Work Paper SCE17HC055

**Revision 0**

**Southern California Edison**

**Circulating Block Heater**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | **See Section 1.1** |
| **Measure Description** | The energy efficiency measure will include adding a recirculation pump with a downsized electric resistance heater to a backup generator. |
| **Base Case Description** | The existing thermo siphon heater relies on the change in density, buoyancy, to circulate the heated coolant within the generator. |
| **Units** | Per Unit |
| **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** | 15 years (EUL ID: Motors-pump) |
| **Measure Installation Type** | Replace on Burnout (ROB), and New Construction(NEW) |
| **Net-to-Gross Ratio** | All-Default<=2yrs = 0.7 |
| **Important Comments** | **This work paper document does not contain a data set in conformance with the 4/1/2014 Ex Ante Database Specification provided by the California Public Utilities Commission (CPUC) Commission Staff (CS); SCE will provide that data set separately.** |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 9/19/2014 | Alfredo Gutierrez & Richard Song(SCE) | *Original Work Paper for 13-14 Program Cycle.* |
| 1 | 11/16/2017 | Ram Dharmarajan & Akhilesh Endurthy (Lincus) | * Updated the cost section * Word template update * Removed ”1100-2500 kW” measures * Consolidated ROB and NEW installation types into one solution code * Changed NTG\_ID from ET\_Default to All-Default<=2yrs * Added reference industry study supporting ISP baseline |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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

## 1.1 Measure Description & Background

The measure is a circulating block heater used on backup diesel generators. This measure will replace an existing thermo siphon pump and heater with a recirculation pump and a smaller electric resistance heater. The measure will be tiered based upon the backup generator sizes shown below:

• 37-199 kW

• 200-799 kW

• 800-1099 kW

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Forced Circulating Block Heater |
| Existing Condition | Thermo siphon pump and heater |
| Code/Standard | N/A |
| Industry Standard Practice | Thermo siphon pump and heater |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| N/A | N/A | PR-93262 | N/A | 37-199 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater |
| N/A | N/A | PR-93796 | N/A | 200-799 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater |
| N/A | N/A | PR-92194 | N/A | 800-1099 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater |
| N/A | N/A | PR-69302 | N/A | 37-199 kW Backup Generator with Circulating Block Heater replacing Properly Sized Thermosiphon Heater |
| N/A | N/A | PR-75840 | N/A | 200-799 kW Backup Generator with Circulating Block Heater replacing Properly Sized Thermosiphon Heater |
| N/A | N/A | PR-82783 | N/A | 800-1099 kW Backup Generator with Circulating Block Heater replacing Properly Sized Thermosiphon Heater |

**Eligibility Requirements**

* Existing backup generator (ROB) is eligible for incentive if it is not currently fitted with a Circulating Block Heater or device utilizing similar electro-mechanical system to heat and circulate generator block pre-warming fluid.
* New generator installation (NEW) where base design prescribes a pre-heating device (e.g., Thermosiphon heater)other than Circulating Block Heater or similar device may also apply for incentive to upgrade from base design to efficient design including a Circulating Block Heater.

**Implementation Requirements**

* Installation of Circulating Block Heater should be performed by a qualified technician (i.e. generator maintenance technician or mechanical service technician).
* Installer should follow manufacturer’s installation requirements and assess and perform (if necessary) fluid hose adjustments that may be associated with the retrofit to enable the Circulating Block Heater to function at optimal energy efficiency..
* Installation shall meet all applicable regulations including but not limited to latest NFPA Code 110 for Emergency Power Systems and NEC.
* These measures are approved for the building types shown in Table 9 for all SCE climate zones. This measure is not offered for residential and is independent of building types.

## 1.2 Technical Description

This technology has an integrated electric pump that circulates coolant throughout the engine block ensuring that there is a minimal temperature difference between the supply and return temperatures. The pump/heater (CBH) is an integral assembly.

According to the Washington State University and Bonneville Power Administration[[1]](#footnote-1), Block heaters typically consist of a simple resistance heater affixed at one of several locations to the engine. Convection circulates heated fluids in a process known as thermosiphon. These systems heat the engine block unevenly and inefficiently and may deteriorate piping materials. Replacing thermosiphon heaters with electrical pump heaters can provide energy savings.

With supported energy efficiency offering, the existing thermo siphon heater is removed as a unit and the new CBH is inserted into the exact same location. It is a single unit installation within one housing with the mechanical element (pump) enclosed in the same "shell" as the smaller resistance heating element (relative to the thermo siphon) integral to the circulating block heater. Disconnect and reconnect points to existing hoses would not change unless improperly plumbed in the first place.

Along with the pump, a small resistance heater is used to heat the coolant within the engine block. When actual installations are completed, field inspections will verify if the existing resistance heater was replaced with smaller resistance heaters. By pumping the heated coolant, a more uniform temperature is obtained throughout the engine block. As a result of using a recirculation pump, a smaller electric resistance heater can be used to heat the coolant as there will be a more uniform temperature achieved through the mixing of fluid throughout the engine block.

The base case equipment is a thermo siphon heater. These types of heaters rely on the change in density (impacting buoyancy) in order to circulate the heated coolant. This type of circulation leads to non-uniform temperature distribution, where the coolant is warmer at the top of the block and colder at the bottom, which requires the electric resistance heater to operate for a longer duration. This also means that there is waste heat in sections of the block, as the heater must operate to maintain a certain temperature, so the top of the block will always be hotter than necessary.

Further, a study in Energy Efficiency on Pump-Driven Block Heater by Avista[[2]](#footnote-2), dated September 2012, is referenced to support Industry Standard Practice (base case) assumptions. The study indicates that historically, the Thermo-Siphon (TS) heater is the technology that has dominated the block heater market. The ubiquity of the TS heater is driven primarily by original equipment manufacturers because they install them at the factory – See Attachment 6.

## 1.3 Installation Types and Delivery Mechanisms

The application type is Replace on Burnout (ROB) and New Construction (NEW).

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Replace on Burnout (ROB) | Above Code or Standard | N/A | EUL | N/A |
| New Construction (NEW/NC) | Above Code or Standard | N/A | EUL | N/A |

The delivery method is:

* Financial Support - Down Stream Incentive – Deemed

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.

**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. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

Currently, DEER does not address this type of measure. Also, DEER interactive effects will not be used as most backup generators are kept in non-conditioned or exterior spaces.

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | No |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | N/A |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | Any | 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 IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

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

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| Motors-pump | Water Loop Pumps | Com | Process | 15 | 5 |

### 1.4.2 Codes and Standards Analysis

Currently, both the 2016 Title 24 [355] and the 2017 Title 20 [422] energy codes do not cover the use or installation of circulating block heaters.

Please note that the Air Quality Management District (AQMD) does set standards regarding what the definition of an emergency backup generator actually is and the allowable air emissions from backup generators. However, the allowable emissions do not impact savings calculations as backup generators are required to be ready at all times for use. Emission standards are not covered in this work paper.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | N/A | N/A |
| Title 20 (2017) | N/A | N/A |
| AQMD | N/A | N/A |

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

The savings for the measures contained within this work paper are based on field monitoring data from the Bonneville Power Administration (BPA). This data was collected from numerous case studies that ran through the BPA’s Emerging Technology program. The data collected included average daily kWh and outside air (OA) temperature for both the preexisting thermo siphon heater and the retrofitted circulating block heater [A]. There are 17 sources of data, which are taken from different sites including waste water plants and data centers. The data was collected for different periods of time for each site, but on average, there are 2 months pre and post for each site used in the regression analysis performed for this work paper.

The Emerging Products study ET08SCE1020 “Air Source Heat Pump for Preheating of Emergency Diesel Backup Generators” [491] investigated usage of air source heat pumps for this measure, but found that the use of air source heat pumps was not cost effective. This study serves to show that the current measures within this work paper were facilitated through SCE’s ET program, utilizing data from BPA that was analyzed through the ET program.

## 1.6 Data Quality and Future Data Needs

Based on phone conversations with HotStart®, one of the major manufactures of circulating block heaters and suppliers to major back-up generator manufactures, stated that BPA is doing a study with more latest version of HotStart products. Once the study is released the calculations may need updates since the existing analysis is based on limited data.

There is a PG&E ET paper “Forced Circulation Engine Generator Block Heater Energy Performance Assessment” ET Project Number: ET13PGE1091, which found out that there are no savings with forced circulation retrofits for ambient temperatures greater than 68 oF. The current calculation methodology does not take this into account. Most of the test data is below 68 oF.

# Section 2. Calculation Methodology

The savings for the measures in this work paper are found from BPA field monitored case study data referenced above. The BPA case studies provide OA temperature and daily average kWh for both the pre-existing thermo siphon heater and the measure. The data provided was then used to create multiple regression models for the different generator sizes where this measure will be offered. These regression models, along with the circulating block heater tool used for SCE’s customized program can be found in attachment 2. The raw data used to generate the regression models has not been attached to this work paper due to size limitations, however, it is available upon request.

**DATA EXPLORATION**

Temperature and Daily kWh Variation within Size Categories

While sites are assigned a size category of 1-4, this categorization corresponds only very loosely to the actual (baseline) usage, and is highly dependent on baseline heater size. There is significant variation and overlap across categories in generator size, heater size, and observed kWh usage.

Site-Specific Heater Sizes

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Site** | **Site Size Category** | **Generator Size kW** | **Baseline Heater Size kW** | **Existing Measured kW** | **Avg Baseline kWh** | **New Rated Heater Size kW** | **New Measured kW** | **Avg Treatment kWh** |
| COCCH | 1 | 15 | 0.5 | 0.46 | 11.0 | 1 | 0.99 | 6.8 |
| Kid Kare | 1 | 40 | 1 | 0.89 | 21.1 | 1 | 0.99 | 13.4 |
| TCWWTP | 1 | 15 | 1 | 0.93 | 10.9 | 1 | 1.03 | 8.2 |
| HCNW | 1 | 600 | 6 | 4.3 | 52.0 | 6 | 5.4 | 46.8 |
| COCFD | 2 | 75 | 1 | 0.88 | 20.9 | 1 | 0.94 | 11.6 |
| COCTV | 2 | 100 | 1 | 0.88 | 20.9 | 1 | 0.92 | 7.2 |
| COMKR | 2 | 50 | 1 | 0.93 | 20.7 | 1 | 1 | 11.7 |
| COMW | 2 | 100 | 1 | 0.95 | 22.7 | 1 | 0.98 | 16.1 |
| KE ECAM | 2 | 65 | 1 | 0.93 | 22.3 | 1 | 0.99 | 12.5 |
| TCWP | 2 | 20 | 1 | 0.97 | 22.3 | 1 | 1.05 | 10.5 |
| BLDG210 | 2 | 250 | 2.5 | 2.22 | 47.1 | 3 | 2.8 | 24.2 |
| PCDC | 2 | 900 | 6[[3]](#footnote-3) | 4.62 | 48.4 | 6 | 5.5 | 44.1 |
| BayView | 3 | 150 | 1.5 | 1.39 | 33.3 | 1.5 | 1.34 | 14.9 |
| BNS GEN | 3 | 500 | 4.95 | 1.85 | 44.3 | 2.5 | 1.89 | 26.3 |
| KRMC*[[4]](#footnote-4)* | 3 | 1000 | 6 | 4.5 | 87.7 | 6 | 5.7 | 21.0 |
| COCWWTP | 3 | 664 | 6 | 5.9 | 112.8 | 3 | 2.9 | 40.8 |
| NQ | 4 | 1000 | 10 | 9.54 | 228.4 | 10 | 10.15 | 110.3 |

Observations take place at varying times of year, and there is significant variation in range of temperatures observed from site to site and from baseline to treatment periods. Some sites show significant temperature dependence in baseline usage, whereas other sites show no temperature dependence (often displaying remarkably consistent usage). Temperature dependence is observed at sites with larger baseline heater sizes (within a size category), and is consistent with a properly-sized heater. Temperature independence (flat baseline) is observed at sites with smaller baseline heater sizes, and is consistent with an undersized heater (reflecting the heater is running consistently on full).

The sites per size category that exhibit flat baselines (indicative of undersized heaters) suggest the following designation of undersized v. proper-sized heaters:

Baseline Heater Size Ranges (as suggested by data)

|  |  |  |
| --- | --- | --- |
| **Site Size Category** | **Undersized Heater Range** | **Proper-sized Heater Range** |
| 1 | 1 kW and below | 2 kW and above |
| 2 | 1 kW and below | 2 kW and above |
| 3 | 5 kW and below | 6 kW and above |

Note: there is not enough data to determine the proper sizing range for size category 4 sites. Only one category 4 site was observed, with baseline heater size of 10 kW, and the data for this site suggests the heater was under-sized. The heater range applies only to baseline heater sizes; the new heaters all exhibit temperature dependence.

**ESTIMATION METHODOLOGY**

Undersized and proper-sized sites behave very differently, and thus should be modeled separately.

**Baseline Usage for Undersized Sites**

Undersized sites frequently showed remarkable consistency; individual sites did not display enough variation to warrant modeling. Therefore a single expected baseline usage[[5]](#footnote-5) was attributed for each site. Across sites, these usages exhibited a fairly linear relationship with heater size across site size categories.

**Baseline Usage for Properly-Sized Sites**

Baseline usage in properly-sized sites were modeled (for each size category) as a function of temperature. There were not enough sites or variation in the baseline heater size to model usage as a function of heater size as well as site size category. The model applied (per site size category) is:

Where:

*Daily\_kWh* is the daily usage (kWh) as collected

*Temperature* is the observed average outside air temperature (°F)

**Treatment Usage (All Sites)**

Measure undersized heaters were not an issue as in the baseline periods, therefore treatment usage was modeled as a function of temperature and new heater size for all sites. The model applied (per site size category) is:

Where:

*Daily\_kWh* is the daily usage (kWh) as collected

*New\_Heater\_Size* is the recorded new heater size (kW)

*Temperature* is the observed average outside air temperature (°F)

**ESTIMATION RESULTS**

**Equation 1: Estimated Baseline Usage for Undersized Sites:**

*daily\_kWh* = 20.2 \* *Baseline\_Heater\_Size* (1)

Estimated Baseline Usage for Properly-Sized Sites (regression results)

|  |  |  |
| --- | --- | --- |
| **Site Size Category** | **Regression Coefficients** | |
| **Intercept** | **Temp.** |
| 1 | 105.91 | -1.178 |
| 2 | 88.92 | -0.701 |
| 3 | 139.85 | -0.932 |

Estimated Treatment Usage (regression results)

|  |  |  |  |
| --- | --- | --- | --- |
| **Site Size Category** | **Regression Coefficients** | | |
| **Intercept** | **Heater Size** | **Heater Size \* Temp.** |
| 1 | 3.70 | 13.135 | -0.136 |
| 2 | 5.86 | 13.195 | -0.133 |
| 3 | 10.26 | 16.688 | -0.179 |
| *4* | *229.52* | *0* | *-2.577* |

Note: As only one site of size category 4 was observed, estimated treatment was not a function of new heater size (regression model was a function of temperature only).

**SAVINGS ESTIMATES**

Using the estimation results to estimate savings from a CBH installation in SCE territory requires the following items:

* Site size category
* Baseline heater size
* New heater size
* Climate zone (to determine average temperature)

Note that the range of observed temperatures are generally lower than those observed in SCE territory climate zones, particularly for baseline regression. These savings estimates thus are projecting heater performance for temperatures generally outside the observed range. Savings estimation is determined by the following steps:

* Determine whether baseline heater is *undersized* or *properly-sized* for the site size category[[6]](#footnote-6).
  + For *undersized* baseline heaters, average daily kWh is determined using Equation (1).
  + For *properly-sized* heaters, averaged daily kWh is determined for climate zone average temperature, using regression results in Table 10.
* Estimate treatment usage based on new heater size and climate zone average temperature, using regression results in Table 11.
* The difference in daily kWh can be projected into annual saving using preferred assumed days of operation.

**Savings Estimation Sample Calculation[[7]](#footnote-7):**

Sample 1: Climate Zone 6, site size category 1, baseline heater size 1 kW, new heater size 1 kW, annual operation 334 days / year.

* Designation: Undersized
* Annual Average Temperature: 61.5°F
* Baseline Daily kWh: 20.2 \* [Baseline Heater Size] = 20.2 kWh / day.
* Treatment Daily kWh: 3.70 + 13.135 \* [New Heater Size] – 0.136 \* [New Heater Size] \* [61.5°F] = 8.4 kWh / day
* Annual Savings: (20.2 kWh/day – 8.4 kWh/day) \* 334 days/year = **3,928 kWh/year.**

Sample 2: Climate Zone 8, site size category 3, baseline heater size 6 kW, new heater size 6 kW, annual operation 334 days / year.

* Designation: Proper-sized
* Annual Average Temperature: 63.4°F
* Baseline Daily kWh: 139.85 – 0.932 \* [63.4°F] = 80.8 kWh / day.
* Treatment Daily kWh: 10.26 + 16.688 \* [New Heater Size] – 0.179 \* [New Heater Size] \* [63.4°F] = 42.1 kWh / day
* Annual Savings: (80.8 kWh/day – 42.1 kWh/day) \* 334 days/year = 12,908 kWh/year.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sample Savings - Climate Zone 6 | | | | | | |
|  | **Baseline Heater Size** | **New Heater Size** | **Baseline Heater Designation** | **Baseline Daily kWh** | **Treatment Daily kWh** | **Annual kWh Savings** |
| 1 | 1 | 1 | Undersized | 20.2 | 8.4 | **3,928** |
| 3 | 3 | Proper-Sized | 33.4 | 17.9 | **5,181** |
| 2 | 1 | 1 | Undersized | 20.2 | 10.9 | **3,124** |
| 6 | 6 | Proper-Sized | 45.8 | 35.8 | **3,349** |
| 3 | 2 | 2 | Undersized | 40.4 | 21.6 | **6,293** |
| 6 | 6 | Proper-Sized | 82.5 | 44.2 | **12,817** |
| 4 | 10 | 10 | Undersized | 202.0 | 71.0 | **43,753** |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sample Savings - Climate Zone 8 | | | | | | |
|  | **Baseline Heater Size** | **New Heater Size** | **Baseline Heater Designation** | **Baseline Daily kWh** | **Treatment Daily kWh** | **Annual kWh Savings** |
| 1 | 1 | 1 | Undersized | 20.2 | 8.2 | **4,014** |
| 3 | 3 | Proper-Sized | 31.2 | 17.1 | **4,693** |
| 2 | 1 | 1 | Undersized | 20.2 | 10.6 | **3,208** |
| 6 | 6 | Proper-Sized | 44.5 | 34.3 | **3,412** |
| 3 | 2 | 2 | Undersized | 40.4 | 20.9 | **6,521** |
| 6 | 6 | Proper-Sized | 80.8 | 42.1 | **12,908** |
| 4 | 10 | 10 | Undersized | 202.0 | 66.1 | **45,389** |

Please note that DEER interactive effects are not used in the calculation of the energy savings as the equipment will either be installed outside or in an unconditioned room. Due to the equipment being installed either outside or in an unconditioned room, the energy savings will not vary by building type.

The Demand reduction for each measure can be found by taking the energy savings and dividing by the total operating hours for each measure. As these measures are typically installed on backup generators which are required to kick on when needed (when the power goes out), the energy savings calculations assume that the circulating block heaters are enabled continuously for 334 days out of the year (accounting for maintenance). A sample calculation has been shown below:

Sample 3: Climate Zone 6, site size category 1, baseline heater size 1 kW, new heater size 1 kW, annual operation 334 days / year.

* Designation: Undersized
* Annual Average Temperature: 61.5°F
* Baseline Daily kWh: 20.2 \* [Baseline Heater Size] = 20.2 kWh / day.
* Treatment Daily kWh: 3.70 + 13.135 \* [New Heater Size] – 0.136 \* [New Heater Size] \* [61.5°F] = 8.4 kWh / day
* Annual Savings: (20.2 kWh/day – 8.4 kWh/day) \* 334 days/year = **3,928 kWh/year.**
* Annual kW Savings: 3,928 kWh/year / (334 days/year \* 24 hours/day) = **0.4900 kW**

**Sensitivity Analysis**

In order to check the validity of using a yearly average temperature vs. a daily average temperature, a sensitivity analysis was performed for climate zones 6 and 15. The sensitivity analysis for both climate zone 6 and climate zone 15 is provided in this work paper for reference (attachment 3).

For climate zone 6, the average daily temperature was found and used with the regression models mentioned above. The savings using daily average temperature were on average, within 0.08% of the savings using the yearly average temperature, as seen below:

Savings Comparison for Climate Zone 6

|  |  |  |  |
| --- | --- | --- | --- |
| Measure | Sensitivity Analysis Savings (kWh) | Original Savings (kWh) | % Difference in Savings |
| 37-199 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater | 3,926 | 3,928 | 0.04% |
| 200-799 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater | 3,122 | 3,124 | 0.05% |
| 800-1099 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater | 6,289 | 6,293 | 0.07% |

For climate zone 15, the average daily temperature was found and used with the regression models mentioned above. The savings using daily average temperature were on average, within 0.03% of the savings using the yearly average temperature, as seen below:

Savings Comparison for Climate Zone 15

|  |  |  |  |
| --- | --- | --- | --- |
| Measure | Sensitivity Analysis Savings (kWh) | Original Savings (kWh) | % Difference in Savings |
| 37-199 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater | 4,553 | 4,552 | -0.01% |
| 200-799 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater | 3,735 | 3,734 | -0.02% |
| 800-1099 kW Backup Generator with Circulating Block Heater replacing Undersized Thermosiphon Heater | 7,937 | 7,936 | -0.02% |

Based on the results of the sensitivity analysis, the savings using the yearly average temperature seems to be an appropriate assumption for this work paper.

# Section 3. Load Shapes

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

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Assembly | Industrial | Industrial |
| Education - Community College | Industrial | Industrial |
| Education - Primary School | Industrial | Industrial |
| Education - Relocatable Classroom | Industrial | Industrial |
| Education - Secondary School | Industrial | Industrial |
| Education - University | Industrial | Industrial |
| Grocery | Industrial | Industrial |
| Health/Medical - Hospital | Industrial | Industrial |
| Health/Medical - Nursing Home | Industrial | Industrial |
| Lodging - Guest Rooms | Industrial | Industrial |
| Lodging - Hotel | Industrial | Industrial |
| Lodging - Motel | Industrial | Industrial |
| Manufacturing - Bio/Tech | Industrial | Industrial |
| Manufacturing - Light Industrial | Industrial | Industrial |
| Office - Large | Industrial | Industrial |
| Office - Small | Industrial | Industrial |
| Restaurant - Fast-Food | Industrial | Industrial |
| Restaurant - Sit-Down | Industrial | Industrial |
| Retail - Multistory Large | Industrial | Industrial |
| Retail - Single-Story Large | Industrial | Industrial |
| Retail - Small | Industrial | Industrial |
| Storage - Conditioned | Industrial | Industrial |
| Storage - Unconditioned | Industrial | Industrial |
| Warehouse - Refrigerated | Industrial | Industrial |

# Section 4. Costs

The base and measure equipment costs were obtained in 2017 from HotStart®, a major equipment manufacturer for engine heaters who supply components to generator companies like Quinn, CAT and Cummins. The following is the step by step methodology used to calculate the baseline and measure costs from the data provided by HotStart®.

* HotStart® representative provided a list of recommended thermosiphon and forced circulation heater models corresponding to engine displacement in liters ranging from 2.4 L and 76.3 L.
* These engine displacements in liters are converted to generator capacities in kW using manufacturer websites like Generac and Kohler. The range of generator capacities after the conversion is 30 kW to 2500 kW. These conversions were reviewed with the HotStart® representative.
* The engine heaters are designed for different voltages, phases, frequencies and features based on the application. Some variations in features include with-thermostats, adjustable thermostats and without thermostats. A detailed listing of all the different specifications is provided in the References tab of the Cost Analysis attachment.
* Pricing information for a variety of HotStart® thermosiphon models was provided. However, for the forced circulation heaters, cost data was available for a few recommended models listed below -

Backup Generator 40 to 600 kW – Single phase and 120 Volts

Backup Generator 750 to 2000 kW – Single phase and 208 Volts

Backup Generator 2500 kW – Three phase and 208 Volts

* To provide an accurate cost analysis, the above forced circulation heater models were compared with the thermosiphon counterparts having the same features.
* The thermosiphon heaters for generators above 350 kW are assumed to be the with-power cord and without-thermostat models.
* The average price for the base and measure equipment was calculated for the (4) categories of the generator capacities identified for measure savings.
* HotStart® representative was not aware of the concept of properly sized and undersized thermosiphon heaters as defined in the calculation methodology. It is assumed that the base case cost is the same for properly sized and undersized. There is no under sizing of the forced circulating heater. Hence, measure cost will always be properly sized circulating block heater.

The labor cost is from RSMean Data Year 2017 Quarter 4 for installing a 2 HP size 00 motor, Magnetic FVNR with enclosures and heaters (Line Number 262419400080). Based on discussion with HotStart®, installing the thermosiphon and circulating block heaters typically takes couple of hours and there is no variation in the installation times. While there is not much variation in the equipment cost, the labor cost has been significantly reduced in this update as compared to earlier version.

## 4.1 Base Case Cost

The table below shows the cost of thermosiphon heaters.

Base Case Cost

|  |  |  |  |
| --- | --- | --- | --- |
| Measure | Base Case Cost | Labor Cost | Total Cost |
| 37-199 kW Backup Generator with Circulating Block Heater | $195 | $164 | $359 |
| 200-799 kW Backup Generator with Circulating Block Heater | $464 | $164 | $628 |
| 800-1099 kW Backup Generator with Circulating Block Heater | $1005 | $164 | $1169 |

## 4.2 Measure Case Cost

The measures costs for this work paper are shown in the table below.

Measure Case Cost

|  |  |  |  |
| --- | --- | --- | --- |
| Measure | Measure Case Cost | Labor Cost | Total Cost |
| 37-199 kW Backup Generator with Circulating Block Heater | $700 | $164 | $864 |
| 200-799 kW Backup Generator with Circulating Block Heater | $793 | $164 | $957 |
| 800-1099 kW Backup Generator with Circulating Block Heater | $1166 | $164 | $1330 |

## 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** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

Full Measure Cost

|  |  |
| --- | --- |
| Measure | GMC |
| 37-199 kW Backup Generator with Circulating Block Heater | $864 |
| 200-799 kW Backup Generator with Circulating Block Heater | $957 |
| 800-1099 kW Backup Generator with Circulating Block Heater | $1330 |

Incremental Measure Cost

|  |  |
| --- | --- |
| Measure | IMC for ROB Measures |
| 37-199 kW Backup Generator with Circulating Block Heater | $505 |
| 200-799 kW Backup Generator with Circulating Block Heater | $330 |
| 800-1099 kW Backup Generator with Circulating Block Heater | $161 |

# Attachments

1. SCE17HC055.0 Circulating Block Heater - Calculation Template\_Final.xlsx
2. SCE17HC055.0 Circulating Block Heater - Cost Analysis.xlsx
3. SCE17HC055.0 Circulating Block Heater - ET08SCE1020\_Air Source Heat Pumps for Diesel Backup Generators.pdf
4. SCE17HC055.0 Circulating Block Heater - Savings Analysis and Estimates.xlsx
5. SCE17HC055.0 Circulating Block Heater - Sensitivity Analysis for CZ6 & CZ15.xlsx
6. SCE17HC055.0 Circulating Block Heater - Avista\_PumpDrivenBlockHeaters-Guide

# References

[31]

[351]

[355]

[422]

[436]

[491]

[A] Bonneville Power Administration (BPA). (2014). Emerging Technology field Test Results and Future Opportunities.

1. Copyright 2012, Washington State University and Bonneville Power Administration - Energy Efficient Stationary Engine Block Heater [↑](#footnote-ref-1)
2. Avista 2012, Pump-Driven Block Heaters: A Study in Energy Efficiency [↑](#footnote-ref-2)
3. PCDC was reported to have a baseline heater size of 12 kW; this value is anomalously large and not consistent with other observable data. Based on measured kW and usage levels, a heater size of 6 is more plausible and more consistent. [↑](#footnote-ref-3)
4. Runtime logging for KRMC strongly suggest that the replacement heaters were significantly oversized for their needs. Therefore, the usage data are not representative of a site with an appropriately-sized heater. As a result, KRMC data are excluded from the analysis. [↑](#footnote-ref-4)
5. At sites where an overwhelming mode value was observed, the mode was used as the expected baseline usage. Otherwise, the mean baseline usage was used. [↑](#footnote-ref-5)
6. Until more data are collected for additional category 4 sites, savings for category 4 sites can only be estimated using the undersized heater methodology. [↑](#footnote-ref-6)
7. Note: decimal rounding may yield slightly different results in these examples. [↑](#footnote-ref-7)