Work Paper SCE17WP001

**Revision 1**

**Southern California Edison**

**Residential Variable Speed Pool Pumps**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | *Single Family:*  Measure A - PM-78394: Commissioned Variable Speed Drive on Pool Pump Controls  Measure B - PM-98422: Self-Installed Variable Speed Drive on Pool Pump Controls  Measure C - PM-69234: Commissioned Variable Speed Drive on Pool Pump Controls  *Multifamily:*  Measure D - PM-79353: Programmable Variable Speed Drive on Pool Pump Control  Measure F - PM-19753 – Spa: Programmable Variable Speed Drive on Pool Pump Control replacing for Spa  Measure G - PM-19754 – Wading Pool: Programmable Variable Speed Drive on Pool Pump Control for Wading Pool |
| **Measure Description** | Variable Speed Swimming Pool, Spa or Wading Pool Pump for residential pools |
| **Base Case Description** | Customer existing single speed pool pumps or code required two speed pool pumps |
| **Units** | Per Pump |
| **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** | 10 years (OutD-PoolPump) |
| **Measure Installation Type** | Early Retirement (ER/RET)  Replace on Burnout (ROB) |
| **Net-to-Gross Ratio** | 0.55 (Res-Default>2) |
| **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 | 9/25/2017 | Lake Casco (TRC) | * This work paper is an update and consolidation of work papers SCE13WP001.3 and SCE17WP009.2 based on direction from a CPUC Disposition (3/1/2017) * New Calculation Template for 2017 Program Year * All 16 Climate Zones Included * Changed Single Family code baseline pump control to two speed per disposition. * Changed Single Family Measure A from Early Retirement (ER) to Replace on Burnout (ROB) because of two speed baseline. * Updated all measures to use both Direct Install and Downstream Incentive – Deemed, except Measure B which only uses Downstream Incentive – Deemed. * Midstream delivery method included for 2-speed baseline measures (Measures A and B) * Updated calculations for Measures A, D, F and G per disposition * Updated costing to be more uniform based on disposition * Clarified PM-98422 measure to be Self Installed (Non-programmed) * Add Solution codes PM-19753 and PM-19754 for spa and wading pool measures * Removed Measure E (PM-80567) from workpaper * Included additional program eligibility and implementation requirements based on CPUC Disposition and CPUC EAR Feedback received on October 16, 2017 regarding file submitted by SCE on July 17, 2017 describing this workpaper in order to comply with the March 1, 2017 disposition |
| 1 | 4/16/2018  7/02/2018 | Andres Fergadiotti / SCE  Lake Casco/ TRC | * Updated MFM measures’ installation type from ROB to AR * Updated POE documentation to better align AR offerings with Commission Staff guidance * Updated allowances on MFM main filtration pump from 1 pump to a maximum of 3 pumps along with POE data collection requirements for validation and documentation of existing conditions * Added language clarifying SCE’s DI/Downstream (or DI with additional incentive to customer) offering/incentive model * Updated measure savings for MFM measures based on AR installation type * Updated cost documentation for MFM measure to reflect AR cost * Updated calculation methodology based on SCE customer installed database, 2016 SCE Multifamily study and 2018 CEC Appliance database calculation factors. |

# 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

This work paper describes statewide calculations and methodologies related to energy savings and demand reduction values for variable-speed pool pumps for single family and multifamily homes.

Variable-speed pool pumps can lower daily electricity usage and can be programmed with explicit timing and flow rates to both minimize kWh and shift the 1-hour or 2-hour, high-speed cycle to an off-peak period to reduce demand.

The following six measures are evaluated in this work paper (designated as Measures A through G for clarity):

* Measure A (PM-78394):

Commissioned Variable Speed Drive on Pool Pump Controls replacing Two Speed Pool Pump.

The measure case is variable speed swimming pool pumps that are programmed to operate outside peak hours (2:00 pm to 5:00 pm) as part of a contractor driven offer. This measure is only for single family building types.

* Measure B (PM-98422):

Self-Installed Variable Speed Drive on Pool Pump Controls replacing Two Speed Pool Pump.

The measure case is variable speed swimming pool pumps that are not installed as part of a contractor driven offer, thus cannot be assumed to be explicitly programmed. This measure is only for single family building types.

* Measure C (PM-69234):

Commissioned Variable Speed Drive on Pool Pump Controls replacing Single Speed Pool Pump.

The measure case is variable speed swimming pool pumps that are programmed to operate outside peak hours (2:00 pm to 5:00 pm) as part of a contractor driven offer. This measure is only for single family building types.

* Measure D (PM-79353):

Programmable Variable Speed Drive on New Pool Pump Control replacing Single Speed Pool Pump in Multifamily Buildings only. The measure case is operating the variable-speed pump to meet the minimum required health code requirements of one turn over every 6 hours.

* Measure F (PM-19753):

Programmable Variable Speed Drive on Pool Pump Control replacing Single Speed Pool Pump for Spa Pool in Multifamily Buildings only. The measure case is operating the variable-speed pump to meet the minimum required health code requirements of one turn over every 1 hour.

* Measure G (PM-19754):

Programmable Variable Speed Drive on Pool Pump Control replacing Single Speed Pool Pump for Wading Pool in Multifamily Buildings only. The measure case is operating the variable-speed pump to meet the minimum required health code requirements of one turn over every 30 minutes.

The following tables summarize the measures included within this workpaper.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Code** | **SCE Solution Code** | **Measure Case** | **Building Type** |
| Measure A | PM-78394 | Programmed/commissioned variable-speed pumps | Single Family Homes |
| Measure B | PM-98422 | Variable-speed pumps (**Self Installed)** | Single Family Homes |
| Measure C | PM-69234 | Programmed/commissioned variable-speed pumps | Single Family Homes |
| Measure D | PM-79353 | Programmed/commissioned variable-speed swimming pool pumps | Multifamily Homes |
| Measure F | PM-19753 | Programmed/commissioned variable-speed spa pumps | Multifamily Homes |
| Measure G | PM-19754 | Programmed/commissioned variable-speed wading pool pumps | Multifamily Homes |

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Variable speed pool pump |
| Existing Condition | Customer existing single speed or two speed pool pump |
| Code/Standard | Two speed pump  (with variances on turnover rate requirements for both SFM and MFM) |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
|  |  | PM-78394 |  | Commissioned Variable Speed Drive on Pool Pump Controls |
|  |  | PM-98422 |  | **Self-Installed** Variable Speed **Motor** + **Drive** on Pool Pump Controls |
|  |  | PM-69234 |  | Commissioned Variable Speed Drive on Pool Pump Controls |
|  |  | PM-79353 |  | Programmable Variable Speed Drive on Pool Pump Control |
|  |  | PM-19753 |  | Programmable Variable Speed Drive on Pool Pump Control for **Spa Pool** |
|  |  | PM-19754 |  | Programmable Variable Speed Drive on Pool Pump Control for **Wading Pool** |

**Eligibility Requirements**

The following eligibility requirements apply to all measures in this workpaper. Please see Attachment 5 for more details.

* Variable speed pool pump must replace existing single or two speed pool pump. For models that require an automatic control system capable of controlling both high and low speeds, a controller must be installed.
* Only main filtration pumps are eligible. Booster pumps which are solely used for added spa jet circulation or secondary pumps used for cleaning purposes are not eligible.
* It is recommended for the variable speed (VS) pool pump to match the capacity of the pump being replaced. For this work paper, horsepower rating refers to the nameplate horsepower before service factor is applied.
* All climate zones are eligible.
* Must be configured to meet program pump configuration requirements (see implementation requirements below).
* The following product types are not eligible:
  + Rebuilt, refurbished, or reconditioned products
  + Rented or leased products
  + Products won as prizes, or
  + New parts installed in existing units.
* All AR/RET measures require third party baseline verification and data gathering in full compliance with established POE requirements – Attachment 5.

Single family

The following additional eligibility requirements apply to only Single Family Building types:

* Rebates are available for existing single-family properties which include in-ground pools for private, residential properties.
* Single Family properties with an active service account(s) served by the utility offering rebate are eligible to participate in the program. The property must be occupied and the existing pool must not already have a Variable Speed Pool Pump.
* The existing pool pump must be a single or two speed type unit.
* Only swimming pool pumps are eligible. Spa, wading pool or Jacuzzi pumps are not eligible for single family residences.

Multifamily

The following additional eligibility requirements apply to only Multifamily Family Building types:

* Property Owners and Managers of residential multifamily property with an active service account(s) served by rebating utility may be eligible to participate in the programs.
* The following residential properties are eligible for Multi-family pool pump rebates: apartment house pools, residential community pools, townhouse pools, condominium pools, mobile home park pools, and homeowner association pools.
* The following pool types are eligible for Multi-family pool pump rebates: swimming pool, wading pool and spa.

**Implementation Requirements**

The following implementation requirements apply to all measures in this workpaper. Please see Attachment 5 for more detail and additional requirements.

* Pumps being replaced must be disposed of rather than refurbished and sold.
* Measure implementation must be completed with both the customer and the installation contractor acknowledgement of energy savings settings.
* Self-Installed Measures: Measure B shall be used in applications where the client installs their own variable speed pump, or when no certified contractor is used to installed the equipment.
* For Direct Install with Down-stream Incentivized Measures, only utility approved contractors must be used to install. These approved contractors will undergo both technical and incentive program related training in order to assure proper installation. The contractors will be trained such that they can properly collect and submit the correct information for both Accelerated Replacement (AR or RET) and Replace-On-Burnout (ROB) measures.
* Per measures’ preponderance of evidence (POE) requirements for both single family (SFM) and multi-family (MF) sectors, contractor shall verify and document existing motor characteristics including, but not limited to, single speed or two-speed.
* Before issuing measure incentives, program participants must provide completed POE documentation for each project.

Single family

The following implementation requirements apply to only Single Family Building types:

* Only one variable-speed pool pump and motor rebate per residence.
* Programming and Operations
  + Filtration settings must be configured to operate outside peak hours, as defined by the utility. Customers must acknowledge and confirm operation on application form in order to be eligible for rebate.

Multifamily

The following implementation requirements apply to only Multifamily Family Building types:

* Installation must be performed by a contractor approved by the Multifamily Program or one who has the appropriate license and training.
* Contractor must follow all manufacturer installation requirements and comply with all applicable regulations.
* Variable speed pool pump or motor must be a new, qualifying product installed in a pre-existing in-ground spa or wading pool.
* Only one rebate is allowed per spa OR wading pool pumps.
* A maximum of 3 rebates are allowed per customer property/site for main filtration pump(s). Incentive applications for more than one mainfiltration pump require supporting documentation verifying existing condition per Authority Having Jurisdiction.
* Programming and Operations
  + During Pool Operating Hours: Variable speed drive setting must be “right sized” to meet turnover requirements as specified by California Code of Regulations, Title 24, Building Standards Code (2016) [505]: Chapter 31B “Public Swimming Pools,” Section 3124B.
  + During Pool Non-Operating Hours: Variable speed drive setting must be configured to at least 50% of full speed operation to achieve energy savings. 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.
* Environmental Health & Safety (EH&S) Department Permit Requirements
  + Must obtain and submit a Permit from the governing Health and Safety Department (i.e. County or City) of jurisdiction, if applicable.
  + Health code requirements and inspections must be passed successfully.
  + EH&S approves size and model of pump for installation, as well as, the required minimum and maximum flow rates based on specific site conditions.

**Data Collection Requirements**

IOU programs will require the collection and submission of several pieces of information and documentation in order to ensure proper conformance to eligibility and implementation requirements. The following are the types of information that will be required for all projects:

* Customer/site information
* Existing equipment
* Replacement equipment
* Permits and associated documentation
* Pump commissioning information.
* 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). Note that POE for both SFM and MFM is documented as part of their corresponding Rebate Application Forms.

Please see Attachment 5 for more specific details on data collection requirements.

**Quality Control and Inspections**

IOU 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. Please see Attachment 5 for more details.

Inspections will serve three main purposes:

1. To verify that equipment claimed for incentive is installed properly and configured per Program requirements.
2. To evaluate and understand program’s effectiveness, and
3. To ensure customer compliance with Program guidelines

## 1.2 Technical Description

Variable speed pool pumps allow the reduction of power consumption by running the motor at slower speeds when compared to single or two speed pumps to perform the same task. The speed is able to modulate based on a schedule or load, based on the type of feedback control tied into the variable speed pool pump. This is in contrast to single or multi-speed pool pumps which run at either a constant speed or have stepped speed levels, typically two-speeds.

## 1.3 Installation Types and Delivery Mechanisms

Please see the table below indicating the installation types and delivery mechanisms for each of the measures.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **SCE Sol Code** | **Building Type** | **Measure Name** | **Install Type** | **Baseline** | **Delivery Type(s)** |
| Measure A | PM-78394 | SFM | Commissioned Variable Speed Drive on Pool Pump Controls | ROB | 2-Speed | Direct Install,  Down-Stream Incentive, Mid-Stream |
| Measure B | PM-98422 | SFM | Self-Installed Variable Speed Drive on Pool Pump Controls | ROB | 2-Speed | Down-Stream Incentive, Mid-Stream |
| Measure C | PM-69234 | SFM | Commissioned Variable Speed Drive on Pool Pump Controls | AR/RET | 1st BL: 1-speed  2nd BL: 2-speed | Direct Install,  Direct Install (with Down-Stream Incentive) |
| Measure D | PM-79353 | MFM | Programmable Variable Speed Drive on Pool Pump Control | AR/RET | 1st BL: 1-speed  2nd BL: 2-speed | Direct Install,  Direct Install (with Down-Stream Incentive) |
| Measure F | PM-19753 | MFM | Programmable Variable Speed Drive on Pool Pump Control Spa Pool | AR/RET | 1st BL: 1-speed  2nd BL: 2-speed | Direct Install,  Direct Install (with Down-Stream Incentive) |
| Measure G | PM-19754 | MFM | Programmable Variable Speed Drive on Pool Pump Control for Wading Pool | AR/RET | 1st BL: 1-speed  2nd BL: 2-speed | Direct Install,  Direct Install (with Down-Stream Incentive) |

**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 |
| 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.

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

**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. |

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.

## 1.4 Measure Parameters

### 1.4.1 DEER Data

DEER 2017/2018 does not include a residential swimming pool, spa and wading pool pump measure.

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 | 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 values were obtained using the DEER READI tool v.2.4.7. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Res | Any | Any | 0.55 |

**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.2.4.7. 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.2.4.7. 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)** |
| OutD-PoolPump | High Efficiency Pool Pump | Res | Recreation | 10 | 3.3 |

### 1.4.2 Codes and Standards Analysis

**Single Family and Multifamily Pools**

**Federal Code**

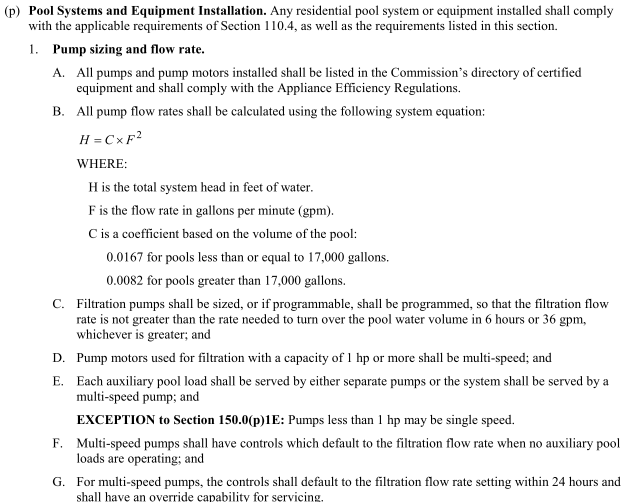
There are no federal regulations governing the energy efficiency of residential swimming pool pumps.

**2016 Building Efficiency Standards, Title-24:**

2016 Title 24 Part 6, “Building Energy Efficiency Standards” [496] does require that any residential pool system or equipment installed shall comply with the following applicable requirements

***Section 110.4(b)3ii*** includes the following requirement regarding scheduling the pool pumps during off peak hours - “*A time switch or similar control mechanism shall be installed as part of a pool water circulation control system that will allow all pumps to be set or programmed to run only during the off-peak electric demand period and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.*”

Additionally, Section 150.0, under Mandatory Features and Devices requires the following:



**California Code of Regulations, Title 20 2016 [508]**

Title 20 Section 1605.1(g).5(B) requires pumps that all pumps 1HP or greater that are sold to have at least two speeds.

“(B) Two-, Multi-, or Variable-Speed Capability.

1. Residential Pool Pump Motors. Residential pool pump motors with a pool pump motor capacity of 1 HP or greater which are manufactured on or after January 1, 2010, shall have the capability of operating at two or more speeds with a low speed having a rotation rate that is no more than one-half of the motor's maximum rotation rate. The pump motor must be operated with a pump control that shall have the capability of operating the pump at least at two speeds.
2. Pump Controls. Pool pump motor controls manufactured on or after January 1, 2008 that are sold for use with a two- or more speed pump shall have the capability of operating the pool pump at least at two speeds. The control's default circulation speed setting shall be no more than one-half of the motor's maximum rotation rate. Any high speed override capability shall be for a temporary period not to exceed one 24-hour cycle without resetting to default settings.”

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Baseline Equipment/Controls** | **Code** |
| Single Family | 2-speed Pump | Title 24 (2016) and Title 20 (2016) |
| Multifamily | 2-speed Pump | Title 24 (2016) |

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | Part 6, Section 110.4(b)3ii | January 1, 2017 |
| Title 24 (2016) | Part 6, Section 150.0(p) | January 1, 2017 |
| Title 20 (2016) | Section 1605.1(g).5(B) | January 1, 2016 |

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

### 1.5.1 SCE Single Family Installation Data (2008-2009) (Attachment 2)

This work paper uses data gathered by SCE’s Measurement and Evaluation team specific to single family residential homes within Climate Zone 15 for installation from 2008 to 2009 (Attachment 2). Over 600 sites were selected where data was collected by site visits and metering of the existing pool pumps. A few of the variables measured for both existing and measure pool pumps were as follows:

* Pool pump size (hp)
* Pool size (gallons)
* Flow rate (gpm)

The study indicated that there were greater energy savings when the variable speed pool pumps were programmed per the specifications listed in the Table below. Data was collected through site visits and metering. The following chart was used by the study authors to program the settings for the programmed variable speed pool pump - See Attachment 7 for more detail. The controller was programmed to run the pump outside of the noon to 6:00 pm timeframe to achieve greater kW reduction.

**Programmed Specifications**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pool Size** | **High Speed** | | **Low Speed** | |
|  | Variable-Speed Pump | Number of hours | Variable-Speed Pump | Number of hours |
| (gallons) | (gpm) |  | (gpm) |  |
| 10,000 | 50 | 2 | 20 | 3.3 |
| 15,000 | 50 | 2 | 20 | 7.5 |
| 20,000 | 50 | 2 | 20 | 11.7 |
| 25,000 | 50 | 2 | 20 | 15.8 |
| 30,000 | 50 | 2 | 25 | 16.0 |
| 35,000 | 50 | 2 | 30 | 16.1 |

***Variable Speed Operation***

Filtration pumps may provide pressure for pool sweeps or for backwashing diatomaceous earth filters. In some cases, additional booster pumps are installed to provide the additional pressure. The data from the SCE Program sites fall into two distinct categories:

1. The pool pumps are used for filtration purposes only.
2. The pumps are used for filtration and for performing pool sweeps and/or filter backwashing.

The categories are broken into three modes. Pumps with Mode 1 include filtering operations only. Pumps with sweeping operations include a filtering mode (Mode 2A) and a sweeping mode (Mode 2B).

The following information was collected for each category for systems with a baseline pump motor size of 1 to 3 HP. The values below are used to calculate the efficiency and energy consumption of the various modes. Details on calculations can be found in Section 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Mode** | **Percent Pools (Vol. Wtd. %)** | **Average Hours** | **Average Flow (gpm)** | **Average Pool Turnovers** |
| Baseline Operation | N/A | 6.6 | 41 | 1.052 |
| Mode 1: Filtering Only | 71.7% | 12.5 | 22 | 1.045 |
| Mode 2A: Filtering | 28.3% | 14.5 | 18 | 1.041 |
| Mode 2B: Pool Sweeps | 2.1 | 48 | 0.446 |

In addition to mode specific information, the following values were obtained from the dataset for pump sizes 1 to 3 HP.

|  |  |
| --- | --- |
| **Description (unit)** | **Value** |
| Average Pool Volume (gal) | 15,700 |
| Baseline pump size (HP) | 1.56 |

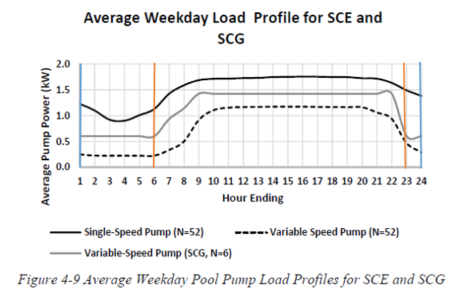
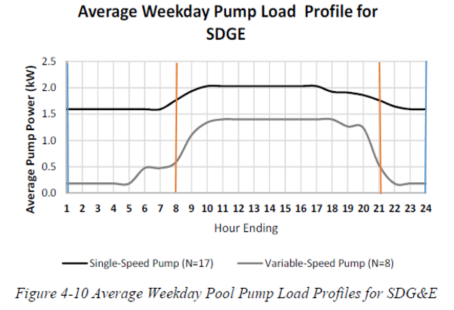
For more details on the origin of these values refer to Attachment 2, Analysis tab, Column AL.

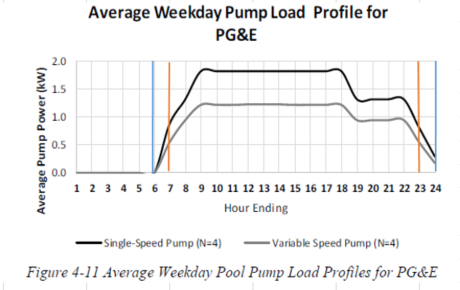
### 1.5.2 SCE’s Multi-Family VSD Pool Pump Report, Phase 2 (2016) (Attachment 12)

The Multi-Family report by SCE covered 84 multi-family pools located in four IOU areas: SCE (53 pools), SCG (5 pools), SDG&E (22 pools) and PG&E (4 pools). In this report, SCE collected data on several parameters, including pump capacity, control type, and pool volume, as well as conducted pre and post case energy monitoring. This workpaper obtains the average pool size, average flow (GPM), and average turnovers for multi-family swimming pools (Measure D) from this report.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Description** | **SCE** | **SDG&E** | **SCG** | **PG&E** |
| Average Pool Size (gallons) | 26,256 | 28,218 | 37,200 | 28,467 |
| Std. Dev. (gallons) | 15,067 | 16,116 | 12,518 | 8,231 |
| Minimum Size (gallons) | 5,900 | 8,000 | 24,000 | 17,213 |
| Maximum Size (gallons) | 100,000 | 70,000 | 56,000 | 37,000 |
| Count | 53 | 22 | 5 | 4 |
| Weighted Average Pool Volume | 27,527 | - | - | - |

The study also measured the hourly loads of the pumps and created average hourly load profiles for baseline and measure pumps for each IOU. The profiles below show that the multi-family pools in the study operate at full load during peak hours of 2pm-5pm (hours 15-17). This is consistent with the understanding that most local health codes require that commercial pool pumps continue to operate during occupied periods, which is estimated to coincide with peak hours. Thus, the coincident diversity factor (CDF) for multifamily pools is assumed to equal one.



Based on the variable speed pumps included within the report, the average flow for the pumps in high mode was found to be 53.5 GPM and 31.8 GPM in low mode. The hourly load profiles for each IOU shown above, were used to define the kW for each mode. High mode was defined as 1.5 kW based on a weighted average of the peak kW per each IOU. Using the defined high mode power (1.5 kW) and high and low speed flows as indicated in the table below, affinity pump law for semi-closed systems (n=2.2) was used to calculate the low speed power. Low speed mode was defined as any speed less than 0.5 kW. (Attachment 2, MFm Report Values Tab)

The run hours for each of the modes, as defined, were estimated using the hourly load profiles. The orange lines on the profiles above indicate high mode and low mode run times are indicated by the blue lines. The run hours per day for each mode are based on a weighted average of all IOUs and are provided in the table below. The turnover/day for each mode was calculated based on the flow, hours per day, and weighted average pool volume of 27,527 gallons. It was observed that for some IOUs, notably PG&E and SDGE, that several hours were measured to be lower than 0.5 kW. These hours were still included in the estimated Low Speed hours estimate in order to be conservative.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Flow Data Description** | **GPM (Avg)** | **Hours Per Day** | **Turnover Rate (hours/turn over)** | **Turnover/day** |
| Single Speed | 63.30 | - | 6.6 | 3.4 |
| VSD (High Speed Mode) | 53.50 | 15.9 | 8.6 | 1.9 |
| VSD (Low Speed Mode) | 31.80 | 7.8 | 14.4 | 0.5 |

The report values for weighted average single speed baseline horsepower are used to inform baseline efficiency values for all multi-family measures.

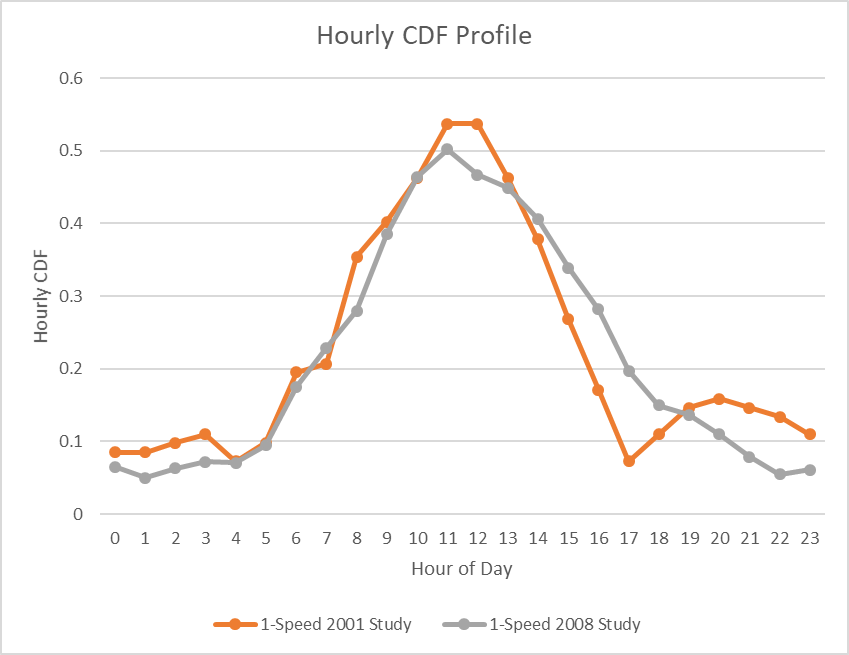
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Avg. Pump Type and HP** | **SCE** | **SDG&E** | **SCG** | **PG&E** |
| Single Speed (HP) | 1.46 | 1.72 | 0.00 | 1.50 |
| VSD (HP) | 1.74 | 3.00 | 1.33 | 2.85 |
| Count (Qty) | 53 | 22 | 5 | 4 |
| Weighted average Single Speed (HP) | 1.53 | - | - | - |
| Weighted average VSD (HP) | 2.10 | - | - | - |

Please refer to Attachment 12 for the full report and Attachment 2, MFm Report Values tab for additional details.

Please refer to Attachment 12 for the full report and Attachment 2, MFm Report Values tab for additional details.

### 1.5.3 *SCE's "Pool pump demand response potential demand and run-time monitored data" study (2008) (Attachment 9)*

This 2008 SCE Report includes 146 pool pumps that were monitored in the SCE territory for a pool pump demand response potential study. In this study, the electric demand was monitored for each pump, and an actual load shape in terms of hourly kW, not just in terms of the percentage of pumps that are on, was recorded. The report also references a 2001 Evaluation [44] which monitored the percentage of 165 pool pumps that are running at any given hour. The coincidence factors for single-speed pool pumps are taken to be the average of the 2001 and 2008 measurements. The PUC nine-hour average peak demand coincidence factor for single-speed pumps is 0.307. The relevant hourly coincidence factors are shown in the Table below.



**Load Shapes for Single Speed Pumps in SCE territory   
as Measured in 2001 and 2008**

**Coincidence Factors for Single-Speed Pool Pumps as Measured in 2001 and 2008**

|  |  |  |  |
| --- | --- | --- | --- |
| **Hour of Day** | **Coincidence Factor (2001 Evaluation)** | **Coincidence Factor (2008 Evaluation)** | **Average Coincidence Factor** |
| 2PM – 3PM | 0.378 | 0.406 | 0.392 |
| 3PM – 4PM | 0.268 | 0.339 | 0.304 |
| 4PM – 5PM | 0.171 | 0.282 | 0.227 |
| ***Average 2PM-5PM*** | ***0.272*** | ***0.342*** | ***0.307*** |

Please refer to Attachment 9 for the full report and Attachment 2, Peak Demand tab for additional details.

1.5.4 Impact Evaluation of 2013-2014 SDG&E Residential VSD Pool Pump Program, DNV-GL, April 01, 2016 (Attachment 8)

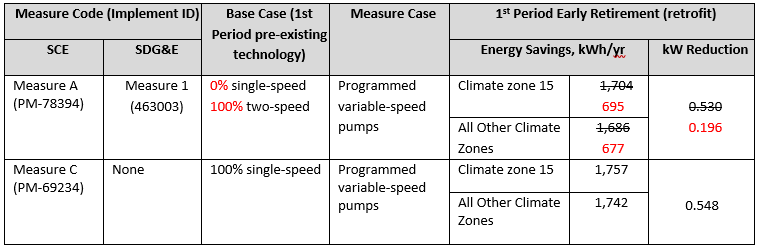
The evaluation approach to calculate volume of water pumped with the installed VSD pump produced site level turnover rates that varied widely from this assumption. Of the 49 successfully sampled sites, 26 sites exhibited a calculated summer period daily turnover rate that fell outside the range of 75-125%. The evaluation-level average turnover rate was 152%.

Recommendations from the Impact Evaluation were acknowledged but not adopted for this workpaper since sampling rate was limited (e.g., 49 sites) and considerably less than supported study. Additionally, Impact Evaluation recommendations suggest that a larger sample will be needed and necessary to improve precision given the large degree of variability of savings on a site by site basis.

### 1.5.5 CPUC’s Disposition FOR WORKPAPERS COVERING RESIDENTIAL VARIABLE SPEED POOL PUMPS (3/1/17) (Attachment 6)

In CPUC’s 2017 disposition, the CPUC provides direction on several assumptions, including the following which impact the savings calculations of this workpaper.

1. CPUC assigned a 100% two-speed pool pump code baseline to Measure A and Measure C and approved the following savings (Section 3.1.1):



1. CPUC directed all non-direct install delivery types for single family pools to adopt Measure B savings values. They approve a volume of 20,341 gallons, and turnover of 0.98 per day (Section 3.2.2).
2. CPUC directed all multifamily measures to be updated using Equation 1, using the following

assumptions, or provide other assumptions based on new or more thorough sources (Section 3.2.2).

* 1. Pool Volume per pump: 31,000 gallons (swimming pools), 720 (wading pools), 1,400 (spa)
  2. Daily water turnover: 4 (swimming pools), 24 (wading pools), 48 (spas)
  3. Pump size & efficiency: develop new EFF values for pumps that are less than 1 HP. For larger pumps, the pump size and efficiency from SCE Measure B may be used.
     1. For downstream rebates, all pre-existing multi-family pool pumps shall be assumed to be 2-speed

The following average flows for spas and wading pools were calculated from the turnovers and pool volumes provided in the disposition, using a conversion of 24 x 60 = 1,440 min/day. These flows are used in the Energy Factor calculations in Section 2.1.1.3 and electric demand calculations in Section 2.2.2.

|  |  |  |  |
| --- | --- | --- | --- |
| **Pool Type** | **Volume (Gal)** | **Turnover (Per day)** | **Average Flow (GPM)** |
| Spa | 1,400 | 48 | 47 |
| Wading | 720 | 24 | 121 |

(1) Although the average flow for the wading pools is 12 GPM based on the turnovers and pool volumes provided in the disposition, the analysis of energy factors for variable speed pumps in Section 2.1.1.2 showed that at low flows (approximately 15 GPM), the energy factor of the pump become independent of flow. Thus, a flow of 15 GPM is used instead of 12 GPM for calculating energy and demand values for wading pools.

## 1.6 Data Quality and Future Data Needs

* N/A

# Section 2. Calculation Methodology

The calculations for estimating energy savings and demand reductions are found below.

**2.1 Energy Savings Estimation Methodologies**

The calculation procedure for the energy savings estimation is outlined below:

* Obtain the average pool size in state
* Obtain average single, two, and variable-speed pump size and efficiency
* Obtain the average number of pool water turnovers per day

The calculation for annual energy usage is shown in Equation 1.

**Equation 1**

EU = V × T × D / EF × C

Where,

EU = annual energy usage, kWh/year

V = pool size, gallons

T = number of turnovers per day, no units

D = average number of days in a year

365 day/yr

EF = Energy Factor, gallons/W-hr

C = conversion factor, 1,000 W/kW

The calculation of the work performed by the pump depends on the amount of water pumped and on the overall hydraulic performance of the pool-pump system. The pool pump Energy Factor accounts for the hydraulic performance of a typical pool. The determination of the base case and measure values used in the equation described above are found in the following sections.

### 2.1.1 Determination of Energy Calculations Inputs

The following sections detail how the values are used in Equation 1 to calculate the base and measure energy savings values.

#### **2.1.1.1 Data Sources and Studies**

In addition to the data sources described in Section 1.5, exports from the California Energy Commission (CEC) appliance database of single speed, two speed and variable speed pool pumps was used to develop the energy factors (EF) for the measure and base case scenarios.

**2.1.1.2 Pool Hydraulic Performance**

Swimming pool hydraulic performance is characterized by system curves that show the resistance presented to the flow of water as a function of flow rate. This resistance is comprised of static head pressure, which does not change as flow changes, and dynamic head pressure, which increases in proportion to the square of flow rate. The CEC has specified Curves A, B and C, which represent different pool systems [508].

The hydraulic performance of a typical swimming pool (i.e., a pool with 2-inch PVC plumbing and a diatomaceous earth filter) is represented by the California Energy Commission’s Curve A. Curve A is defined by a mathematical relationship between the flow rate and system head. Curve A is symbolically written as:

***CEC Curve A***

H = 0.0167 × F2

Where,

H = total system head, ft of water

F = flow rate, gpm

Curve B shows a higher dynamic head pressure and is suited for older pools (e.g., 1.5” copper piping). Curve B is symbolically written as:

***CEC Curve B***

H = 0.05 × F2

Where,

H = total system head, ft of water

F = flow rate, gpm

Curve C shows the lowest dynamic head pressure and is suited for the most efficiently designed pools. Curve C is symbolically written as:

***CEC Curve C***

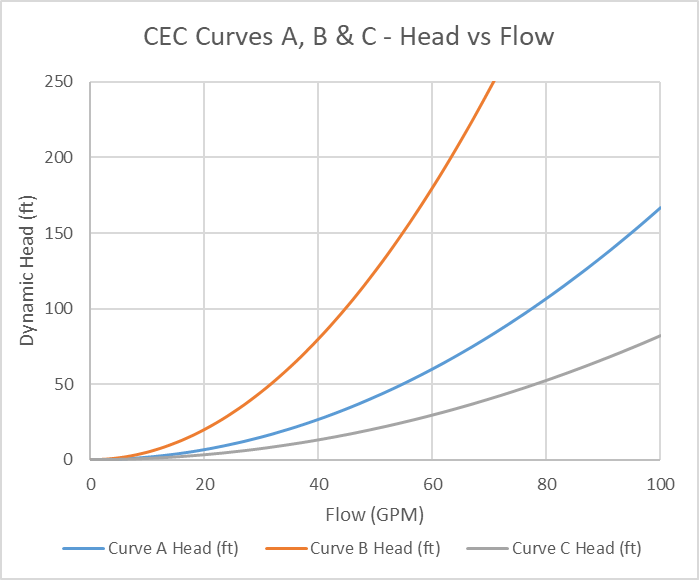
H = 0.0082× F2

Where,

H = total system head, ft of water

F = flow rate, gpm

The figure below shows the CEC system curves A, B and C. Note that the resistance for these curves tend to zero at very low flows. These theoretical curves correspond to zero static head pressure at low flows.

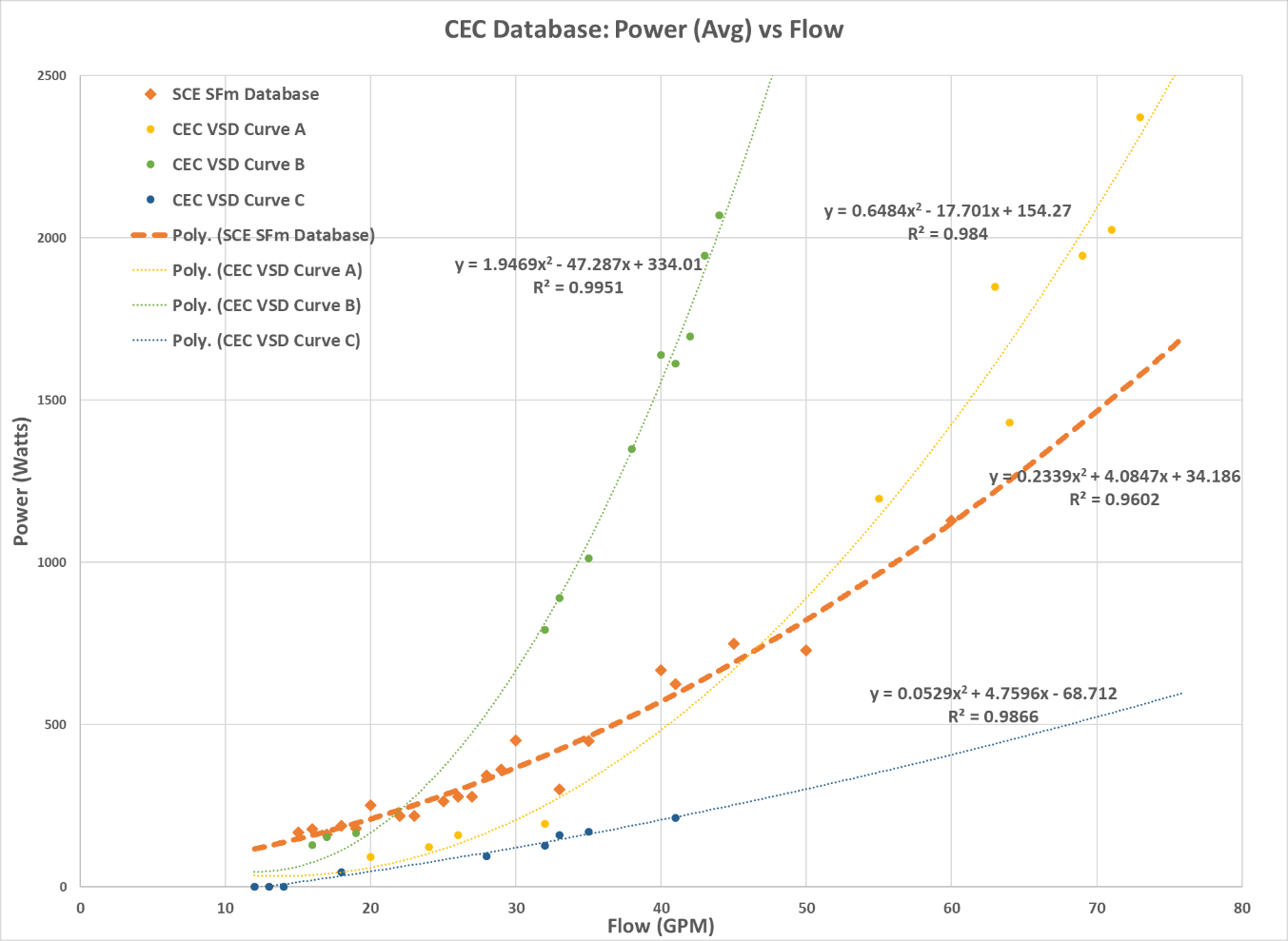


**CEC System Curves Representing Typical Residential Pools.**

**CEC Database Curves**

Two speed and variable speed pool pump values were exported from the 2018 CEC appliance database. Single speed pump data was taken from the previous version of this workpaper, which was based on the 2008 CEC appliance database. This was done because the CEC database currently only includes single speed pool pumps less than 1 HP. The database exports include relevant data such as motor HP, service factor, full capacity, flow (GPM), power (W) and Energy Factor for each CEC curve. For each database, only pumps between 1 and 3 HP are included for the analysis.

The CEC variable speed pump data was compared to the installed power and flow data from SCE’s single-family installation database (Attachment 2). Each data point shown on the figure below represents the average power of each dataset at a number of flows. Due to the quantity of items in each database, only averages with 6 or more data points were used for the CEC curves A, B and C. For the installed single-family data, only averages with 10 or more points are used.



As demonstrated in the figure above, the single-family data does not fit onto either curve perfectly. This is due to the variety of different pool, pump and piping configurations that were included in the data set. The single-family data intersects the CEC Curve B at roughly 23 GPM and Curve A at roughly 47 GPM. This correlates well to the low speed and high speed average flows from the single-family database described in Section 1.5. Thus, it is assumed that at lower (filtering) speeds, Curve B can be used to estimate pump performance. Conversely, at higher speeds, Curve A can be used to estimate pump performance. It was determined that CEC Curve C did not fit the data well at any flow, and therefore was not used in this analysis.

Refer to Attachment 2 - Analysis 2, 1-Spd CEC Data (2008), 2-Spd CEC Data (2018), and VS CEC Data (2018) tabs for more details.

**2.1.1.3 Pool Pump Energy Factor**

The parameter that describes pump energy efficiency performance is the Energy Factor, which is defined as flow rate divided by power and symbolically written as in Equation 2.

**Equation 2**

EFF = F × C2 / P

Where,

EFF = Energy Factor, gallons/W-hr

F = flow rate, gpm

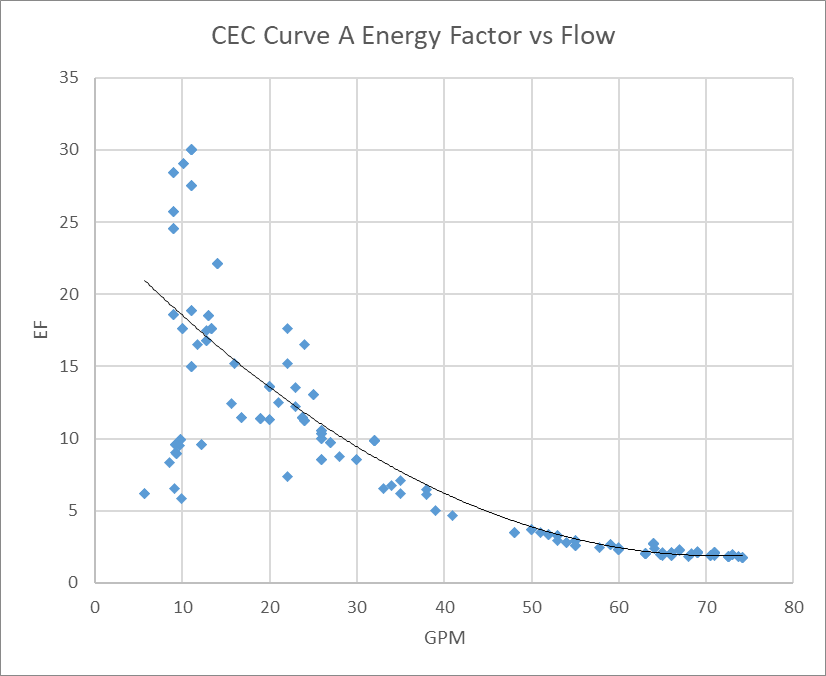
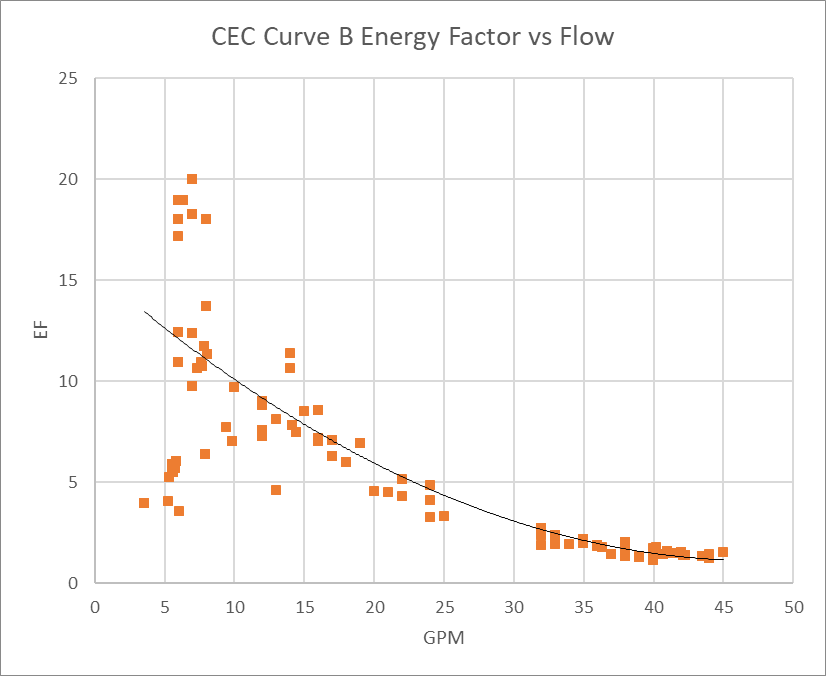
C2 = conversion constant, 60 min/hr

P = power, Watts

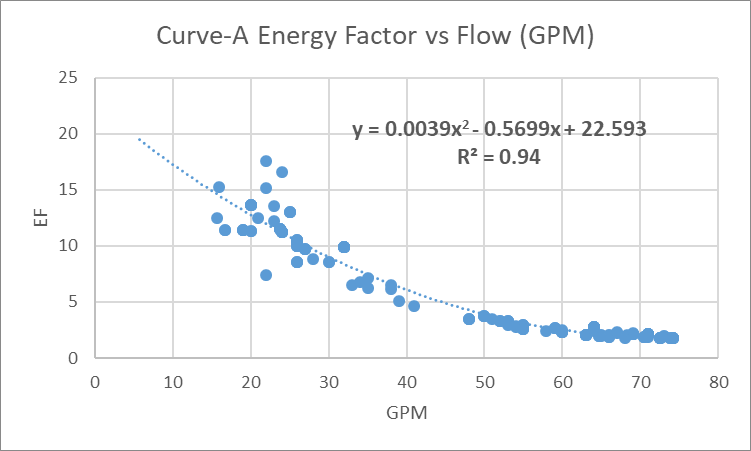
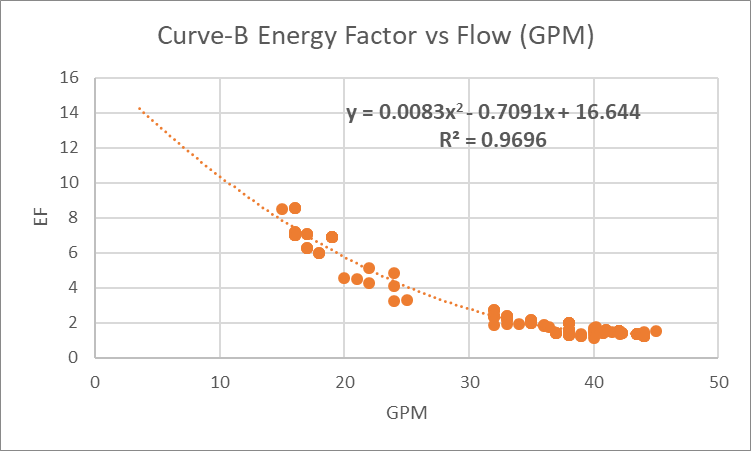
The energy usage can be obtained by dividing the volume of pumped water by the Energy Factor as shown in Equation 1. Energy Factor and energy consumption are inversely related and thus a higher Energy Factor is preferred from an energy efficiency perspective. This figure of merit is posted on the CEC web site for (121) single-speed, (171) two-speed, and (147) variable speed pumps (Attachment 2). Note, however, that, because these Energy Factors are based on the CEC curves that do not account for static head pressure, they are likely to underestimate power usage at low flow rates.

***Energy Factors for Variable-Speed Pumps***

The Energy Factors for variable-speed pool pumps are obtained from a regression analysis of energy factor (EF) versus flow from the CEC database. The dataset was filtered so that only pool pumps of 1 to 3 HP were included. Additionally, it was noted that at low flows (less than 15 GPM) EF became independent of flow (See graphs below) (Attachment 2, VS CEC Data (2018) – Uncleaned tab). From a pure energy efficiency perspective, there seems to be no advantage to operate below 15 gpm. This phenomenon is also demonstrated in a plot in the Pentair IntelliFlo Owner’s Manual (Attachment 11).

Thus, database entries less than 15 GPM were removed from the dataset. The resulting dataset provided the following EF vs Flow (GPM) curves. A polynomial regression curve was created for Curve A and Curve B to estimate EF based on flow. As can be seen, the R-squared values for the curves are close very close to one, showing a close fit of the data to the polynomial regression.

. 

|  |  |  |
| --- | --- | --- |
| **CEC Curve** | **VS Pump EF Equation1** | **Coeff. of Determination** |
| Curve A | **EF** = 0.003922\***F**2 - 0.569902\***F** + 22.592557 | 0.94 |
| Curve B | **EF** = 0.008254\***F**2 - 0.709072\***F** + 16.643590 | 0.97 |

(1) EF = Energy Factor, F = Flow (GPM)

Refer to Attachment 2 - VS CEC Data (2018) tab for details.

Flows for measure and base case systems taken from Section 1.5 were used to estimate EFs for each case. See the table below for details. Again, note that Curve A is used for higher speeds, while Curve B is used for lower speeds as described in the CEC Database Curves Section, 2.1.1.1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Pool Type/Mode** | **Flow (GPM)** | **Curve Selected** | **Calculated Energy Factor (Gal/W-hr)** |
| SFm | Mode 1: Filtering Only | 221 | Curve B | 5.04 |
| SFm | Mode 2A: Filtering | 181 | Curve B | 6.55 |
| SFm | Mode 2B: Pool Sweeps | 481 | Curve A | 4.27 |
| MFm | Swimming Pool (High Speed) | 542 | Curve A | 3.33 |
| MFm | Swimming Pool (Low Speed) | 322 | Curve A5 | 8.44 |
| MFm | Spa Pool | 473 | Curve A | 4.47 |
| MFm | Wading Pool | 154 | Curve B | 7.86 |

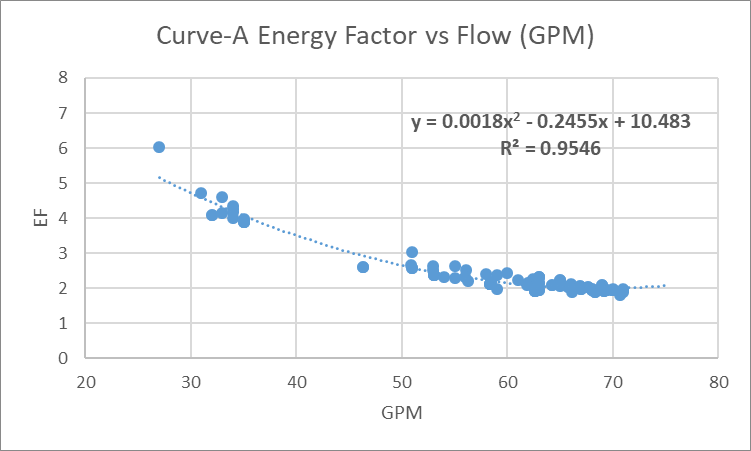
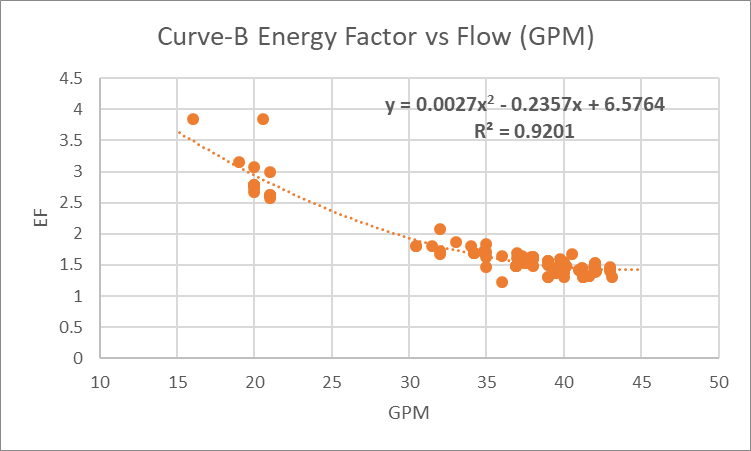
(1) Refer to Section 1.5.1. (2) Refer to Section 1.5.2. (3) Refer to Section 1.5.5. (4) Minimum 15 GPM used to estimate EF, based on Section 2.1.1.2, instead of 12 GPM from average turnover from Section 1.5.5. (5) The flow identified for the multifamily low speed fell between Curve A and Curve B, but Curve A was used because the results more accurately reflected the difference between high and low speed energy factors. Using Curve B for low speeds resulted in a lower energy factor at lower speeds.

Refer to Attachment 2 - VS CEC Data (2018) and Energy Factors Table tabs for more details.

***Energy Factors for Two-Speed Pumps***

The Energy Factor for two speed pumps is calculated in a similar way to variable speed pumps.

The Energy Factors for two-speed pool pumps are obtained from a regression analysis of energy factor (EF) versus flow from the CEC database. The dataset was filtered so that only pool pumps of 1 to 3 HP were included. The resulting dataset provided the following EF vs Flow (GPM) curves. A polynomial regression line was created for Curve A and Curve B to estimate EF based on flow. As can be seen, the R-squared values for the curves are close very close to one, showing a close fit of the data to the polynomial regression.

|  |  |  |
| --- | --- | --- |
| **CEC Curve** | **2-speed Pump EF Equation1** | **Coeff. of Determination** |
| Curve A | **EF** = 0.0018\***F**2 - 0.2455\***F** + 10.483 | 0.95 |
| Curve B | **EF** = 0.0027\***F**2 – 0.2357\***F** + 6.5764 | 0.92 |

(1) EF = Energy Factor, F = Flow (GPM)

Refer to Attachment 2 - 2-Spd CEC Data (2018) tab for details.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Pool Type/Mode** | **Flow (GPM)** | **Curve Selected** | **Calculated Energy Factor (Gal/W-hr)** |
| SFm | Mode 1: Filtering Only | 221 | Curve B | 2.70 |
| SFm | Mode 2A: Filtering | 181 | Curve B | 3.21 |
| SFm | Mode 2B: Pool Sweeps | 481 | Curve A | 2.85 |
| MFm | Swimming Pool (High Speed) | 542 | Curve A | 2.50 |
| MFm | Swimming Pool (Low Speed) | 322 | Curve A5 | 4.50 |
| MFm | Spa Pool | 473 | Curve A | 2.92 |
| MFm | Wading Pool | 154 | Curve B | 7.21 |

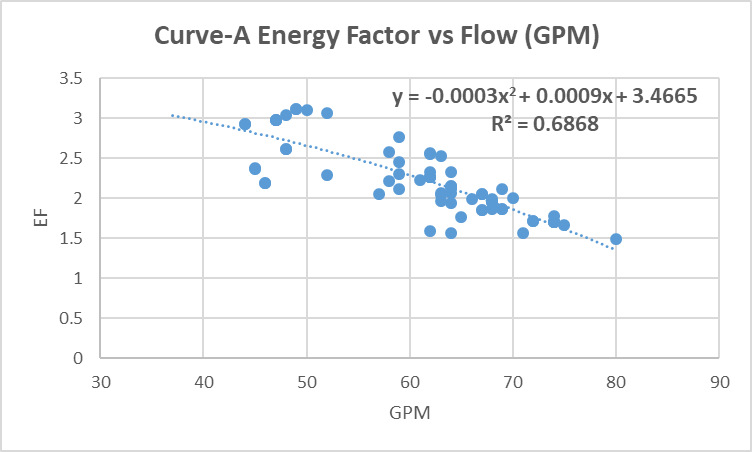
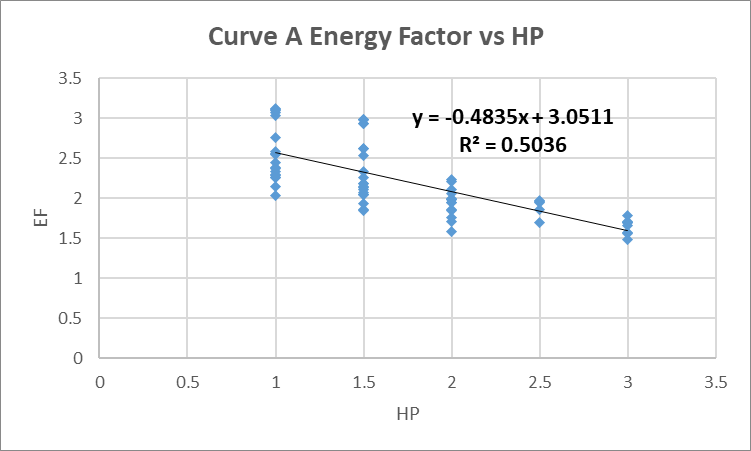
Flows for measure and base case systems taken from Section 1.5 were used to estimate EFs for each case. See the table below for details. Again, note that Curve A is used for higher speeds, while Curve B is used for lower speeds as described in the CEC Database Curves Section, 2.1.1.1.

(1) Refer to Section 1.5.1. (2) Refer to Section 1.5.2. (3) Refer to Section 1.5.5. (4) Minimum 15 GPM used to estimate EF, based on Section 2.1.1.2, instead of 12 GPM from average turnover from Section 1.5.5. (5) The flow identified for low speed fell between Curve A and Curve B, but Curve A was used because the results more accurately reflected the difference between high and low speed energy factors. Using Curve B for low speeds resulted in a lower energy factor at lower speeds.

Refer to Attachment 2 – 2-Spd CEC Data (2018) and Energy Factors Table tabs for more details.

***Energy Factors for Single-Speed Pumps***

The energy factor for single speed pumps was initially analyzed in a similar way to the variable speed and two-speed pumps. However, this analysis showed a poor correlation between flow and energy factor for Curve A (R-Squared = 0.69). An analysis showing the correlation between EF and horsepower (HP) was then completed, but this analysis also showed a poor correlation (R-Squared = 0.50). The poor correlation is demonstrated in the graphs below.

Due to the poor correlations between EF and HP and Flow, no regression formula was chosen to estimate single speed pump efficiency. Instead, the simple average EF of the single speed pumps with nameplate HP equal to 1.5 HP was used. This horsepower was chosen because the average baseline HP from both the SCE Single Family installations (Attachment 2, Analysis tab) and the SCE’s Multifamily study (Attachment 12) were extremely close to 1.5 HP. The average EF for Curve A was used because it is representative of pools in California.

|  |  |  |  |
| --- | --- | --- | --- |
| **Horse Power Source** | **Average Single Speed HP** | **Chosen HP** | **Average CEC Curve A EF (Gal/W-hr)** |
| SCE’s single-family installation database | 1.562 | 1.5 | 2.381 |
| SCE's "Metering and Measuring of Multi-Family Pool Pumps: Phase 2" | 1.533 |

(1) Refer to Attachment 2 – 1-Spd CEC Data (2018) tab for more details. (2) Refer to Section 1.5.1. (3) Refer to Section 1.5.3.

**2.1.1.4 ANNUAL Work Load (Turnover and Volume)**

The annual work load is the total gallons of water that is circulated yearly by the pump. In Equation 1, this is represented by the pool volume and turnovers per day. The sources of the pool volume and turnover for each measure and base case have been described in Section 1.5.

The table below describes the pool volumes by building and pool type used in this analysis and their sources.

|  |  |  |  |
| --- | --- | --- | --- |
| **Building Type** | **Pool Type** | **Volume (Gal)** | **Source** |
| Single Family | Swimming | 15,700 | Average Volume from SCE SFm database (1-3 HP only) |
| Multi Family | Swimming | 27,527 | Wtd Average Vol from 2016 SCE MFm pool study (2016) Attachment 12. |
| Spa | 1,400 | Pool volume provided by CPUC Disposition FOR WORKPAPERS COVERING RESIDENTIAL VARIABLE SPEED POOL PUMPS CPUC, ED, March 1, 2017 (Attachment 6) |
| Wading | 720 |

Pool turnovers are taken directly from Sections 1.5.1, 1.5.2 and 1.5.5. One adjustment is made for the pool turnovers for single family non-commissioned (self-installed) variable speed pool pumps (Measure B). As described in Section 1.5.1, the pumps in SCE’s single family database were programmed not to operate from 12pm to 6pm to get additional energy savings. A non-programmed pool pump would not receive this additional programming, and is assumed to simply not operate during the peak period of 2pm to 5pm. Therefore, the pump is assumed to operate for an additional 3 hours per day, or 0.125 turnovers. This additional turnover is added to the commissioned single family variable speed pump turnover rates for Mode 1 and Mode 1A to estimate the non-programmed turnover rate.

|  |  |  |
| --- | --- | --- |
| **Turnover (per day)** | **Mode 1** | **Mode 2A** |
| Programmed Turnover | 1.045 | 1.041 |
| Non-Programmed Additional Turnover | 0.125 | 0.125 |
| ***Non-Programmed Total Turnover*** | ***1.170*** | ***1.166*** |

The table below describes the turnovers per day by building type, pool type and pump system/mode used in this analysis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building Type** | **Pool Type** | **Case** | **Turnover (per day)** | |
| Single Family | Swimming | Single Speed Pump (Filter only) | 1.0521 | |
| 2-Speed Pump- Mode 1 (Filter only) | 1.0451  (programmed) | |
| VSD Pump- Mode 1 (Filter only) | 1.0451  (programmed) | 1.1704  (non-programmed) |
| 2-Speed Pump - Mode 2A (Filter Mode) | 1.0411  (programmed) | |
| VSD Pump - Mode 2A (Filter Mode) | 1.0411  (programmed) | 1.1664  (non-programmed) |
| 2-speed Pump - Mode 2B (Sweep Mode) | 0.4461 | |
| VSD Pump - Mode 2B (Sweep Mode) |
| Multi Family | Swimming | Single Speed Pump | 3.42 | |
| 2-Speed Pump (High Speed) | 1.92 | |
| VSD Pump (High Speed) |
| 2-Speed Pump (Low Speed) | 0.52 | |
| VSD Pump (Low Speed) |
| Spa | Single Speed Pump | 48.03 | |
| 2-Speed Pump |
| VSD Pump |
| Wading | Single Speed Pump | 24.03 | |
| 2-Speed Pump |
| VSD Pump |

(1) See Attachment 2 – Analysis Tab, or Section 1.5.1 for additional details. (2) See Attachment 12 for the full report, Attachment 2, MFm Report Values tab or Section 1.5.2 for additional detail. (3) See Attachment 6 or Section 1.5.5 for additional details. (4) See Section 2.1.1.4 or Attachment 2 – Analysis tab.

**2.1.1.5 CPUC Disposition Direction and Deviation**

Note that some calculation inputs in this workpaper deviate from the Disposition’s values since new data was available after the Disposition’s initial release. However, Section 3.2.3 of the disposition notes “***Pools in multi-family buildings will update energy impacts following SCE’s calculation approach****:… following assumptions or provide new information that is more recent or more thorough than the multi-family data provided in previous version of the workpaper”*

The following are updated inputs and reasons for changes:

* Single Family
  + Measure A and C methodologies have been revised to be more aligned with Measure B’s methodology, using Equation 1 and CEC pool pump database efficiency assumptions. This deviates from the approved savings from the disposition because SCE has updated data sources with latest CEC databased data from 2008 and 2018. The updated methodology uses inputs from 750+ installed single family pool projects and updated CEC database efficiency assumptions. (Attachment 2) Refer to Sections 1.5.1, and 2.1.1.2 for more details.

* + Single Family pool volume was reduced from 20,341 gallons to 15,700 gallons. Likewise, the 0.98 turnovers per day was updated to roughly 1.05 (differing based on pool operation mode). The source of the original data could not be accessed, thus the average pool data from 600+ installed single family pool projects was used (Attachment 2). Refer to Section 1.5.1 for more details.
* Multifamily
  + Swimming pool volume and turnover were updated from 31,000 gallons and 4 per day, to 27,527 gallons and 1.9 per day in high mode and 0.5 per day in low mode, respectively. As discussed in Section 1.5, SCE’s Multi-Family VSD Pool Pump Report, Phase 2 (2016) (Attachment 12) was used to find updated pool volume and turnover for multifamily swimming pools. (Attachment 2 and Attachment 12) Refer to Section 1.5.2 for more details.
  + Energy Factor values for multifamily pools were changed to be dependent on their average flow rates, rather than simply mimicking the Single Family Measure B’s Energy Factor. This was done because multifamily pool volumes, flows and turnover requirements vary from Single Family pools, which are shown to impact the energy factor. Refer to Section 2.1.1.2 for more details.

### 2.1.2 Energy Savings Calculations

Based on the findings of Section 2.1.1, the following section outlines the calculation inputs per measure that shall be used to calculate the annual energy savings.

All energy usage values in this workpaper are calculated using Equation 1

EU = V × T × D / EF × C

Where,

EU = annual energy usage, kWh/year

V = pool size, gallons

T = number of turnovers per day, no units

D = average number of days in a year

365 day/yr

EF = Energy Factor, gallons/W-hr

C = conversion factor, 1,000 W/kW

Below is an example calculation of the energy usage for a single family 1-speed pool pump (EU\_SFm, 1-spd) with the following inputs:

V = 15,700 gallons

T = 1.052 per day

D = 365 day/yr

EF = 2.38 gallons/W-hr

C = 1,000 W/kW

EUA2-spd:M-1 = (15,700 gallons)(1.052 turnover)(365 day/yr)

/(2.38 gallons/W-hr)(1,000 W/kW)

EUA2-spd:M-1 = 2,531.13kWh/yr

Each building type, pool type, pool pump system type, and controls mode is calculated identically, except with varying values for pool volume, turnover, and energy factor. The sources of the individual inputs can be found in Section 2.1.1. The table below shows the input values for each building type, pool type, pool pump system type, and controls mode used in this workpaper. The Energy Usage ID is used as a short hand to identify the building type, pool type, pool pump system type, and controls mode associated with each energy usage.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Building** | **Pool Type** | **System/Mode** | **Pool Volume (Gal), [V]** | **Turnover (/day), [T]** | **Energy Factor (Gal/W-hr), [EF]5** | **Energy Usage ID** | **Energy Usage (kWh/ year)** |
| Single Family | Swimming | 1-Speed | 15,7001 | 1.0521 | 2.38 | EU\_SFm, 1-spd | 2,531.13 |
| Single Family | Swimming | 2-Speed: Mode 1 (Filter Only) | 15,7001 | 1.0451 | 2.70 | EU\_SFm, 2-spd: M1 | 2,219.72 |
| Single Family | Swimming | 2-Speed: Mode 2A (Filter) | 15,7001 | 1.0411 | 3.21 | EU\_SFm, 2-spd: M2A | 1,859.21 |
| Single Family | Swimming | 2-Speed: Mode 2B (Sweeping) | 15,7001 | 0.4461 | 2.85 | EU\_SFm, 2-spd: M2B | 897.83 |
| Single Family | Swimming | Variable Speed: Mode 1 (Filter Only), Programmed | 15,7001 | 1.0451 | 5.04 | EU\_SFm, VS: M1, Pr | 1,188.42 |
| Single Family | Swimming | Variable Speed: Mode 1 (Filter Only), Non-Programmed | 15,7001 | 1.1704 | 5.04 | EU\_SFm, VS: M1, NPr | 1,330.89 |
| Single Family | Swimming | Variable Speed: Mode 2A (Filter), Programmed | 15,7001 | 1.0411 | 6.55 | EU\_SFm, VS: M2A, Pr | 910.12 |
| Single Family | Swimming | Variable Speed: Mode 2A (Filter), Non-Programmed | 15,7001 | 1.1664 | 6.55 | EU\_SFm, VS: M2A, NPr | 1,019.57 |
| Single Family | Swimming | Variable Speed: Mode 2B (Sweeping) | 15,7001 | 0.4461 | 4.27 | EU\_SFm, VS: M2B | 597.96 |
| Multi-Family | Swimming | 1-Speed | 27,5272 | 3.42 | 2.38 | EU\_MFm, Swim, 1-spd | 14,342.88 |
| Multi-Family | Swimming | 2-Speed (High Speed) | 27,5272 | 1.92 | 2.50 | EU\_MFm, Swim, 2-spd High | 7,452.75 |
| Multi-Family | Swimming | Variable Speed (High Speed) | 27,5272 | 1.92 | 3.33 | EU\_MFm, Swim, VS High | 5,599.40 |
| Multi-Family | Swimming | 2-Speed (Low Speed) | 27,5272 | 0.52 | 4.50 | EU\_MFm, Swim, 2-spd Low | 1,208.90 |
| Multi-Family | Swimming | Variable Speed (Low Speed) | 27,5272 | 0.52 | 8.44 | EU\_MFm, Swim, VS Low | 644.35 |
| Multi-Family | Spa | 1-Speed | 1,4003 | 483 | 2.38 | EU\_MFm, Spa, 1-spd | 10,298.36 |
| Multi-Family | Spa | 2-Speed | 1,4003 | 483 | 2.92 | EU\_MFm, Spa, 2-spd | 8,397.99 |
| Multi-Family | Spa | Variable Speed | 1,4003 | 483 | 4.47 | EU\_MFm, Spa, VS | 5,486.19 |
| Multi-Family | Wading | 1-Speed | 7203 | 243 | 2.38 | EU\_MFm, Wade, 1-spd | 2,648.15 |
| Multi-Family | Wading | 2-Speed | 7203 | 243 | 7.21 | EU\_MFm, Wade, 2-spd | 875.33 |
| Multi-Family | Wading | Variable Speed | 7203 | 243 | 7.86 | EU\_MFm, Wade, VS | 801.97 |

(1) See Attachment 2 – Analysis Tab, or Section 1.5.1 for additional details. (2) See Attachment 12 for the full report, Attachment 2, MFm Report Values tab or Section 1.5.2 for additional detail. (3) See Attachment 6 or Section 1.5.5 for additional details.

For more details on the calculations refer to Attachment 4. (4) See Section 2.1.1.4 or Attachment 2 – Analysis tab. (5) See Section 2.1.1.3 or Attachment 2 for additional details.

#### **2.1.2.1 Energy use for Multispeed Operations**

As noted in Section 1.5.2, the multi-speed Multifamily Swimming pools (Measure D) are estimated to operate at both high and low speeds. Thus, the total energy usage for Measure D multispeed pumps simply the sum of both high and low speed operations.

Note that the single family Measures A, B and C assume that multispeed pumps operate in two categories with an estimated market percentage for each:

1. Mode 1 includes only a low speed filter mode
2. Mode 2 includes two modes:
   1. Mode 2A: Low speed filter mode
   2. Mode 2B: High Speed Sweeping mode

The following equation is used to estimate the weighted multispeed pump energy consumption

EU\_SFm: Wtd = (W%\_M1 x EU\_SFm: M1) + (W%\_M2 x (EU\_SFm: M2A + EU\_SFm: M2B))

Where,

W%\_M1 = estimated market percent of pumps with Mode 1 operations

W%\_M2 = estimated market percent of pumps with Mode 2 operations

The source of the estimated market percentages is described in Section 1.5.1.

Below is an example calculation of the weighted energy usage of a single family swimming pool variable speed pool pump with the following inputs:

W%\_M1 = 71.7%

W%\_M2 = 28.3%

EU\_SFm, VS: M1 = 1,188.42

EU\_SFm, VS: M2A = 910.12

EU\_SFm, VS: M2B = 597.96

EU\_SFm, VS: Wtd = (71.7% x 1,188.42) + (28.3% x (910.12 + 597.96))

EU\_SFm, VS: Wtd = 1,278.93 kWh/yr

The table below shows the values used, and weighted energy usage for the single family two speed and variable speed pumps.

|  |  |  |  |
| --- | --- | --- | --- |
| **System/Mode** | **EU Name** | **Energy Usage (kWh/year)** | **Market %, [W%]** |
| SFm 2-speed Weighted | EU\_SFm, 2-spd: M1 | 2,219.72 | 71.7% |
| EU\_SFm, 2-spd: M2A | 1,859.21 | 28.3% |
| EU\_SFm, 2-spd: M2B | 897.83 |
| **EU\_SFm, 2-spd: Wtd** | **2,371.86** | |
| SFm Variable speed Weighted, Programmed | EU\_SFm, VS: M1, Pr | 1,188.42 | 71.7% |
| EU\_SFm, VS: M2A, Pr | 910.12 | 28.3% |
| EU\_SFm, VS: M2B | 597.96 |
| **EU\_SFm, VS: Wtd, Pr** | **1,278.93** | |
| SFm Variable speed Weighted, Programmed | EU\_SFm, VS: M1, NPr | 1,330.89 | 71.7% |
| EU\_SFm, VS: M2A, NPr | 1,019.57 | 28.3% |
| EU\_SFm, VS: M2B | 597.96 |
| EU\_SFm, VS: Wtd, NPr | **1,412.05** | |

Using the calculated energy usages for each case, the 1st baseline and 2nd baseline energy savings can be calculated for each measure using the following formulas.

ES\_1st BL = EU\_1BL – EU\_M

ES\_2nd BL = EU\_2BL – EU\_M

Where EU\_1BL and EU\_2BL are the energy usage of the single or two speed baseline and EU\_M is the energy usage of the variable speed measure case.

The example below shows the calculation of a 1st and 2nd baseline energy savings for single family Measure C, which is RET.

ES\_1st BL = EU\_SFm, 1-spd – EU\_SFm, VS: Wtd

ES\_1st BL = 2,531.13 – 1,278.93 = 1,252.20

ES\_2nd BL = EU\_SFm, 2-spd: Wtd – EU\_SFm, VS: Wtd

ES\_2nd BL = 2,371.86 – 1,278.93 = 1,092.93

The savings table below shows the 1st and 2nd baseline energy savings for each measure in this workpaper. These savings apply to all climate zones.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Program Type** | **Building** | **Pool Type** | **Baseline/ Measure Case** | **System/Mode** | **EU Name** | **Energy Usage (kWh/year)** | **1st Baseline Savings** | **2nd Baseline Saving** |
| Measure A  (PM-78394) | ROB | Single Family | Swimming | 1st Baseline | 2-Speed: Mode 1 and 2 Weighted | EU\_SFm, 2-spd: Wtd | 2,371.86 | 1,092.93 | N/A |
| Measure Case | Variable Speed: Mode 1 and 2 Weighted, Programmed | EU\_SFm, VS: Wtd, Pr | 1,278.93 |
| Measure B  (PM-98422) | ROB | Single Family | Swimming | 1st Baseline | 2-Speed: Mode 1 and 2 Weighted | EU\_SFm, 2-spd: Wtd | 2,371.86 | 959.81 | N/A |
| Measure Case | Variable Speed: Mode 1 and 2 Weighted, Non-Programmed | EU\_SFm, VS: Wtd, NPr | 1,412.05 |
| Measure C  (PM-69234) | RET | Single Family | Swimming | 1st Baseline | 1-Speed | EU\_SFm, 1-spd | 2,531.13 | 1,252.20 | 1,092.93 |
| 2nd Baseline | 2-Speed: Mode 1 and 2 Weighted | EU\_SFm, 2-spd: Wtd | 2,371.86 |
| Measure Case | Variable Speed: Mode 1 and 2 Weighted, Programmed | EU\_SFm, VS: Wtd, Pr | 1,278.93 |
| Measure D (PM-79353) | RET | Multi-Family | Swimming | 1st Baseline | 1-Speed | EU\_MFm, Swim, 1-spd | 14,342.88 | 8,099.13 | 2,417.90 |
| 2nd Baseline | 2-Speed  Sum of High and Low Speed Operations | EU\_MFm, Swim, 2-spd High +EU\_MFm, Swim, 2-spd Low | 8,664.65 |
| Measure Case | Variable Speed  Sum of High and Low Speed Operations | EU\_MFm, Swim, VS High +EU\_MFm, Swim, VS Low | 6,243.75 |
| Measure F  (PM-19753) | RET | Multi-Family | Spa | 1st Baseline | 1-Speed | EU\_MFm, Spa, 1-spd | 10,298.36 | 4,812.17 | 2,911.80 |
| 2nd Baseline | 2-Speed | EU\_MFm, Spa, 2-spd | 8,397.99 |
| Measure Case | Variable Speed | EU\_MFm, Spa, VS | 5,486.19 |
| Measure G  (PM-19753) | RET | Multi-Family | Wading | 1st Baseline | 1-Speed | EU\_MFm, Wade, 1-spd | 2,648.15 | 1,846.18 | 73.36 |
| 2nd Baseline | 2-Speed | EU\_MFm, Wade, 2-spd | 809.01 |
| Measure Case | Variable Speed | EU\_MFm, Wade, VS | 676.50 |

Refer to Attachment 4 for additional calculation details.

**2.2 Demand Reduction Estimation Methodologies.**

The coincident peak demand savings take into account the degree to which the demand savings coincides with the DEER peak demand, defined as average demand between 2:00 P.M. and 5:00 P.M. during a three-day summer heat wave. The demand savings are equal to the difference in electric demand, times a peak coincidence factor.

The peak coincident electric demands can be calculated by using Equation 3 symbolically written as:

**Equation 3**

PC = P × CF

Where,

PC = Peak Coincident Demand, kW

P = Power, kW

CF = Coincidence Factor, no units

In the following sections, the hourly coincidence factors for the three technologies are derived are the non-coincident electric demands for single-speed, two-speed, and variable-speed pumps are established, enabling the calculation of demand reductions.

**2.2.1 Peak Coincidence Factor and Load Shapes**

The coincidence factor is the ratio of coincident demand to maximum demand. It determines the degree to which a customer’s peak demand coincides with the utility’s system peak demand. The Public Utility Commission (PUC) peak demand reduction is the average demand across the nine hours that fall between 2:00 pm and 5:00 pm during a three-day summer heat wave. Pool pumps are non-weather sensitive, and thus are expected to run, on average, during the same hours each day.

Due to 2016 Title 24 [496] requirements discussed in Section 1.4.2, residential pool pumps are not allowed to operate during the peak electric demand period. Thus, for single family measures, the code baseline two speed pumps and the measure case variable speed pumps are expected to operate during the DEER peak periods of 2:00 pm and 5:00 pm, and have a coincidence factor equal to zero.

However, for early retirement measures, which use single speed pumps, and Multifamily measures, which are required to run during occupied periods to satisfy local health codes, peak operating hours are expected.

***Single-Speed Pumps Coincidence Factor***

As described in Section 1.5, SCE's "Pool pump demand response potential demand and run-time monitored data" study (2008) (Attachment 9) uses studies from roughly 150 single speed pool pumps from both 2001 and 2008 to estimate an average coincidence factor for single family single speed pumps.

**Coincidence Factors for Single-Speed Pool Pumps as Measured in 2001 and 2008**

|  |  |  |  |
| --- | --- | --- | --- |
| **Hour of Day** | **Coincidence Factor (2001 Evaluation)** | **Coincidence Factor (2008 Evaluation)** | **Average Coincidence Factor** |
| 2PM – 3PM | 0.378 | 0.406 | 0.392 |
| 3PM – 4PM | 0.268 | 0.339 | 0.304 |
| 4PM – 5PM | 0.171 | 0.282 | 0.227 |
| ***Average 2PM-5PM*** | ***0.272*** | ***0.342*** | ***0.307*** |

***Multifamily Pool Coincidence Factors***

As described in Section 1.5, “SCE’s Multi-Family VSD Pool Pump Report, Phase 2” (2016) study, average hourly profiles measured from 84 variable speed pumps from all four IOUs show that the variable speed pumps operate at full speed during peak periods. This is consistent with the understanding that most local health codes require that commercial pool pumps be operating during occupied periods, which is estimated to coincide with peak hours. Thus, the coincident diversity factor (CDF) for multifamily pools is assumed to equal one.

The table below shows the Coincidence Factors for each pool and pump system type.

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Pump System** | **Coincidence Factor** |
| Single Family | 1-speed | 0.307 |
| Single Family | 2-speed | 0 |
| Single Family | Variable Speed | 0 |
| Multi-family (All pool types) | All | 1 |

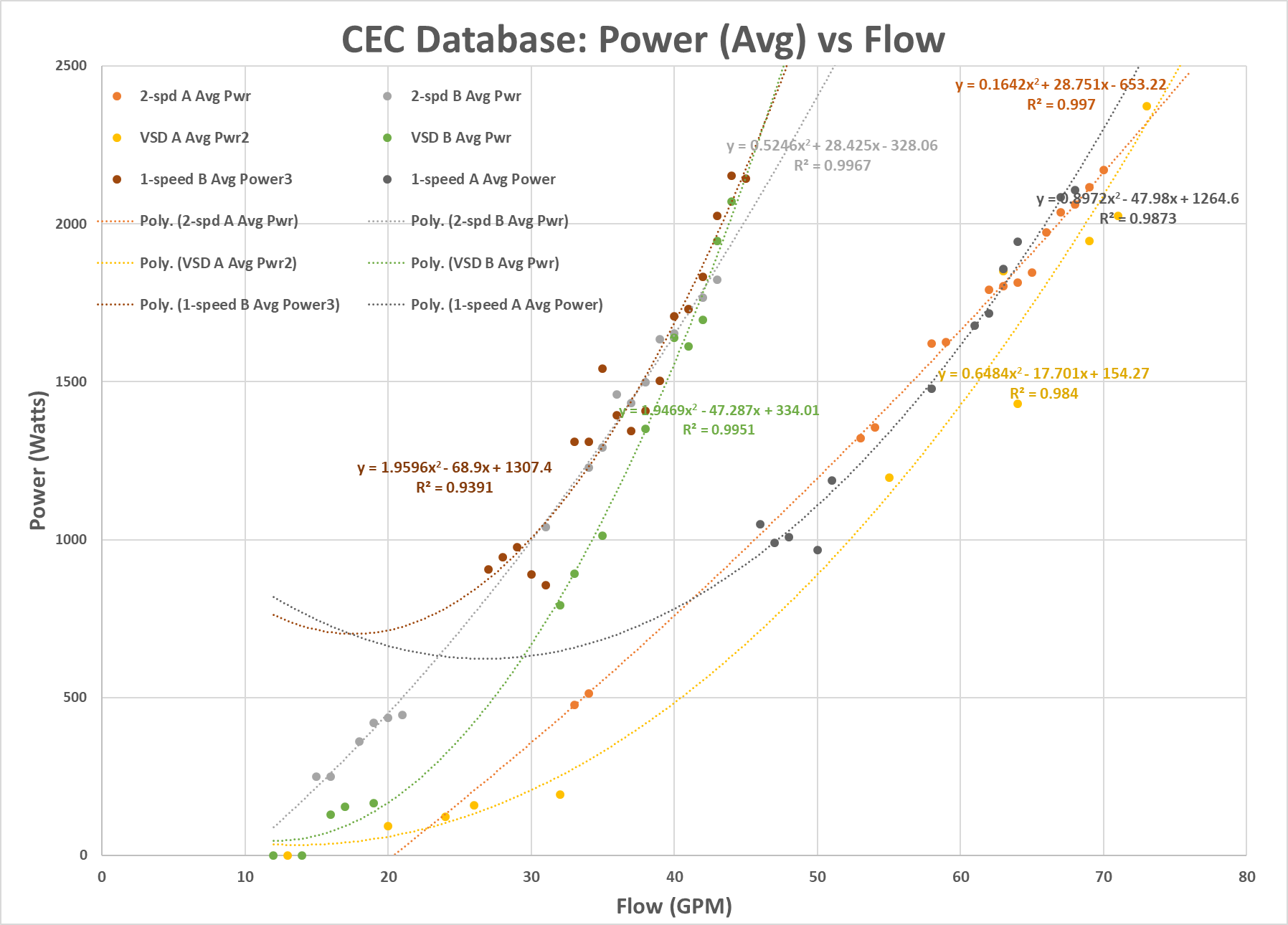
Refer to section 1.5 or Attachment 2 – Peak Demand tab for additional details.

### 2.2.2 Electric Demand

Since only single family 1-speed pumps and multifamily pool systems are assumed to operate during peak times, only those electric demands are calculated in this section.

The electric demand for each case is calculated using the power versus flow regression curves from applicable CEC pool pump database exports. Two speed and variable speed pool pump values were exported from 2018 CEC appliance database. Single speed pump data was taken from the previous version of this workpaper which used the 2008 CEC database. This was done because the CEC database currently only includes single speed pool pumps less than 1 HP. The database exports include relevant data such as motor HP, service factor, full capacity, flow (GPM), power (W) and Energy Factor for each CEC curve. For each database, only pumps between 1 and 3 HP are included for the analysis.

Each data point shown on the figure below represents the average power of each dataset at a number of flows. Due to the quantity of items in each database, only averages with 6 or more data points were used for the CEC curves A and B for single speed, two speed and variable speed databases. The graph and table below show the curves applicable to this workpaper and their corresponding regression formulas.



Refer to attachment 2, Peak Demand tab for more details.

|  |  |  |  |
| --- | --- | --- | --- |
| **Pump Type** | **CEC Curve** | **CEC Curve Demand Equation1** | **Coeff. of Determination (R-squared)** |
| 1-Speed | Curve A | **D** = 0.8972\***F2** - 47.98\***F** + 1264.6 | 0.9873 |
| 1-Speed | Curve B | **D** = 1.9596\***F2** - 68.9\***F** + 1307.4 | 0.9391 |
| 2-Speed | Curve A | **D** = 0.1642\***F2** + 28.751\***F** - 653.22 | 0.997 |
| 2-Speed | Curve B | **D** = 0.5246\***F2** + 28.425\***F** - 328.06 | 0.9967 |
| Variable Speed | Curve A | **D** = 0.6484\***F2** - 17.701\***F** + 154.27 | 0.984 |
| Variable Speed | Curve B | **D** = 1.9469\***F2** - 47.287\***F** + 334.01 | 0.9951 |

(1) D = Demand (W), F = Flow (GPM)

Flows for measure and base case systems taken from Section 1.5 were used to estimate the electric demand for each case based on the equations above. See the table below for details. Note that Curve A is used for higher speeds, while Curve B is used for lower speeds as described in the CEC Database Curves Section, 2.1.1.1. As indicated in the table below, the flow of 54 GPM is used for the Multi-Family 2-Speed and Variable Speed measures because the pumps are operating in the high mode during the peak demand hours. Please refer to Section 1.5 for additional details.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building Type** | **Pool Type** | **Pump Type** | **Flow (GPM)** | **CEC Curve Selected** | **Electric Demand** |
| Single Family | Swimming | 1-Speed | 411 | Curve A | 806 |
| Multi-Family | Swimming | 1-Speed | 632 | Curve A | 1,822 |
| Multi-Family | Swimming | 2-Speed | 542 | Curve A | 1,355 |
| Multi-Family | Swimming | Variable Speed | 542 | Curve A | 1,063 |
| Multi-Family | Spa | 1-Speed | 473 | Curve A | 991 |
| Multi-Family | Spa | 2-Speed | 473 | Curve A | 1,061 |
| Multi-Family | Spa | Variable Speed | 473 | Curve A | 755 |
| Multi-Family | Wading | 1-Speed | 154 | Curve B | 715 |
| Multi-Family | Wading | 2-Speed | 154 | Curve B | 216 |
| Multi-Family | Wading | Variable Speed | 154 | Curve B | 63 |

(1) Refer to Section 1.5.1. (2) Refer to Section 1.5.2. (3) Refer to Section 1.5.5. (4) Minimum 15 GPM used to estimate EF, based on Section 2.1.1.2, instead of 12 GPM from average turnover from Section 1.5.5.

Refer to Attachment 2 – Peak Demand tab for more details.

**2.2.3 Electric Peak Demand Reductions**

Based on Equation 3, the demands and the coincidence factors mentioned above, the peak coincident electric demands for each building type, pool type, and pump system type are identified in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building Type** | **Pool Type** | **Pump Type** | **Coincidence Factor** | **Electric Demand (kW)** | **Coincident Demand** |
| Single Family | Swimming | 1-speed | 0.3071 | 0.806 | 0.247 |
| Single Family | Swimming | 2-speed | 0.000 | N/A | 0.000 |
| Single Family | Swimming | Variable Speed | 0.000 | N/A | 0.000 |
| Multi Family | Swimming | 1-speed | 1.0002 | 1.822 | 1.822 |
| Multi Family | Swimming | 2-speed | 1.0002 | 1.355 | 1.355 |
| Multi Family | Swimming | Variable Speed | 1.0002 | 1.063 | 1.063 |
| Multi Family | Spa | 1-speed | 1.0002 | 0.991 | 0.991 |
| Multi Family | Spa | 2-speed | 1.0002 | 1.061 | 1.061 |
| Multi Family | Spa | Variable Speed | 1.0002 | 0.755 | 0.755 |
| Multi Family | Wading | 1-speed | 1.0002 | 0.715 | 0.715 |
| Multi Family | Wading | 2-speed | 1.0002 | 0.216 | 0.216 |
| Multi Family | Wading | Variable Speed | 1.0002 | 0.063 | 0.063 |

(1) See section Attachment 9 or Section 1.5.3 for details. (2) See attachment 12 or Section 1.5.2 for details.

Refer to Attachment 2 – Peak Demand tab or Attachment 4 Peak Demand tab for more details.

Using the calculated coincident demand for each case, the 1st baseline and 2nd baseline demand reductions (DR) can be calculated for each measure using the following formulas.

DR\_1st BL = CD\_1BL – CD\_M

DR\_2nd BL = CD\_2BL – CD\_M

Where CD\_1BL and CD\_2BL are the energy usage of the single or two speed baseline and CD\_M is the energy usage of the variable speed baseline.

The example below shows the calculation of a 1st and 2nd baseline demand reduction for single family Measure C, which is RET.

DR\_1st BL = CD\_SFm, 1-spd – CD\_SFm, VS

DR\_1st BL = 0.25 – 0.00 = 0.25 kW

DR\_2nd BL = CD\_SFm, 2-spd– CD\_SFm, VS

DR\_2nd BL = 0.00 – 0.00 = 0.00

The table below shows the 1st and 2nd baseline peak demand reduction for all measures. These values apply to all climate zones.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Program Type** | **Building** | **Pool Type** | **Baseline/ Measure Case** | **Pump Type** | **Peak Electric Demand (kw)** | **1st Baseline Savings (kW)** | **2nd Baseline Saving (kW)** |
| Measure A  (PM-78394) | ROB | Single Family | Swimming | 1st Baseline | 2-Speed | 0.00 | 0.00 | N/A |
| Measure Case | Variable Speed | 0.00 |
| Measure B  (PM-98422) | ROB | Single Family | Swimming | 1st Baseline | 2-Speed | 0.00 | 0.00 | N/A |
| Measure Case | Variable Speed | 0.00 |
| Measure C  (PM-69234) | RET | Single Family | Swimming | 1st Baseline | 1-Speed | 0.25 | 0.25 | 0.00 |
| 2nd Baseline | 2-Speed | 0.00 |
| Measure Case | Variable Speed | 0.00 |
| Measure D (PM-79353) | RET | Multi-Family | Swimming | 1st Baseline | 1-Speed | 1.27 | 0.76 | 0.29 |
| 2nd Baseline | 2-Speed | 1.35 |
| Measure Case | Variable Speed | 1.06 |
| Measure F  (PM-19753) | RET | Multi-Family | Spa | 2nd Baseline | 1-Speed | 0.99 | 0.24 | 0.31 |
| 2nd Baseline | 2-Speed | 1.06 |
| 2nd Baseline | Variable Speed | 0.75 |
| Measure G  (PM-19753) | RET | Multi-Family | Wading | Measure Case | 1-Speed | 0.76 | 0.65 | 0.15 |
| Measure Case | 2-Speed | 0.09 |
| Measure Case | Variable Speed | 0.05 |

Refer to Attachment 2 – Peak Demand tab or Attachment 4 Peak Demand tab for more details.

For Measures A, B, and C (2nd baseline) both the base case and measure case are assumed to be programmed outside of peak hours, per 2016 Title 24 [496], thus have zero demand reduction. For Measure C 1st baseline, demand reduction is realized from programming the variable-speed pumps to not operate during peak hours (noon to 6 P.M.). For Measures D, F and G variable-speed pool pumps provide more reliable peak demand reduction than single or two speed pumps. Based on the regression equation the 2nd baseline demand reduction for Measure F is calculated to be higher than its 1st baseline reduction. This is because, as demonstrated in Section 2.2.2, the best fit curve for the two speed pumps dips below the single speed pump, and for some flows is slightly less efficient.

# 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** |
| Residential Single Family | Residential Pool Pumps | Residential |
| Residential Multifamily | 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 sources including 2017 retail equipment cost were used to search for each of the base case 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 material costs found for each equipment type is used in this work paper.

Labor costs for the single speed and two speed full pump replacements are assumed to be the same as the labor costs used for the Self Installed pump measure case. This is because the base case equipment will not require any programming to operate. Please see the Measure Case Cost section for additional details.

In addition to material and labor costs, permit costs are also incurred during the installation for Multifamily sites. The table below shows permit costs for several counties in Southern California. The average permit cost was included in addition to the material and labor cost for each Multifamily measure. See Attachment 3, tab “SCE MF Summary” 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.*

The table below shows the base costs for each measure.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Base Case Equipment** | **Building Type** | **Material Costs** | **Labor Costs** | **Permit Costs** | **Total Installation Costs** |
| 1-Speed Pump | Single Family | $385.90 | $613.59 | $0.00 | $999.49 |
| 2-Speed Pump | $591.24 | $613.59 | $0.00 | $1,204.83 |
| 1-Speed Pump | Multifamily | $385.90 | $613.59 | $220.94 | $1,220.43 |

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**

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 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 of $1,071.00 was found and is used for the material costs in this work paper.

The average material cost was subtracted from the pump installation costs found from the SCE Programs data to find the estimated materials costs for the programmed variable speed pumps (Measures A, C, D, F and G).

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

**Self-Installed Labor Measure Adjustment**

To calculate the self-installed installation measures (Measure B), one hour of an electrician time’s, equal to $65.85 was acquired from RS Means 2017 Labor Rates. This was subtracted from the estimated labor for the programmed pump installation, to account for the absence of programming in the measure.

*Self-installed Labor Cost*

Labor Cost (Self Installed Pump) = Labor Costs(Programmed Pump) – Programming Cost

*Measure B: Full Pump Installation*

Labor Cost (Self Installed Pump) = $679.44 - $65.85

Labor Cost (Self Installed Pump) = $613.59

**Permit Costs**

Just as in the base case, an average 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** | **Building Type** | **Material Costs** | **Labor Costs** | **Permit Costs** | **Total Installation Costs** |
| Variable Speed Programmed Pump Costs | Single Family | $1,071.00 | $679.44 | $0.00 | $1,750.44 |
| Variable Speed Self Installed Costs (Not Programmed) | $1,071.00 | $613.59 | $0.00 | $1,684.59 |
| Variable Speed Programmed Pump Costs | Multifamily | $1,071.00 | $679.44 | $220.94 | $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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure** | **Solution Code** | **Measure Name** | **Base Cost** | **Measure Cost** | **Incremental Cost** |
| Measure A | PM-78394 | Commissioned Variable Speed Drive on Pool Pump Controls | $1,204.83 | $1,750.44 | $545.61 |
| Measure B | PM-98422 | **Self-Installed** Variable Speed Drive on Pool Pump Controls | $1,204.83 | $1,684.59 | $479.76 |
| Measure C | PM-69234 | Commissioned Variable Speed Drive on Pool Pump Controls | $999.49 | $1,750.44 | $750.95 |
| Measure D | PM-79353 | Programmable Variable Speed Drive on Pool Pump Control | $1,220.43 | $1,971.38 | $750.95 |
| Measure F | PM-19753 | Programmable Variable Speed Drive on Pool Pump Control for **Spa Pool** | $1,220.43 | $1,971.38 | $750.95 |
| Measure G | PM-19754 | Programmable Variable Speed Drive on Pool Pump Control for **Wading Pool** | $1,220.43 | $1,971.38 | $750.95 |

## 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 |
| RET/AR | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |

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** |
| Measure A PM-78394 | ROB | $545.61 | $545.61 | $0.00 |
| Measure B PM-98422 | ROB | $479.76 | $479.76 | $0.00 |
| Measure C PM-69234 | RET/AR | $750.95 | $1,750.44 | $750.95 |
| Measure D PM-79353 | RET/AR | $750.95 | $1,971.38 | $750.95 |
| Measure F PM-19753 | RET/AR | $750.95 | $1,971.38 | $750.95 |
| Measure G PM-19754 | RET/AR | $750.95 | $1,971.38 | $750.95 |

# Attachments

1. SCE17WP001.1 A1 - Calculation Templates
2. SCE17WP001.1 A2 - Database Analysis
3. SCE17WP001.1 A3 - Cost Calculations
4. SCE17WP001.1 A4 - Savings Calculations
5. SCE17WP001.1 A5 - Program Support & Data Collection
6. SCE17WP001.1 A6 - Residential VS Pool Pumps Disposition (3-1-17)
7. SCE17WP001.1 A7 - Programs Settings Guidelines
8. SCE17WP001.1 A8 - SDGE VSD Pool Pump Program Eval.
9. SCE17WP001.1 A9 - Pool Pump DR Potential Study
10. SCE17WP001.1 A10 - SFM HEER Rebate Application & POE
11. SCE17WP001.1 A11 - Pentair Intelliflo Owner's Manual
12. SCE17WP001.1 A12 - SCE Multi-Family VSD Pool Pump Report Phase 2 Final
13. SCE17WP001.1 A13 - MFEER Pool Application & POE

# References

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