Work Paper SCE17WP008

**Revision 2**

**Southern California Edison**

**Commercial Variable Speed Swimming Pool Pump**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | PM-20470  PM-20471 |
| **Measure Description** | A Variable Speed (VS) Pool Pump 1-3 horsepower (HP) in a commercial setting |
| **Base Case Description** | Existing Case: A Single-speed Pool Pump 1-3HP in a commercial setting  Standard Practice: A Two-speed Pool Pump 1-3HP in a commercial setting |
| **Units** | Per pump |
| **Energy Savings** | Refer to Excel Calculation Attachment 1 |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 1 |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 1 |
| **Effective Useful Life** | EUL ID: OutD-PoolPump  EUL = 10 years  RUL = 3.3 Years |
| **Measure Installation Type** | Early Retirement (ER/RET)  Replace on Burnout (ROB/NR) |
| **Net-to-Gross Ratio** | 0.6 (NTGR ID: Com-Default>2yrs) |
| **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

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 12/9/16 | Theodore D’Williams/TRC | * This work paper is an update of SCE13WP008.0 * New Calculation template for 2017 program year * Base, Measure and Incremental Cost was updated * All (16) California Climate Zones have been added to the calculation template |
| 1 | 1/12/2018 | Andres Fergadiotti/SCE | * NTG Update; changed NTG\_ID from ET-Default (0.85) to Com-Default>2yrs (0.60) |
| 2 | 8/6/18 | Lake Casco / TRC | * Added two new solution codes: ROB with two-speed baseline and RET measure with single speed baseline. * Updated calculations to utilize 2018 CEC database for variable speed and two speed pumps * Updated costs based on multifamily methodology used for SCE workpaper Residential Pool Pump VFD (SCE17WP001.1). * Updated NTG ID to Commercial Default > 2 years. * Added POE documentation to better align RET/AR offerings with Commission Staff guidance. * Clarified measure scope to include pumps between 1 and 3 HP, instead of only less than 3 HP. * Added additional eligible commercial building types |
| 12/24/18 | Jesse Manao/SCE | * Added AR measure net saving calculation with NTG adjustment factor post Resolution E-4952 * Updated DEER READi tool to version 2.5.1 |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  |  |  |  |

Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | A Variable Speed (VS) Pool Pump 1-3 horsepower (HP) in a commercial setting |
| Existing Condition | A Single-speed Pool Pump 1-3 HP in a commercial setting |
| Code/Standard | A Two Speed Pool Pump 1-3 HP in a commercial setting |
| Industry Standard Practice | A Two Speed Pool Pump 1-3 HP in a commercial setting |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | PM-20470 |  | Commercial Variable Speed Pool Pump replacing Single Speed Pool Pump 1-3 HP |
|  |  | PM-20471 |  | Commercial Variable Speed Pool Pump replacing Two Speed Pool Pump 1-3 HP |

This work paper describes statewide calculations and methodologies related to energy savings and demand reduction values for variable-speed pool pumps for public swimming pools with filtration pumps less than or equal to 3 HP.

SCE offers a variety of program delivery approaches which include downstream, direct install and mid-stream incentives. For direct install and downstream programs (with same stringency and data gathering requirements as direct install), a licensed contractor will install and commission the measure according to manufacturer installation requirements, follow all applicable permitting requirement, health code requirements, inspections, and all applicable Standards and Regulations.

Installation contractors will be required to collect information on existing condition of the measure, and new installed measure.  Programs will select a percentage of post-installation inspections to establish a performance baseline and/or to ensure that the contractor has met all installation criteria. Inspectors evaluate and verify all retrofit work.

Installation contractor will provide information to participating customers about the newly installed measure, explaining the energy efficiency benefits to ensure sustained performance.

1. **Eligibility Requirements**

Only filtration pool systems that meet ALL of the following are eligible:

* Pump rated capacity does not exceed 3 HP.
* Hydronic pool system maintains a minimum flow rate of 1 turnover every 6 hour or less in full compliance with Section 3124B of Chapter 31B of the California Building Standards Code.
* Pool operation is nearly continuous year around - minimum of 10 months a year at a minimum of 12 hours a day.
* Both base and measure case pool pump VFD shall have a comparable rated (HP) capacity so that the level of service after the investment is made in this energy efficiency measure is comparable to the baseline level of service [351].
* For this work paper, horsepower rating refers to the nameplate horsepower before service factor is applied.
* Only 1-for-1 pump replacements are eligible. Motor-only replacements are not eligible for this offer.
* All climate zones are eligible.
* All AR/RET measures require 3rd Party (e.g., the approved installing contractor) baseline verification and data gathering in full compliance with established POE requirement – Attachment 5.

1. **Building Types**

The following building types are eligible:

* Lodging – Guest Rooms
* Lodging - Hotel
* Lodging – Motel
* Assembly
* Education - Community College
* Education - Secondary School
* Education – University
* Health/Medical – Hospital
* Health/Medical - Nursing Home

1. **Implementation Requirements**

* Must obtain building permit from Environmental Health Department (i.e. County or City) of jurisdiction.
* Installation must be performed by a contractor approved by SCE that has the appropriate CSLB license(s) and training.
* Contractor must follow all manufacturer installation requirements.
* Equipment and materials must meet or exceed all applicable local, state and federal standards.
* VS pool pump must be a new, qualifying product installed in an existing in-ground swimming pool.
* Installation including all associated work must meet latest applicable Codes, Energy Standards, and Regulations including but not limited to Title-24, Health Department, and NEC.
* Customer, as part of the incentive application process – see Attachment 5, shall acknowledge that the replacement pool pump VSD has been configured to achieve energy savings and agreed to have the pump filtration settings programmed for reduced flow during pool non-operating hours. Further, the customer shall agree not to modify and/or alter in any way programmed settings on the pump VSD to ensure persistency of the measure savings.

1. **Documentation Requirements**

* The Program will capture existing pool pump information including the brand, model number, nameplate horsepower, in addition to start and end filtration setting, GPM, and wattage on an application form.
* The Program will capture new variable speed pool pump information including the brand, model number, nameplate horsepower, in addition to start and end filtration setting, GPM, and wattage on an application form.
* The Program will capture facility’s daily operating schedule.
* Pump control type of existing unit: single speed or two speed - obtained from collected brand/model and permit documentation;
* Pool volume turnover – obtained from permit documentation.
* As part of the application process, the customer agreed to (a) have the pump filtration settings programmed for reduced flow during pool non-operating hours and (b) NOT to modify and/or alter in any way programmed pool pump VSD settings to ensure persistency of the measure’s savings for the expected life of the measure.
* Installation contractor will provide permit documentation for each project with application submittal.
* For early retirement measures Preponderance of Evidence (POE) Questionnaire – POE establishes verification of existing conditions and data collection requirements for supporting Accelerated Replacement measures. The questionnaire is intended to evaluate and demonstrate program influence). All (RET/ER) measures shall be supported by Application Form and POE per Attachment 5.

## 1.2 Technical Description

Pool pumps are used to circulate swimming pool water through a filtration system in order to keep it clear and remove debris and disease-causing agents. A pool pump motor in California is typically 0.5 to 3 horsepower (HP), single phase, alternating current (AC), and either a permanent split capacitor (PSC) or capacitor-start capacitor-run (CSCR) design [467]. Most run at a fixed single-speed of 3450 revolutions per minute (rpm) [468].

The constant speed pumps meet the Title 24 turnover requirement [505] by pumping excess water. This is done to ensure that the Title 24 minimum turnover requirement is met at all times, even when the pool filter is in need of cleaning, which causes the pumping head requirement to increase and the pumping flow to reduce.

A VS pool pump uses a motor controller that can be programmed to modulate motor speed and flow rate. For VS pool pumps 1-3HP, the controller and pump are integrated into a single unit as shown in Figure 1. Larger pumps typically use a VS control unit housed in a separate enclosure; these are not included in the scope of this work paper. VS pool pumps typically use electronically-commutated motors (ECMs), which offer higher efficiencies than PSC motors.



Variable Speed Pool Pump

Significant energy savings can be achieved by reducing flow rate when it is not necessary to operate at full flow. This is indicated by the Pump Affinity Law, which expresses the relationship between power (P), speed (n), and flow (Q):

Running the pump at half speed will theoretically reduce power draw to 1/8 of full power, but actual power draw will likely be higher due to lower motor efficiencies at part load. For this work paper, savings are derived from test data and not the Affinity Law.

Benefits of VS pool pumps are not limited to energy savings. They are quieter and need less maintenance than single-speed pumps. Lower flow rates allow the filter to more effectively remove debris, which improves water clarity. Reduced strain on the pump, filters, and plumbing prolong the useful life of the equipment [466]. Bundling VS pumps with other pool energy efficiency measures such as LED lighting should be considered.

## 1.3 Installation Types and Delivery Mechanisms

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Replace on Burnout (ROB/NR) | Above Code or Standard | N/A | EUL | N/A |
| Retrofit or Early Replacement (RET/ER) | Above Customer Existing | Above Code or Standard | RUL | EUL-RUL |

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 table below indicates applicable installation and delivery types for this offering.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Building Type** | **Measure Name** | **Install Type** | **Baseline** | **Applicable Delivery Type(s)** |
| PM-20470 | Applicable Commercial | Commercial Variable Speed Pool Pump replacing Single Speed Pool Pump 1-3 HP | RET/ER | 1st: Single Speed  2nd: 2-Speed | Direct Install,  Down-Stream Incentive with the same rigor as Direct Install and supported by approved licensed contractor |
| PM-20471 | Applicable Commercial | Commercial Variable Speed Pool Pump replacing Two Speed Pool Pump 1-3 HP | ROB | 2-Speed | Down-Stream Incentive not supported by an approved licensed contractor,  Mid-Stream |

Note that SCE supports a Direct Install with "Down-Stream" Incentive program with the same program design model as the Direct Install (DI) program in which the installation and commissioning of the energy efficiency measure is done by a trained and approved contractor with the same data (e.g., POE) collection rigor as the DI program, however, with an additional financial incentive to the customer.

**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. |
| Partnership | The program implements projects through a partnership between the utility and an institutional, government, or community-based organization. |
| Mid-Stream Programs | *See Mid-Stream Incentive in the Incentive Method Descriptions table.* |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |
| 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. |
| Mid-Stream Incentive  Mid-Stream Buy Down | The program gives a financial incentive to a midstream market actor (distributor, vendor, or retailer) to encourage the promotion of efficient measures. Buy Down means that the incentive is required to be passed down to the end-use customer. |
| On-bill Finance – Loan (OBF) | The program offers financing for the cost of an efficient measure as part of the utility bill. This can be an add-on option to an existing program or can serve as an organizing principle for its own program. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

DEER does not have a measure for variable speed pool pumps. DEER previously had a measure for two speed swimming pool pumps (2005: D03-967). This measure used a single speed pool pump as the base case and an efficient 1.5 hp two speed pool pump as the measure case. The savings were based on an average 25,000 gallon residential single family swimming pool, and the measure was limited to pool pumps used for filtration. These savings are not applicable to this measure because greater energy savings result from using a variable speed pump compared to a two-speed pump and the application has differing operation than a residence.

The most recent version of DEER (2018) does not include pool pump measures.

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Work paper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER does not contain this measure. |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG value is obtained using the DEER READI tool v.2.5.1. The relevant NTG value for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanisms for more than 2 years | Com | Any | Any | 0.6 |

In CPUC Resolution E-4952 – Section 5.4, it was determined that a net-to-gross adjustment factor for below-code savings for accelerated replacement measures are necessary. Recent “Energy Efficient Potential and Goals Study for 2018 and Beyond” (Potential Study) notes that savings for equipment has below-code savings that are already captured through codes and standards. In addition, Potential Study considers the possibility of free ridership in the below-code savings that occurs during the remaining useful life of the early removed equipment. Therefore, the above-code and to-code portion of the savings require separate treatment in the NTG determination (Figure A). It was established that an adjustment of 0.75 for accelerated replacement measures be applied to the below-code portion of savings.

Below is an example of a net savings calculation where the adjustment factor is applied to the below-code savings for Solution Code PM-20740 in building type “Lodging-Motel” in climate zone 9.

Post E-4952 Calculation of Net Savings:

|  |  |
| --- | --- |
| Net 1st Baseline kWh | = (kWhAC \* NTG)+ (kWhBC \* NTG \* NTGBC) |
|  | = (1,233 kWh \* 0.6) + (6,842 kWh \* 0.6 \* 0.75) |
|  | = (1,233 kWh \* 0.6) + (6,842 kWh \* 0.45) |
|  | = 739.8 kWh + 2,052.6 kWh |
|  | **= 2,792 kWh** |

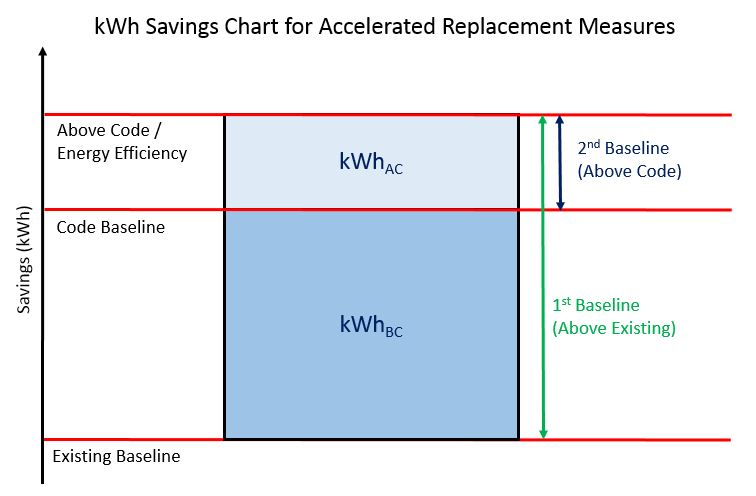


Figure A. AR Measure Savings Chart

where, kWhAC = Kilo-Watt-Hour for above-code savings

kWhBC = Kilo-Watt-Hour for below-code savings

NTG = Net-to-Gross

NTGBC = Net-to-Gross for Below Code Savings

**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 v.2.5.1. 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 v.2.5.1. 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. Although the sector for chosen EUL ID is Res, the READI tool notes that it is applicable to any building type, thus it is applicable to this measure.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| OutD-PoolPump | High Efficiency Pool Pump | Res | Recreation | 10 | 3.3 |

### 1.4.2 Codes and Standards Analysis

**California Code of Regulations, Title 24, and Building Standards Code (2016) [505]:**

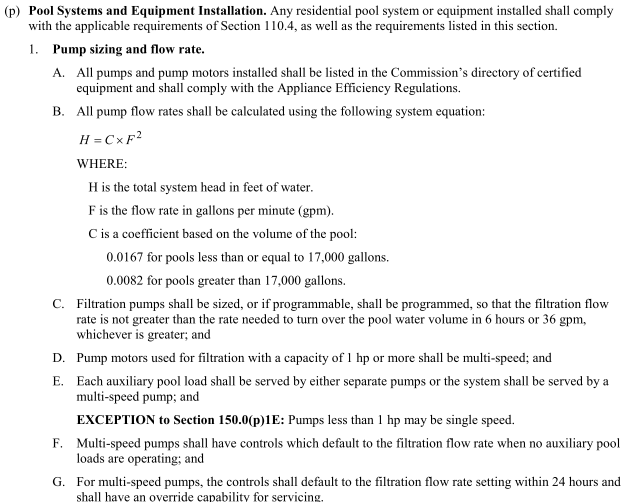
**Turnover Time Requirement**

Chapter 31B “Public Pools,” Section 3124B provides capacity requirements for several types of pools. The pools eligible for this work paper fall under item 5, “other types of public pools.” The Title 24 language does not explicitly state that pool water must be turned over in 6 hours during pool open hours; it only states that the pump system must have the capability to do so. However, based on discussions with health inspectors and pool operators, the flow rate corresponding with a six hour turnover time is treated as the minimum flow rate during pool open hours. This minimum flow rate is site-specific and calculated from pool volume.



**Speed Control Requirements**

Title 24, under Section 150.0 - Mandatory Features and Devices [496], requires pump motors used for filtration with a capacity of 1 hp or greater shall be multi-speed. Hence, baseline speed control requirements for ROB and RET/AR (2nd baseline) are driven by this mandatory requirement.



**California Code of Regulations, Title 22, Social Security (2016) [506]:** Chapter 20 “Public Swimming Pools,” Section 65525 states that during filtration, the flow rate shall not be lowered below 75% of that required by Title 24. This does not impact the work paper because this work paper assumes that the measure case VS pool pump will operate at 100% of the Title 24-required flow rate during filtration during pool open hours.

22 CCR § 65525

§ 65525. Recirculation and Water Treatment System Operation.

(a) The pool operator shall operate pumps, filters, disinfectant and chemical feeders, flow indicators, gauges, recirculation systems, disinfection systems, and all parts of the water treatment system whenever the public pool is available for use and at such additional times as necessary to maintain clean pool water, clear pool water, and the disinfection standards required in section 65529.

(b) The variation in flow rate of an operating recirculation system shall be such as not to reduce the flow below 75 percent of the rate required in section 3124B, Title 24, California Code of Regulations.

Note: Authority cited: Sections 116050 and 131200, Health and Safety Code. Reference: Sections 116040, 116043 and 116050, Health and Safety Code.

**Local Health Codes:** Health departments at the city, county, or other level may provide regulations and guidelines for public swimming pools. Most counties will cite the Title 24 turnover time requirements.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | Part 6, Section 150.0 | January 1, 2017 |
| Title 22 (2016) | Division 4, Chapter 20, Article 3, Section 65525 | January 15, 2016 |
| Title 20 (2016) | N/A | N/A |

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

### 1.5.1 Commercial Variable Speed Pool Pump Market Characterization and Metering Study ET13SCE1170/ET13SCE1171 [468] (Attachment 4)

This study assessed the energy savings benefits of installing pool pumps equipped with Variable Speed Drives (VSD) for commercial customers. To do this, market information was gathered from several sites across the Hotel/Motel, Education, and Assemblies market sectors to develop an estimate of operating characteristics that can be generalized across these market segments. In addition, five hotel/motel sites were selected to receive new VSD-equipped pool pumps for a metering study to measure the actual energy savings from a device to support and further validate energy savings estimates for potential inclusion into SCE incentive programs.

**Market Characterization Study**

This workpaper only leverages the Market Characterization study data only for only the Lodging (Hotel and Motel) building types, because the School and Assembly building types were found to have pools sizes and pump motor horse powers that varied to greatly or were too large to support in this workpaper.

An attempt was made to survey 50 randomly selected sites (in SCE service territory) for equipment and operational characteristics, including:

* Pool and pump operating schedule, including DEER peak coincident hours.
* Pool system: Volume, filtration medium, pressure drop,
* Pool pump and motor: Size, service factor, age, efficiency, controls, nameplate, flow rate, speed, etc.
* Spot measurement of voltage, current,
* Health code requirements, turnover rates

**Field Monitoring**

The field monitoring showed that persistency is a problem with variable speed pool pump installations. Two of the five sites yielded negative savings due to poor installation, commissioning, and/or customer interference with pump programming. However, the remaining three sites yielded an average savings of 0.55 kW. This study did not provide any training for the customer as part of the field monitoring on the proper use of the VSD equipped pool pump in conjunction with retrofitting their original single-speed pump. It is concluded that the customer training is critical to achieve the potential savings and this persistence issue will be addressed by SCE Program through both program implementation and documentation requirements. See Section 1.1 for more details.

### 1.5.2 DOE Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings [466]

This report discusses the function, energy consumption, and energy savings potential for pool pumps. It was prepared for by the DOE by the Building Media and the Building America Retrofit Alliance, in 2012. This work paper uses the report as a general source of information about the benefits, potential, and costs of VS pool pumps when compared to single-speed pumps.

## 1.6 Data Quality and Future Data Needs

The savings in this work paper are based on Commercial Variable Speed Pool Pump Market Characterization Study, ET13SCE1170 [468]. The data can be augmented in the future with additional collected data. Namely, monitoring data of commercial variable speed pool pump installations would inform future updates of this workpaper.

# Section 2. Calculation Methodology

## 2.1 Dataset and Analysis Description

The savings in this work paper were developed based on Commercial Variable Speed Pool Pump Market Characterization Study data, ET13SCE1170 [468] (Attachment 4). This workpaper follows the same methodology, except that it uses updated 2018 CEC appliance database pump data and also includes a two-speed ISP baseline. The following table shows the relevant data values and/or input parameters that were used in the calculation, and their associated sources:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Value (Unit)** | **Source\*** |  | **Value (Unit)** | **Source\*** |
| Electrical Conditions (V, A, Phase) | ET13SCE1170 (Measured) |  | Health Code Turnover Rate | ET13SCE1170 (Surveyed) |
| Pool Annual Hours | ET13SCE1170 (Surveyed) |  | Single Speed Flow Rate | ET13SCE1170 (Surveyed) |
| Ex. Pump Annual Hours | ET13SCE1170 (Surveyed) |  | Multispeed Flow Rates (GPM) | ET13SCE1170 (Calculated) |
| Pool Volume (Gal) | ET13SCE1170 (Measured) |  | 1-speed Power (kW) | ET13SCE1170 (Calculated) |
| Pool Pump Motor Size (HP) | ET13SCE1170 (Surveyed) |  | 2-speed High and Low Speed Power (kW) | CEC Database (Calculated) |
| Filter Pressure Drop (ft) | ET13SCE1170 (Measured) |  | Variable -speed High and Low Speed Power (kW) | CEC Database (Calculated) |

\*All values shown here are found in Attachment 2, Calculations tab.

All calculations are in Attachment 2.

1. **Assemble eligible data set**

In order to support deemification of the measure under a “single speed” pump baseline, only “typical” pump operating and system characteristics were used from referenced ET study. Hence, of the (50) sites that were surveyed for Hotels and Motels, (25) sites were removed based on the following conditions:

* Existing pump is not a single speed with 90% of sites equipped with single speed equipment,
* Existing pump had a rated capacity less than 1 HP or greater than 3 HP with 84% of the sites equipped with pump motors with rated capacity within 1 HP and 3 HP,
* Current pool pump sizing was inadequate for pool turnover requirements requiring larger than 3 HP motor.

See Attachment 2, Calculations tab for details. Reasons for removal from dataset are included in column AZ.

Note that measure savings estimates for ROB under 2-speed baseline, were supported using CEC’s Database.

1. **Energy Consumption and Demand for each site**

As described later in Section 2.2, energy consumption and coincident demand were calculated for single speed, two speed and variable speed operation at each site using both survey data from ET study and engineering equations. See Section 2.2 and Attachment 2, Calculations Tab for more detail.

1. **Average Energy Savings**

Once energy consumption and demand were calculated, the 1st and 2nd baseline savings were calculated per site, the average 1st and 2nd baseline energy savings and coincident demand for the 25 sites. See Section 2.2 and Attachment 2, Calculations or Summary Tabs for more details.

This measure is assumed to be unaffected by climate zone, so no further adjustments were made. Furthermore, the averages were taken across the both Hotel and Motel building types, thus savings for both building types are estimated to be the same.

Other commercial building types are supported using adopted data sets and calculation as long as the commercial building type has operating characteristics consistent with that for Hotel/Motel buildings and meet all the criteria listed under Measure’s eligibility requirements.

## 2.2 Energy Savings and Demand Reduction Estimation Methodology

This section demonstrates how energy savings and demand reduction for each site was calculated using both survey data from the ET study and engineering equations. As described in Section 2.1, the energy savings and demand reduction for this measure are based on the average of the per-site energy savings and demand reduction calculated for each of the 25 sites individually.

The information in the table below shows an example motel site. Data from this site will be used to demonstrate the equations in the following sections. Calculations for this specific site can be followed in Row 7 on the Calculation tab in Attachment 2.

|  |
| --- |
| **Example Site (Site # 5 on Calculations Tab, Attachment 2, Calculations tab, Row 7)** |
| This site will be used in all following examples:  Building type: Motel  Pool hours: 7:00am‒7:00pm  Pump run hours: 24 hours per day, 365 days per year  Pump: Single-speed, 1.5 HP  Pool: 26,393 gallons  Electrical: 1-phase, 8.8 amps, 230 V, no power factor measured |

The following tables show the glossary of variables, subscripts and their meanings used in this workpaper.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **Value** |  | **Subscript** | **Value** |
| P | Demand (kW) |  | 1-speed | Value for 1-speed pump |
| E | Energy Consumption (kWh) |  | 2-speed | Value for 2-speed pump |
| Q | Flow (gpm) |  | VS | Value for variable speed pump |
| ΔE | Energy Savings (kWh) |  | Average | Average value of 25 sites |
| ΔP | Demand Reduction (kW) |  | 1st BL | 1st baseline value |
| - | - |  | 2nd BL | 2nd baseline value |
| - | - |  | Open | Value when pool is open |
| - | - |  | Closed | Value when pool is closed |

**2.2.1 Single Speed Base Case Energy Usage**

The base case power consumption is calculated using voltage (V), current (I) and power factor (pf) measurements taken during the surveys. Due to issues with the meters, in most cases only voltage and current readings were obtained. Therefore, if power factor is not available, a value of 0.8 is assumed (from the Handbook of Pumps and Pumping [472], full load for 0.75‒7.5 kW; see figure below).



Typical Power Factors by Motor Size *[472]*

The annual energy usage (E) is calculated as shown:

Motel Example, Site #5

Electrical: 1-phase, 8.8 amps, 230 V, no power factor measured

Operation: 24 hours per day, 365 days per year

The energy consumption for this measure is the average across 25 sites as found in Attachment 2, and is found to be:

P1-speed and E1-speed can be found in columns AK and AS, on the Calculation tab in Attachment 2, respectively. Tables showing average values and savings is found in column BC, on the Calculation tab in Attachment 2.

**2.2.2 Two-Speed and Variable Case Energy Usage**

The multispeed pump power consumption is determined from regression analysis of data from the California Energy Commission (CEC) Appliance Efficiency Database, for Residential Pool Pumps downloaded in 2018. In Title 20 code [508], there is no significant distinction between residential and commercial pool pumps [467], so the use of residential data is applied to commercial applications.

**CEC System Curves**

For each pool pump in the CEC database, flow rates and watt draws at each of the three CEC system curves (A, B, C) are provided. Each multispeed pump has several entries because they are tested at multiple speed (rpm) settings. See the figure below for a sample pump curve and the CEC curves and equations.



Sample Pump Performance Curve and CEC System Curves

Since pool plumbing head losses are site-specific, the CEC curves are used to represent three typical plumbing scenarios:

* Curve A corresponds to a system with high head losses. This is typical of a new pool with 2” PVC pipe [469, 470].
* Curve B corresponds to an older system with very high head losses. This is typical of a pool with 1½” copper pipe [469, 470].
* Curve C corresponds to a system with medium head losses. This is typical of a new pool with 2½” PVC pipe [469].

For the multispeed pool pump cases, Curve C is used because it is assumed to be the most representative of multispeed commercial pump installations. This is further supported by the observation that the average pressure drop from the commercial pool study is 36 ft, with an average high speed flow of 71 gpm. Curve C calculates a pressure of 40 ft at 71 gpm - Attachment 2, Summary Tab.

The Los Angeles County Department of Public Health has issued guidelines for the installation of VS pumps, which state:

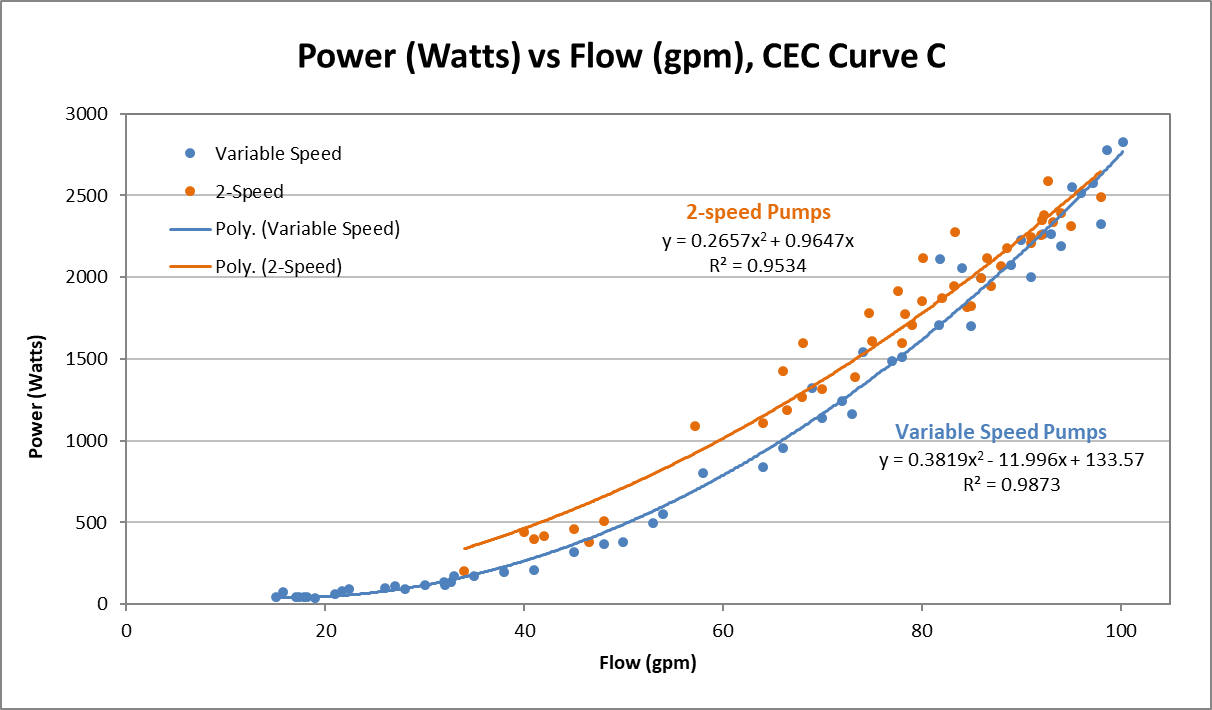
“For existing pools, installation will be allowed only when plumbing and equipment is sized to accommodate the maximum flow of the pump at 60 feet of head at the highest rpm.”

The guidelines also include specific requirements for a particular VS pump model:

“Installation of this pump will only be allowed when the plumbing size of the suction line is at least 3” and the plumbing size of the return line is at least 2 ½“. These are the pipe sizes needed to accommodate the maximum flowrate of this pump.”

While these guidelines may not be standard for other counties, and while many other variables such as filters and piping configuration will influence head losses, for this work paper it is assumed that during installation some system improvements will be performed so that the post-retrofit system curve resembles Curve C. Exports of Curve C pumps from the 2018 CEC database were downloaded and filtered for both variable and two-speed pumps. The data was also filtered to only include pool pumps with horsepower between 1 HP and 3 HP to match the requirements of this workpaper.

The figure below displays the power versus flow polynomial regressions for two-speed and variable speed pumps. Please refer to Attachment 2, for more detail:



CEC Curve C Flow vs Power for Variable Speed Pool Pumps

Note that the both regressions have high R-squared values, showing a good fit of the data to the curves. The following equations from the regression analysis are used to estimate the power for the two-speed and variable speed pumps based on flow. (Attachment 2, CEC VS (Curve C) and CEC 2S (Curve C) tabs)

See Attachment 2, CEC VS (Curve C) and CEC 2 speed (Curve C) tabs for more details.

**Pool Open Hours Energy Consumption**

The Title 24 6-hour turnover requirement for public pools [505] is used to determine the minimum flow rate (Qopen) during pool open hours:

Motel Example, Site #5

Pool skimmers require a minimum of 25 gpm to function adequately [466], so a minimum value of 25 gpm is used if flow is calculated to be below 25 gpm. This is also the minimum flow in the Energy Star Pool Pump Calculator [469]. In addition, pool heaters may shut down if the flow is too low. It is noted that not all multispeed pool pump models will be able to lower flow rate to 25 gpm or below, so in those cases the energy consumption will decrease. Pool flows for open hours can be found in column AM, on the Calculation tab in Attachment 2.

Using the regression results for both variable speed and 2-speed in Figure 4, the expected watt draw of a each type of pump providing 73.31 gpm is:

P2-speed, open and PVS, open can be found in columns AO and AN, on the Calculation tab in Attachment 2, respectively.

Note that some counties may require a turnover rate greater than Title 24’s 6 hours/turnover, so the watt draw may be greater in those cases.

**Pool Closed Hours Energy Consumption**

There are no regulations that specify minimum flow rates for public pools during closed hours, but it is recommended that the water be filtered two hours before and two hours after open hours [471]. Therefore pool pumps can be run at any speed during closed hours as long as the water passes health code water quality criteria (including pH, disinfectant concentration, and clarity/turbidity). Since residential pools have a suggested turnover rate of 24 hours/turnover [466], this work paper uses that turnover rate for commercial pools during closed hours. Again, a minimum of 25 gpm is set for the multispeed pumps as described in the previous section. Pool flows for closed hours can be found in column AP, on the Calculation tab in Attachment 2.

Motel Example, Site #5

Since skimmers require 25 gpm to function adequately, and since some multispeed pool pumps have a limit on how low speed can be reduced:

At 25 gpm, the expected watt draw of a VS pump is 0.073 kW.

However, as a conservative assumption, the minimum watt draw is set at 120 W, which is the lowest possible watt draw from the Pentair Commercial Pool Pump Savings Calculator [469].

P2-speed, closed and PVS, closed can be found in columns AR and AQ, on the Calculation tab in Attachment 2, respectively.

**Annual Energy Consumption**

The following assumptions are used in the annual energy usage calculations:

* Non-filtration tasks such as pool cleaning, backwashing filters, and water features may require a pool pump to run at high speed. The Title 24 6-hour turnover time for public pools requires that, in many cases, commercial multispeed pool pumps operate at high speed for filtration during open hours. Therefore, it is assumed that the open hours flow rate Qopen is sufficient to perform non-filtration tasks as well.
* Approximately 10% of a pool pump’s operation time is used for non-filtration tasks [466]. Therefore, the open hours are extended by applying a factor of 1.1:

The annual energy usage (E) is calculated as shown:

Motel Example, Site #5

Pool Open Hours: 7:00am‒7:00pm = 12 hours

However, the energy consumption for this measure is the average across 25 sites as found in Attachment 2, and is found to be:

E2-speed and EVS can be found in columns AT and AU, on the Calculation tab in Attachment 2, respectively. Tables showing average values and savings is found in column BC, on the Calculation tab in Attachment 2.

The measure case variable speed solution allows for fine tuning of the flow that is not possible with the baseline constant speed system. As such, during pool open hours (on-peak TOU), the proposed variable speed pump is assumed to obtain a small energy savings and on-peak demand reduction.

**2.2.3 Energy Savings and Demand Reduction**

**Energy Savings**

The annual energy savings for the Motel Example are:

Motel Example, Site #5 (Calculated in Sections 2.2.1 and 2.2.2)

E1-speed = 14,184.19 kWh

E2-speed = 7,971.10 kWh

EVS = 6,769.09 kWh

The 1st baseline Early Retirement energy savings is the difference the existing case (1-speed pump) and the measure case (variable speed pump).

The energy savings for this measure is the average across 25 sites as found in Attachment 2, and is found to be:

The 2nd baseline Early Retirement and 1st baseline Normal Replacement energy savings is the difference the ISP case (2-speed pump) and the measure case (variable speed pump).

The energy savings for this measure is the average across 25 sites as found in Attachment 2, and is found to be:

E1st BL and E2nd BL can be found in columns AV and AX, on the Calculation tab in Attachment 2, respectively. Tables showing average values and savings is found in column BC, on the Calculation tab in Attachment 2.

**Per-site Demand Reduction**

Most lodging sites are open year-round, but several only open during summer or winter. Nearly all sites operate their pools between 2pm and 5pm. The coincident diversity factors (CDFs) are calculated by averaging the number of open hours during 2‒5pm and dividing by 3. The number of coincident hours per site was captured in the ET study (Attachment 2 on Calculation tab in Col J and Attachment 4). The CDF is found in Attachment 2, Calculations page.

Coincident Diversity Factors

|  |  |
| --- | --- |
| **Building Type** | **CDF** |
| Lodging (Hotel and Motel) | 0.98 |

The non-coincident demand is found by taking the difference between the power values obtained from either the baseline measurements or the CEC database curves. As the pools were shown to operate at full speed during peak hours, the full speed demand is used to estimate demand reduction. The non-coincident demand must be multiplied by the Coincidence Diversity Factor as described in the equations below.

Motel Example, Site #5 (Calculated in Sections 2.2.1 and 2.2.2)

P1-speed = 1.61920 kW

P2-speed,Open = 1.49884 kW

PVS, Open = 1.30678 kW

The 1st baseline Early Retirement energy demand is the difference the existing case (1-speed pump) and the measure case (variable speed pump).

The demand reduction for this measure is the average across 25 sites as found in Attachment 2, and is found to be:

The 2nd baseline Early Retirement and 1st baseline Normal Replacement demand reduction is the difference the ISP case (2-speed pump) and the measure case (variable speed pump).

However, the demand reduction for this measure is the average across 25 sites as found in Attachment 2, and is found to be:

P1st BL and P2nd BL can be found in columns AW and AY, on the Calculation tab in Attachment 2, respectively. Tables showing average values and savings is found in column BC, on the Calculation tab in Attachment 2.

The table below summarizes the 1st and 2nd baseline savings for each solution code.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Solution Code** | **Install Type** | **1st Baseline Energy Savings (kWh)** | **1st Baseline Demand Reduction (kW)** | **2nd Baseline Energy Savings (kWh)** | **2nd Baseline Demand Reduction (kW)** |
| PM-20470 | RET | 8,075.04 | 0.66116 | 1,233.06 | 0.18434 |
| PM-20471 | ROB | 1,233.06 | 0.18434 | N/A | N/A |

See tables in column BC, on the Calculation tab in Attachment 2 for more details.

# 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. Although the load shape is noted as Residential, the load shape of residential pool pumps will best match the load shape commercial pool pumps since there is currently no specific commercial pool VFD load shapes.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Lodging - Guest Rooms | Residential Pool Pumps | Residential |
| Lodging - Hotel | Residential Pool Pumps | Residential |
| Lodging - Motel | Residential Pool Pumps | Residential |
| Assembly | Residential Pool Pumps | Residential |
| Education - Community College | Residential Pool Pumps | Residential |
| Education - Secondary School | Residential Pool Pumps | Residential |
| Education - University | Residential Pool Pumps | Residential |
| Health/Medical - Hospital | Residential Pool Pumps | Residential |
| Health/Medical - Nursing Home | Residential Pool Pumps | Residential |

# Section 4. Costs

## 4.1 Base Case Cost

The base case material costs for the single and two speed pumps come from online searches. Various online retail sources from 2017 were used to search for each of the base case pump equipment between 1 and 3 HP (see Attachment 3, tabs “1-Spd Pump Mtl” and “2-Spd Pump Mtl” for details and supporting documentation). The average per pump material costs found for each equipment type are used in this work paper.

**Permitting Cost**

In addition to material and labor costs, permit costs are also incurred during the installation for commercial pool pumps. The table below shows permit costs for several counties in Southern California as documented by SCE programs in Quarter 2 of 2017. It is assumed that a single permit is needed per pump, so the average permit cost was included in addition to the material and labor cost for each measure. See Attachment 3, Permit Costs tab for more details.

|  |  |  |
| --- | --- | --- |
| **Jurisdiction** | **Permit Fee** | **Notes** |
| Orange County | $56.50 | per body of water |
| San Bernardino County | $245.00 | per body of water |
| Riverside County | $204.00 | per body of water |
| Ventura County | $250.68 | per enclosure\* |
| Los Angeles County | $130.00 | per body of water |
| City of Long Beach | $275.00 | per body of water |
| **Average Permit Fee** | **$220.94** |  |

\* *Includes all bodies of water within a single gated area.*

Plan check fees for New Construction and Retrofits pool projects are generally assessed per “body of water” and based on the type of pool and volume but independent from the building sector. Remodel fees are assessed per body of water and based on the number of remodel activities proposed for evaluation. See Attachment A6 for additional supporting information on permit cost per County.

To calculate the labor for the single speed pumps, which are not programmed, one hour of an electrician’s time, equal to $72.25 was acquired from RS Means 2018 Residential Labor Rates (Attachment 3, RS Means Res. Labor Rates tab). This was subtracted from the estimated labor for the SCE Multifamily programmed pump installation, to account for the absence of programming in the measure (Attachment 3, Pump Costs Calculations tab). Refer to Section 4.2 for details on the programmed pump costs source.

*Non-Programmed Labor Cost*

Labor Cost (Non-Programmed) = Labor Costs(Programmed Pump) – Programming Cost

Labor Cost (Non-Programmed) = $679.44 - $72.25 = $607.79

The table below shows the base costs for each measure.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Base Case Equipment** | **Material Costs** | | | **Labor Costs** | **Total Installation Costs** |
| **Pump Material Costs** | **Permit Costs** | **Total Material Costs** |
| 1-Speed Pump | $385.90 | $220.94 | $606.84 | $607.19 | $1,214.03 |
| 2-Speed Pump | $591.24 | $220.94 | $812.18 | $679.44 | $1,491.62 |

See Attachment 3 (tab Pump Costs Calculations) for the base case cost calculations and backup data.

Base costs are adjusted for each climate zone using 2008 DEER cost adjustments for motor measures (M50) in Attachment 1.

## 4.2 Measure Case Cost

**Pump Replacement Costs**

Due to the similarity in pump size and installation requirements, this workpaper estimates that the installed cost for the commercial pool pumps covered in this workpaper will closely match the installation costs of the Multifamily Program. Furthermore, the average horsepower from the SCE Multifamily Program data (1.84 HP) (Attachment 3) closely matches the average horsepower from the Commercial Pool Pump Study (1.82 HP) (Attachment 2).

The total material and labor cost for the variable speed pumps measure case comes from data collected from the installation of (101) pumps from SCE’s Multifamily Programs (Attachment 3 – tab SCE MF Summary) for the years 2016-2017. The average cost per pump installation was found to be $1,750.44. However, these costs do not separate out the material and labor costs for the installation. In order to break out the costs further, material costs for various variable speed pumps ranging from 1 to 3 HP were found using searches of online retailers in 2017. The average material costs per pump of $1,071.00 was found and is used for the material costs in this work paper.

The average pump material cost was subtracted from the total pump installation costs found from the SCE Programs data to find the estimated labor costs for the programmed pumps. This labor cost is used for both the variable speed measure case, and the two-speed baseline.

Labor Costs (Programmed Pump) = Total Installation Cost – Average Material Cost

Labor Costs (Programmed Pump) = $1,750.44 - $1071.00

Labor Costs (Programmed Pump) = $679.44

**Permit Costs**

Just as in the base case, an average per pump permit cost of $220.94 from several counties in Southern California was used included on top of the labor and material costs for the Multifamily measures.

Please see the table below for a summary of the measure costs.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Case**  **Equipment** | **Material Costs** | | | **Labor Costs** | **Total Installation Costs** |
| **Pump Material Costs** | **Permit Costs** | **Total Material Costs** |
| Variable Speed Programmed Pump Costs | $1,071.00 | $220.94 | $1,291.94 | $679.44 | $1,971.38 |

See Attachment 3 (tab Pump Costs Calculations) for the measure case cost calculations and backup data.

Measure costs are adjusted for each climate zone using 2008 DEER cost adjustments for motor measures (M50) in Attachment 1.

The following table shows the total baseline, measure, and incremental costs for each measure.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SCE Sol Code** | **Base Case** | **Measure Case** | **Install Type** | **Measure Cost** | **Base Cost** | **Incremental Measure Cost** |
| PM-20470 | **1st BL:** Single Speed Pool Pump 1-3HP **2nd BL:** Two Speed Pool Pump 1-3HP | Variable Speed Pool Pump | RET | $1,971.38 | $1,214.03 | $757.35 |
| PM-20471 | Two Speed Pool Pump 1-3HP | Variable Speed Pool Pump | ROB | $1,971.38 | $1,491.62 | $479.76 |

## 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** |
| RET/AR | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| ROB/NR | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| PM-20470 | RET/AR | $757.35 | $1,971.38 | $479.76 |
| PM-20471 | ROB/NR | $479.76 | $479.76 | N/A |

# Attachments

* + 1. SCE17WP008.2 A1 - Calc Templates
    2. SCE17WP008.2 A2 - Survey Results and Calculations
    3. SCE17WP008.2 A3 - Cost Calculations
    4. SCE17WP008.2 A4 - ET13SCE1170 – Commercial Pool Pump ET Study (2015)
    5. SCE17WP008.2 A5 - SCE Commercial Pool Pump POE
    6. SCE17WP008.2 A6 – County VSD Pool Pump Permitting\_V2.xlsx

# References

References\_12122016\_100741.xlsx

[351]

[466]

[467]

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