the labor to install the basecase recirculation pump and measure case recirculation pump will be the same. Labor cost is the additional labor required to install demand control sensors and commission the new system. The price is assumed to be the same for both pump size categories for the measure case as there is currently no other data for different pump sizes.

This gross measure cost for a retrofit measure is the sum of the measure equipment cost and the measure labor cost.

For **RET** first baseline period, GMC is represented by the equation below:

*GMC = Measure Equipment Cost + Measure Labor Cost*

For a high rise building,

GMC = $18.55 + $1.34 = $19.89

For a low rise building,

GMC = $37.10 + $2.68 = $39.78

For **RET** second baseline period, GMC is represented by the equation below:

*GMC =*

(Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

For a high rise building,

GMC = ($18.55 + $1.34) – (10.65 + $1.34)= $7.9/dwelling unit

For a low rise building,

GMC = ($37.10 + $2.68) – ($10.11 - $2.68)= $26.99/dwelling unit

The climate zone specific costs were calculated using the DEER cost table SWH50.

**4.3 Incremental Measure Cost**

Incremental measure cost (IMC) can be calculated using the following equation:

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

(Base Case Equipment Cost + Base Case Labor Cost)

For a high rise building,

GMC = ($18.55 + $1.34) – (10.65 + $1.34)= $7.9/dwelling unit

For a low rise building,

GMC = ($37.10 + $2.68) – ($10.11 - $2.68)= $26.99/dwelling unit

The climate zone specific costs were calculated using the DEER cost table SWH50.

1. 2014 DEER READI Version 2.0.1 Tool, <http://www.deeresources.com/> [↑](#endnote-ref-1)
2. [] Attachment 5 [↑](#endnote-ref-2)
3. [] “Codes and Standards Enhancement Initiative (CASE) - Multifamily Central DHW and Solar Water Heating – 2013 California Building Energy Efficiency Standards.” California Utilities Statewide Codes and Standards Team, September 2011. [↑](#endnote-ref-3)
4. [] “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule.” Federal Register, 10 CFR Part 430. Vol. 75, No. 73, Page 20234. April 16, 2010. [↑](#endnote-ref-4)
5. [] Attachment 4 [↑](#endnote-ref-5)
6. [] Attachment 1 [↑](#endnote-ref-6)
7. [] WORKPAPER DISPOSITION FOR On-Demand Pump Control for Central Domestic Hot Water Systems California Public Utilities Commission, Energy Division June 20, 2013 (Revised) [↑](#endnote-ref-7)
8. []Attachment 2 – Savings Calculations.xlsx [↑](#endnote-ref-8)
9. [] Attachment 3 – Cost Calculations and References.xlsx [↑](#endnote-ref-9)