|  |
| --- |
| Pools  VSD for Pool & Spa Pump  SWRE002-01 |

CONTENTS

Measure Name 2

Statewide Measure ID 2

Technology Summary 2

Measure Case Description 3

Base Case Description 4

Code Requirements 4

Normalizing Unit 8

Program Requirements 8

Program Exclusions 13

Data Collection Requirements 13

Use Category 13

Electric Savings (kWh) 13

Peak Electric Demand Reduction (kW) 40

Gas Savings (Therms) 48

Life Cycle 49

Base Case Material Cost ($/unit) 49

Measure Case Material Cost ($/unit) 50

Base Case Labor Cost ($/unit) 51

Measure Case Labor Cost ($/unit) 51

Net-to-Gross (NTG) 51

Gross Savings Installation Adjustment (GSIA) 52

Non-Energy Impacts 52

DEER Differences Analysis 52

Revision History 53

Measure Name

VSD for Pool & Spa Pump

Statewide Measure ID

SWRE002-01

Technology Summary

A pool pump circulates swimming pool water through a filtration system to keep it clear and remove debris and disease-causing agents. A pump is also used for pool cleaning sweeps, heating, and water features, such as fountains and waterfalls. A pool pump motor in California is typically 0.5 to 3.0 horsepower (hp), single phase, alternating current (AC), and either a permanent split capacitor (PSC) or capacitor-start capacitor-run (CSCR) design.[[1]](#footnote-2) Most pumps operate at a fixed single-speed of 3,450 revolutions per minute (rpm).[[2]](#footnote-3)

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

A variable speed drive (VSD) pool pump uses a motor controller that can be programmed to modulate motor speed and flow rate.

**A variable speed pool pump reduces power consumption by running the motor at slower speeds, compared to single or two-speed pump to perform the same task. The speed is modulated based on a schedule or can be load-based on the type of feedback control tied into the variable speed pool pump. In contrast, a single- or multi-speed pool pump runs at either a constant speed or has stepped speed levels (typically two-speeds).

A VSD pool pumps ≤ 3 hp has the controller and pump integrated into a single unit (see figure). A larger pump (not included in this measure) typically uses a VSD control unit housed in a separate enclosure. A VSD pool pump typically uses a electronically-commutated motor (ECM), which offers higher efficiencies than a PSC motor.

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

Running a 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 measure, savings are derived from test data and not the Affinity Law.* (See Electric Savings.)

In addition to energy savings, a VSD pool pump is quieter and requires less maintenance than a single-speed pump. 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.[[3]](#footnote-4) Bundling VSD pumps with other pool energy efficiency measures, such as LED lighting should be considered.

Measure Case Description

This measure is defined as a programmable variable speed drive (VSD) pump for a swimming pool, spa, or wading pool for residential single family, multifamily, and double-wide mobile homes, and for some commercial pool pumps between 1 hp and 3 hp. (For this measure, horsepower rating refers to the nameplate horsepower before service factor is applied.)

As shown below, most single-family offerings are designated to be programmed with explicit timing and flow rates to both minimize energy use and shift the one-hour or two-hour, high-speed cycle to an off-peak period to reduce demand. The self-installed VSD pump is not installed by an installation contractor and thus cannot be assumed to be explicitly programmed.

All measure offerings are specified in the following table. *Throughout this measure characterization, measure offerings are referenced by the Statewide Measure Offering ID.*

Measure Offerings

| **Statewide Measure Offering ID** | **Building Type** | **First Base Case  Description** | **Second Base Case Description** | **Measure Case  Description** |
| --- | --- | --- | --- | --- |
| A | SFm | 100% Two Speed Pool Pumps, Swimming, SFm, Any |  | Programmed variable-speed pumps, Swimming, SFm, Any, NR |
| B | SFm | 100% Two Speed Pool Pumps, Swimming, SFm, Any |  | Variable-speed pumps (Self Installed), Swimming, SFm, Any, NR |
| C | SFm | 100% Single Speed Pool Pumps, Swimming, SFm, Any | 100% Two Speed Pool Pumps | Programmed variable-speed pumps, Swimming, SFm, Any, AR |
| D | DMo, MFm | 100% Single Speed Pool Pumps, Swimming, DMo, Any | 100% Two Speed Pool Pumps | Programmed variable-speed pumps, Swimming, DMo, Any, AR |
| F | DMo, MFm | 100% Single Speed Pool Pumps, Spa, DMo, Any | 100% Two Speed Pool Pumps | Programmed variable-speed pumps, Spa, DMo, Any, AR |
| G | DMo, MFm | 100% Single Speed Pool Pumps, Wading, DMo / MFm, Any | 100% Two Speed Pool Pumps | Programmed variable-speed pumps, Wading, DMo / MFm, Any, AR |
| H | Com | 100% Single Speed Pool Pumps, Swimming, Any | 100% Two Speed Pool Pumps | Programmed variable-speed pumps, Swimming, Asm, Any, AR |
| I | Com | 100% Two Speed Pool Pumps, Swimming, Any |  | Programmed variable-speed pumps, Swimming, Asm, Any, NR |
| J | DMo, MFm | Two Speed Pool Pumps, Swimming, DMo, Any |  | Programmed variable-speed pumps, Swimming, DMo, Any, NR |
| K | DMo, MFm | Two Speed Pool Pumps, Spa, DMo, Any |  | Programmed variable-speed pumps, Spa, DMo, Any, NR |
| L | DMo, MFm | Two Speed Pool Pumps, Wading, DMo or MFm, Any |  | Programmed variable-speed pumps, Wading, [DMo or MFm], Any, NR |

Base Case Description

The base case of this measure for residential (single or multifamily) and commercial installations is defined as an existing single-speed or two-speed (if required by code or industry standard practice) pool pump. See Measure Case Description for the base case specification for each measure offering.

Code Requirements

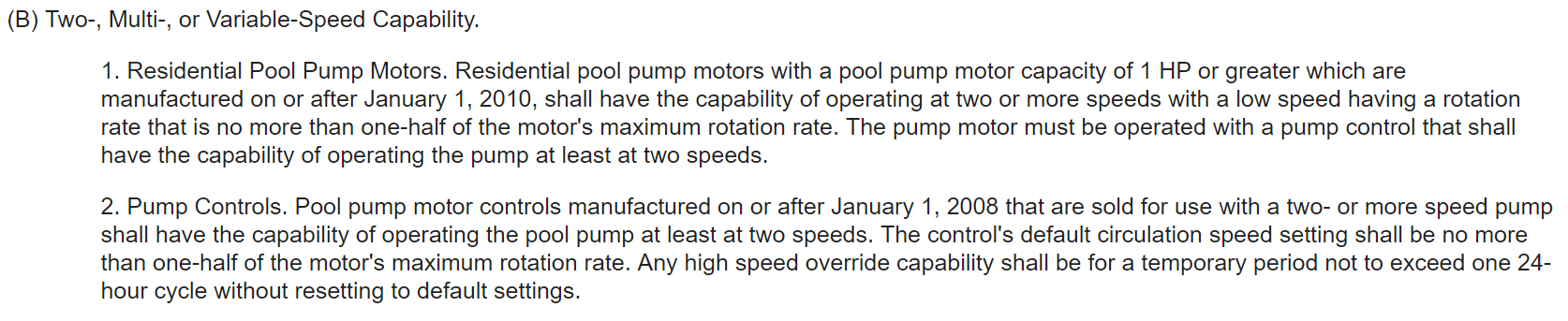
Residential pool systems and equipment must meet requirements specified in the California Appliance Efficiency Regulations (Title 20)[[4]](#footnote-5) and the California Building Efficiency Standards (Title 24)[[5]](#footnote-6) as presented below. Based upon the Title 20 and Title 24 codes, single-family pool pumps greater than 1-hp must use two-speed motors as a baseline for normal replacement. Multifamily and commercial pools are considered “Public Pools”[[6]](#footnote-7) and thus must abide by turnover requirements set forth by Title 24 Chapter 31B[[7]](#footnote-8) and any other local health standards.

As of July 19, 2021, the Title 10 Federal Code will require variable speed controls for all pool pumps.

Applicable State and Federal Codes and Standards

|  |  |  |  |
| --- | --- | --- | --- |
| **Applicable Building / Pool Types** | **Code** | **Applicable Code Reference** | **Effective Date** |
| Single Family, Multifamily, Commercial | CA Appliance Efficiency Regulations – Title 20 (2019) | Section 1605.3(g)(5)(B) | January 1, 2019 |
| Single Family, Multifamily | CA Building Energy Efficiency Standards – Title 24 (2019) | Section 110.4(b)3ii Section 150.0(p) | January 1, 2020 |
| Multifamily, Commercial | CA Building Standards – Title 24 (2016) | Chapter 31B, Section 3124B | January 1, 2017 |
| Multifamily, Commercial | CA Division of Environmental Health Title 22 Division 4 (2016) | Chapter 20, Article 1 | January 22, 2016 |
| Single Family, Multifamily, Commercial | Title 10 Federal Code | 10 CFR Part 431 | July 19, 2021 *(pending)* |

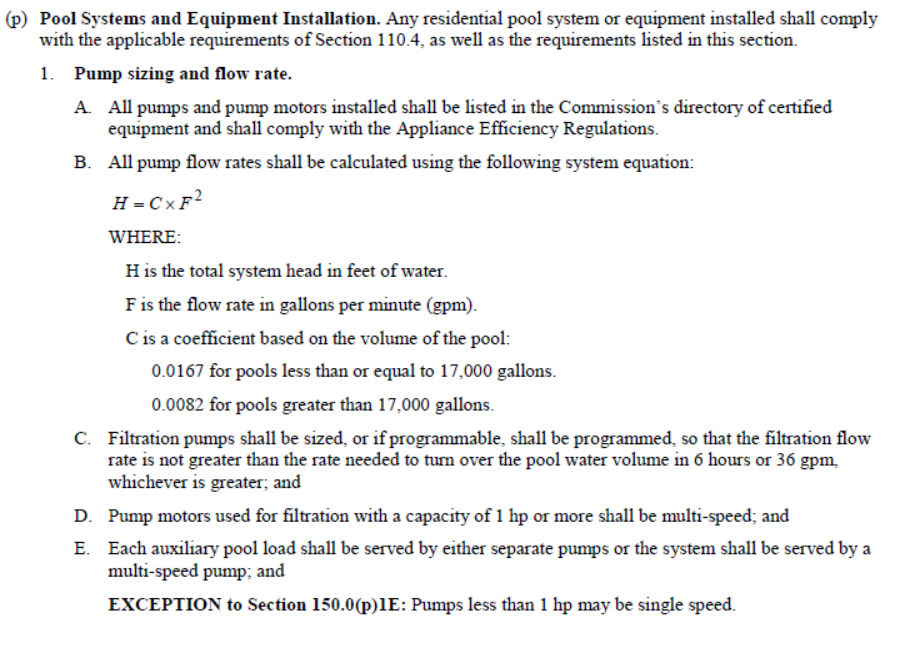
***California Appliance Efficiency Regulations – Title 20 (2019).*** Title 20 Section 1605.3(g)(5)(B) requires that residential pool systems or equipment shall comply with the following applicable requirements:

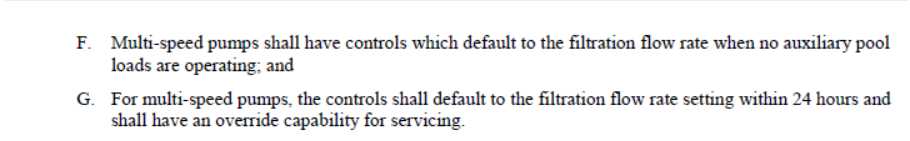


***California Building Energy Efficiency Standards – Title 24 (2019).*** Title 24 Section 110.4(b)3ii specifies the following requirement regarding scheduling the pool pumps during off peak hours.

*ii. 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.*

Title 24 Section 150.0(p) specifies the following for pump sizing and flow rate:





***California Building Standards – Title 24 (2016) Section 3124B, Chapter 31B “Public Swimming Pools”***. Chapter 31B provides capacity requirements for several types of pools. The pools eligible for this measure fall under items 1, 3, and 5. The Title 24 language states that the pump system must have the capability to turn over based on the following:

*“The recirculation system shall have the capacity to provide a complete turnover of pool water in:*

1. *One-half hour or less for a spa pool; and*
2. *One-half hour or less for a spray ground; and*
3. *One hour or less for a wading pool; and*
4. *Two hours or less for a medical pool; and*
5. *Six hours or less for all other types of public pools.”*

***California Division of Environmental Health - Title 22 Division 4 (2016) Division 4 “Environmental Health”, Chapter 20 for “Public Swimming Pools.*** Chapter 20 for “Public Swimming Pools”defines pools at several multifamily and commercial building types, as “public swimming pools.” As such, pools at these locations are subject to 2016 Title 24, Chapter 31B for Public Swimming Pools.

*§ 65501. Definitions.*

*(a) “Swimming Pool” or “Pool” means an artificial basin, chamber or tank used, or intended to be used, for public swimming, diving, or recreative bathing, but does not include baths where the main purpose is the cleaning of the body, nor individual therapeutic tubs.*

*(b) “Wading Pool” means an artificial basin, chamber or tank used, or intended to be used, for wading by small children and having a maximum depth of not to exceed 46 centimeters (18 inches) at the deepest point nor more than 30 centimeters (12 inches) at the side walls.*

*I “Special Use Pools” means pools designed and used exclusively for a single purpose such as wading, instruction, diving, competition or medical treatment where a licensed professional in the healing arts is in attendance.*

*(d) “Enforcing Agent” means the Health Officer or Director of Environmental Health or their designated registered sanitarian representative.*

*I “Temporary Training Pool” means an artificial basin, chamber or tank intended to be used for instruction in swimming and so constructed as to be readily disassembled for storage or for transporting to and reassembling at a different location.*

*(f) “Spa Pool” means a pool, not used under medical supervision, that contains water of elevated temperature, and incorporates a water jet system, an aeration system or a combination of the two systems.*

*(g) “Department” means the State Department of Health Services.*

*§ 65503. Scope*

*a) The provisions of this Chapter shall apply to all pools as defined in Section 65501, including but not limited to:*

*(1) Commercial pools.*

*(2) Real estate pools.*

*(3) Community pools.*

*(4) Hotel pools.*

*(5) Motel pools.*

*(6) Resort pools.*

*(7) Auto and trailer park pools.*

*(8) Auto court pools.*

*(9) Apartment house pools.*

*(10) Club pools.*

*(11) Public or private school pools.*

*(12) Gymnasium pools.*

*(13) Health establishment pools.*

*(14) Townhouse pools.*

*(15) Condominium pools.*

*(16) Mobile home park pools.*

*(17) Campground pools.*

*(18) Homeowner association 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 this particular measure because this measure assumes that the measure case VSD pool pump will operate at 100% of the Title 24-required flow rate during filtration during pool open hours.

*§ 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.*

***Title 10 Federal Code (10 CFR Part 431).*** Title 10 Federal Code (10 CFR Part 431) currently does not require variable speed pool pumps. However, starting on July 19, 2021, compliance with Title 10 Federal code will include three prescriptive requirements, two of which are relevant to this measure:

*“DPPP motors must not operate with a capacitor start induction run (CSIR) or split phase (SP) configuration at maximum operating speed.”*

*“Each dedicated-purpose pool pump motor with a dedicated-purpose pool pump motor total horsepower greater than or equal to 1.15 THP shall meet the definition of a variable speed control dedicated- purpose pool pump motor.”*

The proposed definition of a “variable-speed control dedicated purpose pool pump motor” includes a number of available controls strategies not included here.

Note that the Centers for Disease Control also requires a six-hour turnover rate for swimming pools according to its *Healthy Housing Reference Manual*.[[8]](#footnote-9) Additionally, 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.

Normalizing Unit

Each (per pump)

Program Requirements

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements.  Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

*Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.*

Implementation Eligibility

| **Measure Application Type** | **Delivery Type** | **Sector** |
| --- | --- | --- |
| Normal replacement | DnDeemDI | Com |
| Normal replacement | DnDeemDI | Res |
| Normal replacement | DnDeemed | Com |
| Normal replacement | DnDeemed | Res |
| Normal replacement | UpDeemed | Com |
| Normal replacement | UpDeemed | Res |
| Accelerated replacement | DnDeemDI | Com |
| Accelerated replacement | DnDeemDI | Res |
| Accelerated replacement | DnDeemed | Com |
| Accelerated replacement | DnDeemed | Res |
| Accelerated replacement | UpDeemed | Com |
| Accelerated replacement | UpDeemed | Res |
| New construction | DnDeemDI | Com |
| New construction | DnDeemDI | Res |
| New construction | DnDeemed | Com |
| New construction | DnDeemed | Res |
| New construction | UpDeemed | Com |
| New construction | UpDeemed | Res |

For *accelerated replacement application types,* the customer must be approached by a direct install implementer. Preponderance of evidence (POE) will be assessed at the program-level based on the direction outlined in the “Accelerated Replacement Using Preponderance of Evidence” of the T1 Working Group Report prepared for the California Public Utilities Commission (CPUC).[[9]](#footnote-10)

Additional information and documentation to ensure conformance to eligibility and implementation requirements, include (but are not limited to) the following:

* Customer/site information
* Existing equipment
* Replacement equipment
* Permits and associated documentation
* Pump commissioning information.

General Eligibility Requirements for All Measure Offerings

Only main filtration pumps are eligible.

Only one-for-one pump replacements are eligible.

Both base case and measure case pool pumps must be between 1 hp and 3 hp, with horsepower referring to the (rated) nameplate horsepower before service factor is applied.

The variable speed drive (VSD) pump must replace an existing single- or two-speed pool pump and meet base case and measure case requirements, as specified in the Base Case Description and Measure Case Description, respectively.

Nominal capacity of the new VSD pump should match the capacity of the pump being replaced (recommended).

The VSD pump must be configured to meet program pump configuration requirements.

For models that require an automatic control system capable of controlling both high and low speeds, a controller must be installed.

General Implementation Requirements for All Measure Offerings

The customer must have an active service account(s) served by rebating utility to be eligible to participate in the program(s).

Measure implementation must be completed with both the customer and the installation contractor acknowledgement of energy savings settings.

All *accelerated replacement* measures require third-party baseline verification and data gathering in full compliance with the established POE requirements.

The installation contractor shall follow all manufacturer installation requirements and comply with all applicable regulations.

The installation shall meet all applicable standards and regulations including (but not limited to) NEC and the California Title 24 and Title 20 regulations (see Code Requirements).

Pumps being replaced must be disposed of rather than refurbished and sold.

Equipment and materials must meet or exceed all applicable local, state and federal standards.

Residential Implementation Requirements

In addition to the General Eligibility Requirements, installations in residential facilities must meet the following requirements.

***All Residential Installations***

Measure implementation as required must be completed with both the customer and the installation contractor acknowledgement of energy savings settings.

Self-Installed Measures: Measure B shall be specified on applications for which the client installs their own variable speed pump, or if no certified contractor is used to install the equipment.

All *direct installation* with *downstream delivery installations* must be completed by *a* utility-approved contractor. Utility-approved contractors will complete both technical and program-related training to ensure proper installation. Each approved contractor will be trained such that they can properly collect and submit the correct (and corresponding) information for both *accelerated replacement* (AR) and *normal replacement* (NR) measures.

In accordance to the POE requirements for both single-family and multifamily building types, the 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.

***Additional Requirements for Single Family Residences***

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.

***Additional Requirements for Multifamily Properties***

The installation must be completed by a utility-approved contractor or a contractor with the appropriate license and training.

The 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 pump.

A maximum of three rebates are allowed per customer property/site for main filtration pump(s). Incentive applications for more than one main filtration pump require supporting documentation verifying existing condition per Authority Having Jurisdiction.

*Programming and Operations:*

* During pool operating hours, the VSD setting must be “right sized” to meet turn-over requirements as specified by the 2019 Title 24 standards, Chapter 31B “Public Swimming Pools,” Section 3124B. (See Code Requirements).
* During pool non-operating hours, the VSD 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 Department (EH&S) permit requirements:*

* Must obtain and submit a permit from the governing Environmental Health & Safety Department (i.e. County or City) of jurisdiction; if applicable.
* Health code requirements and inspections must be passed successfully.
* EH&S Department approves size and model of pump for installation, as well as, the required minimum and maximum flow rates based on specific site conditions.

Commercial Implementation Requirements

In addition to the General Eligibility Requirements, installations at a commercial facility must meet the following implementation requirements.

***All Commercial Facilities***

Installation must be performed by a utility-approved contractor with the appropriate CSLB license(s) and training.

The contractor-installed VSD pumps must be installed by a utility-approved contractor that has completed technical and program related training 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) and normal replacement (NR) installations.

The VSD pool pump must be a new, qualifying product installed in an existing in-ground swimming pool.

The customer, as part of the incentive application process 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.

The customer shall agree not to modify and/or alter in any way programmed settings on the pump VSD to ensure persistence of the measure savings.

*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): 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.

Quality Control and Inspections

The program may select a percentage of post-installation inspections to establish a performance baseline, to ensure that installation contractors meet all installation criteria, and/or evaluate and verify all retrofit work. Inspections 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 effectiveness, and 3) to ensure customer compliance with program guidelines

Eligible Building Types and Vintages

This measure is applicable to the following existing building types, of any vintage.

| **Commercial** | **Residential** |
| --- | --- |
| Lodging - Hotel | Single family |
| Lodging – Motel | Multifamily |
| Assembly | Double-wide mobile homes |
| Education - Community College |  |
| Education - Secondary School |
| Education – University |
| Health/Medical - Hospital |
| Health/Medical - Nursing Home |

Eligible Climate Zones

This measure is applicable to any California climate zones.

Program Exclusions

|  |  |
| --- | --- |
| **Residential Exclusions** | **Commercial Exclusions** |
| Rebuilt, refurbished, or reconditioned products  Rented or leased products  Products won as prizes  New parts installed in existing units  Booster pumps solely used for an added spa jet circulation or secondary pumps used for cleaning purposes  Pool Pumps installed in a spa/jacuzzi at a single-family residence. | Pool Pumps installed in a spa/jacuzzi  Motor-only replacements |

Data Collection Requirements

Data collection to satisfy preponderance of evidence (POE) requirements for accelerated replacement installations. POE requirements verify existing conditions, and the POE questionnaire is intended to evaluate and demonstrate program influence.

Use Category

Recreate

Electric Savings (kWh)

Summaries of Key Studies

***Southern California Edison (SCE) Single-family Installation Data (2008-2009).****[[10]](#footnote-11)* This measure analysis uses data gathered by the SCE Measurement and Evaluation team specific to single family residential homes within climate zone 15 for installations from 2008 to 2009. Data was collected via site visits and metering of the existing pool pumps at over 600 single family homes. A few of the variables measured for both existing and measure pool pumps include pool pump size (hp), pool size (gallons), and flow rate (gpm).

The study indicated that there were greater energy savings when the variable speed pool pumps were programmed per the specifications listed below. The following chart was used by the study authors to program the settings for the programmed variable speed pool pump. The controller was programmed to run the pump outside of the noon to 6:00 p.m. timeframe to achieve greater demand reduction.

**Programmed Specifications**

| **Pool Size** | **High Speed** | | **Low Speed** | |
| --- | --- | --- | --- | --- |
| **Variable-Speed Pump (gpm)** | **Number of hours** | **Variable-Speed Pump (gpm)** | **Number of hours** |
| 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 |

The following information was collected for each category for systems with a baseline pump motor size of 1 hp to 3 hp. The values below were used to calculate the efficiency and energy consumption of the various modes.

Inputs by Mode of Operation

| **Mode** | **Percent of Pools Pools (vol. wtd. %)** | **Average Hours** | **Average Flow (gpm)** | **Average Pool Turnovers per Day** |
| --- | --- | --- | --- | --- |
| Baseline Operation | n/a | 6.6 | 41 | 1.052 |
| Mode 1: Filtering Only  (Low Speed) | 71.7% | 12.5 | 22 | 1.045 |
| Mode 2A: Filtering  (Low Speed) | 28.3% | 14.5 | 18 | 1.041 |
| Mode 2B: Pool Sweeps  (High Speed) | 2.1 | 48 | 0.446 |

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

| **Parameter** | **Value** |
| --- | --- |
| Average pool volume (gal) | 15,700 |
| Baseline pump size (hp) | 1.56 |

***Metering and Measuring of Multi-Family Pool Pumps, Phase 2.******(ADM Associates, Inc., 2016).[[11]](#footnote-12)*** This study involved the data collection for 84 multifamily pools located in the four investor-owned utility (IOU) service areas: Southern California Edison (SCE, 53 pools), Southern California Gas Company (SCG, 5 pools), San Diego Gas and Electric (SDG&E, 22 pools) and Pacific Gas and Electric (PG&E, 4 pools). For this study, SCE collected data on several parameters, including pump capacity, control type, and pool volume, as well as pre and post case energy monitoring. Data for the average pool size, average flow (gpm), and average turnovers for multifamily swimming pools (Measure D) were drawn from this study to support this measure savings analysis.

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

The study also measured the hourly loads of the pool pumps and created average hourly load profiles for baseline and measure pumps for each IOU. The profiles below show that the multifamily pools in the study sample operated at full load during the majority of the peak period between 4 p.m. to 9 p.m. (hours 17-21). 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.

|  |  |  |
| --- | --- | --- |
|  |  |  |

Based on the variable speed pumps included within the report, the average flow rate for the pumps was 53.5 gpm in high mode and 31.8 gpm in low mode. The hourly load profiles for each IOU shown above were used to define the demand for each mode. High mode was defined as 1.5 kW based on a weighted average of the peak demand per each IOU. Using the defined high mode power (1.5 kW) and high and low speed flows as indicated in the table below, the 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.[[12]](#footnote-13)

The run hours for each of the modes, as defined, were estimated using the hourly load profiles. The orange lines on the profiles in the figures above indicate high mode and the blue lines indicate low mode run times. 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 turnovers per 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 PG&E and SDG&E several hours were measured to be lower than 0.5 kW. Nonetheless, these hours were still included in the estimated low-speed mode hours estimate to be conservative.

| **Flow Data Description** | **Average Flow (gpm)** | **Hours per Day** | **Turnover Rate (hours/turn over)** | **Turnovers per 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 reported values for the weighted average single-speed baseline horsepower (below) were used to inform baseline efficiency values for the savings analysis of all multifamily measures.

| **Avg. Pump Type and HP** | **SCE** | **SDG&E** | **SCG** | **PG&E** | **Weighted Average** |
| --- | --- | --- | --- | --- | --- |
| Count (Qty) | 53 | 22 | 5 | 4 | n/a |
| Single speed (hp) | 1.46 | 1.72 | 0.00 | 1.50 | 1.53 |
| Variable speed (hp) | 1.74 | 3.00 | 1.33 | 2.85 | 2.10 |

***Disposition for Workpapers Covering Residential Variable Speed Pool Pumps (CPUC, 2017).[[13]](#footnote-14)*** The disposition issued by the Energy Division of the California Public Utilities Commission (CPUC) in 2017 provided direction for several assumptions that impact the savings calculations of this measure:

* Assigned a 100% two-speed pool pump code baseline to Measure A and Measure C and approved the following savings (Section 3.1.1)
* Directed all non-direct install delivery types for single-family pools to adopt savings values of measure offering B. They approve a volume of 20,341 gallons, and turnover of 0.98 per day (Section 3.2.2).
* Directed all multifamily measure offerings 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).
* Specified the pool volume per pump to be 31,000 gallons for swimming pools, 720 gallons for wading pools, and 1,400 gallons for spa
* Daily water turnover: 4 for swimming pools, 24 for wading pools, and 48 for spas
* Developed new energy factor (EF) values for pumps that are less than 1 hp.
* For larger pumps, the pump size and efficiency from Measure B may be used.
* For downstream delivery types, all pre-existing multifamily pool pumps shall be assumed to be two-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.

|  |  |  |  |
| --- | --- | --- | --- |
| **Pool Type** | **Volume (gal)** | **Turnovers per Day** | **Average Flow (gpm)** |
| Spa | 1,400 | 48 | 47 |
| Wading | 720 | 24 | 12 |

***Commercial Variable Speed Pool Pump Market Characterization and Metering Study (SCE, 2015).******[[14]](#footnote-15)*** This study assessed the energy savings due to the installation of a pool pump equipped with a VSD for a commercial pool. The research involved collecting market information from several sites across the Hotel/Motel, Education, and Assemblies building types to develop an estimate of pool pump operating characteristics that can be generalized across these building types. In addition, five hotel/motel sites were selected to receive new VSD-equipped pool pumps for a metering study to measure the energy savings from a device to support and further validate energy savings estimates.

*Market Characterization Data.* This measure analysis leverages the 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 horsepower ratings that varied too greatly or were too large.

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

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

*Field Monitoring Data.* The field monitoring showed that persistence 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 PA Programs through both program implementation and documentation requirements.

***Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings (U.S. DOE, 2012).[[15]](#footnote-16)*** This report discusses the function, energy consumption, and energy savings potential for pool pumps. It was prepared for the U.S. 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.

***Impact Evaluation of 2013-2014 SDG&E Residential VSD Pool Pump Program (DNV-GL, 2016).[[16]](#footnote-17)*** 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 this evaluation were acknowledged but *not* adopted for this measure analysis due to the limited sampling rate (e.g., 49 sites). The impact evaluation recommendations suggested that a larger sample will be necessary to improve precision, given the large degree of variability of savings on a site by site basis.

Methodology

Fundamentally, the unit energy saving (UES) is calculated as the difference between the baseline unit energy consumption (UEC) of a pool with an existing single-speed or two-speed pool pump and the UEC of a measure case pool with a pump with a VSD.

The calculation of the work performed by the pump depends on the total gallons of water that is circulated by the pump per year (pool volume and pool turnover), and the overall hydraulic performance of the pool-pump system. The pool pump energy factor (EF) accounts for the hydraulic performance of a typical pool. The UEC is a function of the average pool size (gallons), the average pump size (hp), average pump efficiency (EF), the average number of pool water turnovers per day, and the average number of operating days per year.

The general form of the UEC calculation is represented as:

*UEC = V × T × D / EF × C*

*UEC = Annual unit energy consumption, kWh/year*

*V = Pool volume, gallons*

*T = Number of turnovers per day, no units*

*D = Average number of days in a year*

*EF = Energy factor, gallons/W-hr*

*C = Conversion factor, 1,000 W/kW*

The UEC for each pool type, building type, pool pump system type, and controls mode was calculated identically with the pool volume, turnover, and EF values explained below.

For this measure, a key consideration is the pump mode of operation; some filtration pumps may provide pressure for pool sweeps or backwashing diatomaceous earth filters. In some cases, additional booster pumps are installed to provide the additional pressure. The SCE single-family pump installation data (summarized above) fall into two distinct categories:

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

Thus, this analysis considers the UEC for three modes:

* Pumps for filtering operations only (Mode 1),
* Pumps with sweeping operations include a filtering mode (Mode 2A) and
* Pumps with sweeping mode (Mode 2B).

The modes of operation and corresponding methodologies to compute the baseline and measure case UEC and the UES are presented below, followed by a discussion of the approaches and sources for the calculation inputs.

The single-family measure offerings (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:

Mode 2A (low-speed filter mode)

Mode 2B (high speed sweeping mode)

The multi-speed multifamily offering (D) is estimated to operate at both high and low speeds. Thus, the UEC for Measure D multispeed pumps is equal to the sum of both high and low speed operations. The weighted multispeed pump UEC is calculated as the following:

*UEC\_SFm: Wtd = (W%\_M1 x UEC\_SFm: M1) + [W%\_M2 x (UEC\_SFm: M2A + UEC\_SFm: M2B)]*

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

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

Using the calculated energy usage for each case, the 1st baseline and 2nd baseline UES was calculated for each measure using the following formulas.

*UES\_1st BL = UEC\_1BL – UEC\_M*

*UES\_2nd BL = UEC\_2BL – UEC\_M*

*UEC\_1BL and UEC\_2BL = UECs of the single or two-speed baseline*

*UEC\_M = UEC of the variable speed measure case.*

Derivation of Inputs for Residential Measure Offerings

The data to develop the inputs for the residential measure offerings were drawn from the following sources.

* Southern California Edison (SCE) Single-family Installation Data (referred to as the “SCE database of single-family installations”) (2008-2009).[[17]](#footnote-18)
* California Energy Commission (CEC) Modernized Appliance Efficiency Database System (MAEDBS, or “CEC database”) data from 2008 and 2018 for pool pumps.
* Metering and Measuring of Multi-Family Pool Pumps, Phase 2 (referred to as the “2016 multifamily pool pump study”).[[18]](#footnote-19)
* Disposition for Workpapers Covering Residential Variable Speed Pool Pumps (referred to as the “2017 disposition”). *Note that an explanation of deviations from the 2017 disposition can found at the end of this section.*

Turnovers per Day

The average turnover rate for a *single-family* pool was based on pool volume and run time from the SCE database of single-family installations. Averages were computed for filter only (Mode 1), and filtering plus sweep modes (Modes 2A and 2B).

*The turnover rate for a multifamily* pool single-speed pump was derived from the 2016 multifamily pool pump study. The turnover rate for a pool with a variable speed pump was calculated using average high-speed and low-speed flow rates from the same study.

The turnover rates for spa and wading pools used were stipulated in the disposition issued by the CPUC in 2017.

Turnovers – Base Case

| **Statewide Measure Offering ID** | **Turnovers –  1-Speed** | **Turnovers –  2-Speed** | **Turnovers -  2-Speed, Mode 1** | **Turnovers -  2-Speed, Mode 2  (low speed)** | **Turnovers -  2-Speed, Mode 2  (high speed)** | **Turnovers -  2-Speed, (low speed)** | **Turnovers -  2-Speed,  (high speed)** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| A |  |  | 1.04 | 1.04 | 0.45 |  |  |
| B |  |  | 1.04 | 1.04 | 0.45 |  |  |
| C | 1.05 |  | 1.04 | 1.04 | 0.45 |  |  |
| D | 3.40 |  |  |  |  | 0.54 | 1.86 |
| F | 48.00 | 48.00 |  |  |  |  |  |
| G | 24.00 | 24.00 |  |  |  |  |  |
| J |  |  |  |  |  | 0.54 | 1.86 |
| K |  | 48.00 |  |  |  |  |  |
| L |  | 24.00 |  |  |  |  |  |

Turnovers – Measure Case

| **Statewide Measure Offering ID** | **Turnovers –  Var Speed** | **Turnovers – Var Speed Low** | **Turnovers – Var Speed High** | **Turnovers –  Var Speed,  Mode 1 Progr.** | **Turnovers –  Single Speed,  Mode 1 Non-progr.** | **Turnovers –  Var Speed, Mode 2  Low speed, Progr.** | **Turnovers –  Var Speed,  Mode 2  Low speed,  Non-Progr.** | **Turnovers – Var Speed, Mode 2 High speed** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| A |  |  |  | 1.04 |  | 1.04 |  | 0.45 |
| B |  |  |  |  | 1.09 |  | 1.08 | 0.45 |
| C |  |  |  | 1.04 |  | 1.04 |  | 0.45 |
| D |  | 0.54 | 1.86 |  |  |  |  |  |
| F | 48.00 |  |  |  |  |  |  |  |
| G | 24.00 |  |  |  |  |  |  |  |
| J |  | 0.54 | 1.86 |  |  |  |  |  |
| K | 48.00 |  |  |  |  |  |  |  |
| L | 24.00 |  |  |  |  |  |  |  |

One adjustment was made for the pool turnovers for single family non-commissioned (self-installed) variable speed pool pumps (measure offering B). The pumps in the SCE single family database were programmed not to operate from 12 p.m. to 6 p.m. to produce additional energy savings. A non-programmed pool pump would not receive this additional programming and is assumed to not operate during the peak period of 4 p.m. to 9 p.m. Therefore, the pump is assumed to operate for an additional 1 hour per day, or 0.042 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 – Non-programmed

| **Turnover (per day)** | **Mode 1** | **Mode 2A** |
| --- | --- | --- |
| Programmed Turnover | 1.0450 | 1.0410 |
| Non-Programmed Additional Turnover | 0.0420 | 0.0420 |
| ***Non-Programmed Total Turnover*** | 1.0869 | 1.0829 |

Pool Volume (gal)

Swimming pool volumes for *single-family and multifamily building types* were calculated as the average of the recorded pool volumes from the SCE database of single-family installations (1 hp to 3 hp only) and the weighted average of pool volumes from the 2016 multifamily pool pump study, respectively.

Spa and wading pool volumes were specified in the 2017 disposition.

Pool Volume

| **Statewide Measure Offering ID** | **Pool Volume  (gal)** [[19]](#footnote-20) |
| --- | --- |
| A | 15,700.00 |
| B | 15,700.00 |
| C | 15,700.00 |
| D | 27,527.00 |
| F | 1,400.00 |
| G | 720.00 |
| J | 27,527.00 |
| K | 1,400.00 |
| L | 720.00 |

Average Flow Rate (gpm)

The average flow rate for the *single-family* pool pump was determined as the average flow rate of installations recorded in the SCE database of single-family installations. Averages were computed for filter only (Mode 1), and filter plus sweep modes (Modes 2A and 2B).

The average flow rates for the *multifamily* single speed and variable speed pool pumps were obtained from the 2016 multifamily pool pump study.

The average flow rates for *spa and wading pools* were stipulated in the 2017 disposition.[[20]](#footnote-21)

Estimated Pump Flow Rates

| **Building Type** | **Pool Type/Mode** | **Flow (gpm) [[21]](#footnote-22)** |
| --- | --- | --- |
| SFm | Mode 1: Filtering Only | 22 |
| SFm | Mode 2A: Filtering | 18 |
| SFm | Mode 2B: Pool Sweeps | 48 |
| MFm | Swimming Pool (High Speed) | 54 |
| MFm | Swimming Pool (Low Speed) | 32 |
| MFm | Spa Pool | 47 |
| MFm | Wading Pool [[22]](#footnote-23) | 15 |

Average Pump Size (hp)

The average horsepower value for *single family* pools was calculated as the average single-speed baseline horsepower from the SCE database of single-family installations.[[23]](#footnote-24)

The average hp for *multifamily* offerings was calculated as the weighted average of horsepower values from the 2016 multifamily pool pump study.[[24]](#footnote-25) (Note that average values from both datasets were similar, roughly 1.5 hp.)

Pump Efficiency, Energy Factor (EF)

Pump energy efficiency performance is represented by its EF value. A general discussion of pool hydraulic performance and the approaches to calculate the EF values for variable speed, two-speed, and single-speed pumps are explained below.

Energy Factors – Base Case

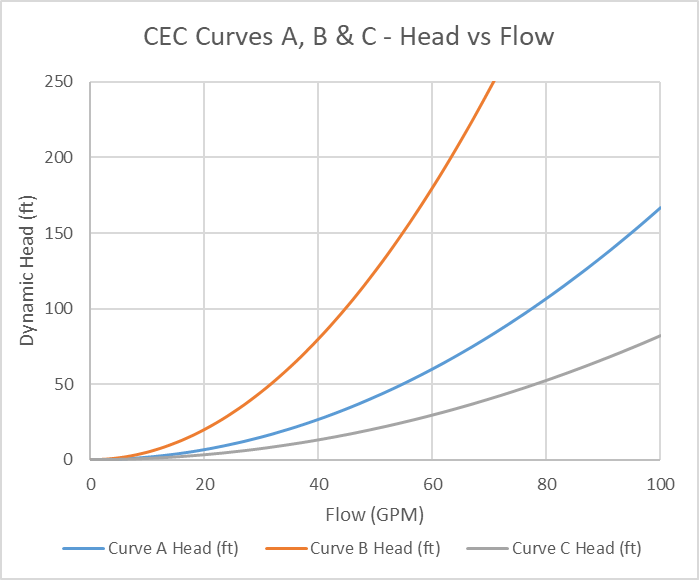
| **Statewide Measure Offering ID** | **EF –  1-Speed (gal/Wh)** | **EF –  2-Speed (gal/Wh)** | **EF –  2-Speed, Mode 1(gal/Wh)** | **EF – 2-Speed, Mode 2  (low speed) (gal/Wh)** | **EF – 2-Speed, Mode 2  (high speed) (gal/Wh)** | **EF – 2-Speed, (low speed)  (gal/Wh)** | **EF – 2-Speed,  (high speed)  (gal/Wh)** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| A |  |  | 2.70 | 3.21 | 2.85 |  |  |
| B |  |  | 2.70 | 3.21 | 2.85 |  |  |
| C | 2.38 |  | 2.70 | 3.21 | 2.85 |  |  |
| D | 2.38 |  |  |  |  | 4.50 | 2.50 |
| F | 2.38 | 2.92 |  |  |  |  |  |
| G | 2.38 | 7.21 |  |  |  |  |  |
| J |  |  |  |  |  | 4.50 | 2.50 |
| K |  | 2.92 |  |  |  |  |  |
| L |  | 7.21 |  |  |  |  |  |

Energy Factors – Measure Case

| **Statewide Measure Offering ID** | **EF –  Var Speed (gal/Wh** | **EF – Var Speed Low (gal/Wh** | **EF – Var Speed High (gal/Wh** | **EF –  Var Speed,  Mode 1 Programmed (gal/Wh** | **EF – Single Speed,  Mode 1 Non-programmed (gal/Wh** | **EF –  Var Speed, Mode 2  Low speed, Programmed (gal/Wh** | **EF –  Var Speed,  Mode 2  Low speed,  Non-Programmed (gal/Wh** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| A |  |  |  | 5.04 |  | 6.55 |  |
| B |  |  |  |  | 5.04 |  | 6.55 |
| C |  |  |  | 5.04 |  | 6.55 |  |
| D |  | 8.44 | 3.33 |  |  |  |  |
| F | 4.47 |  |  |  |  |  |  |
| G | 7.86 |  |  |  |  |  |  |
| J |  | 8.44 | 3.33 |  |  |  |  |
| K | 4.47 |  |  |  |  |  |  |
| L | 7.86 |  |  |  |  |  |  |

Swimming pool hydraulic performance is characterized by system curves that show the resistance presented to the flow of water as a function of the flow rate. This resistance is comprised of static head pressure that does not change as flow changes, and dynamic head pressure that increases in proportion to the square of flow rate. The CEC has specified system curves A, B and C that represent different pool systems.[[25]](#footnote-26) 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.

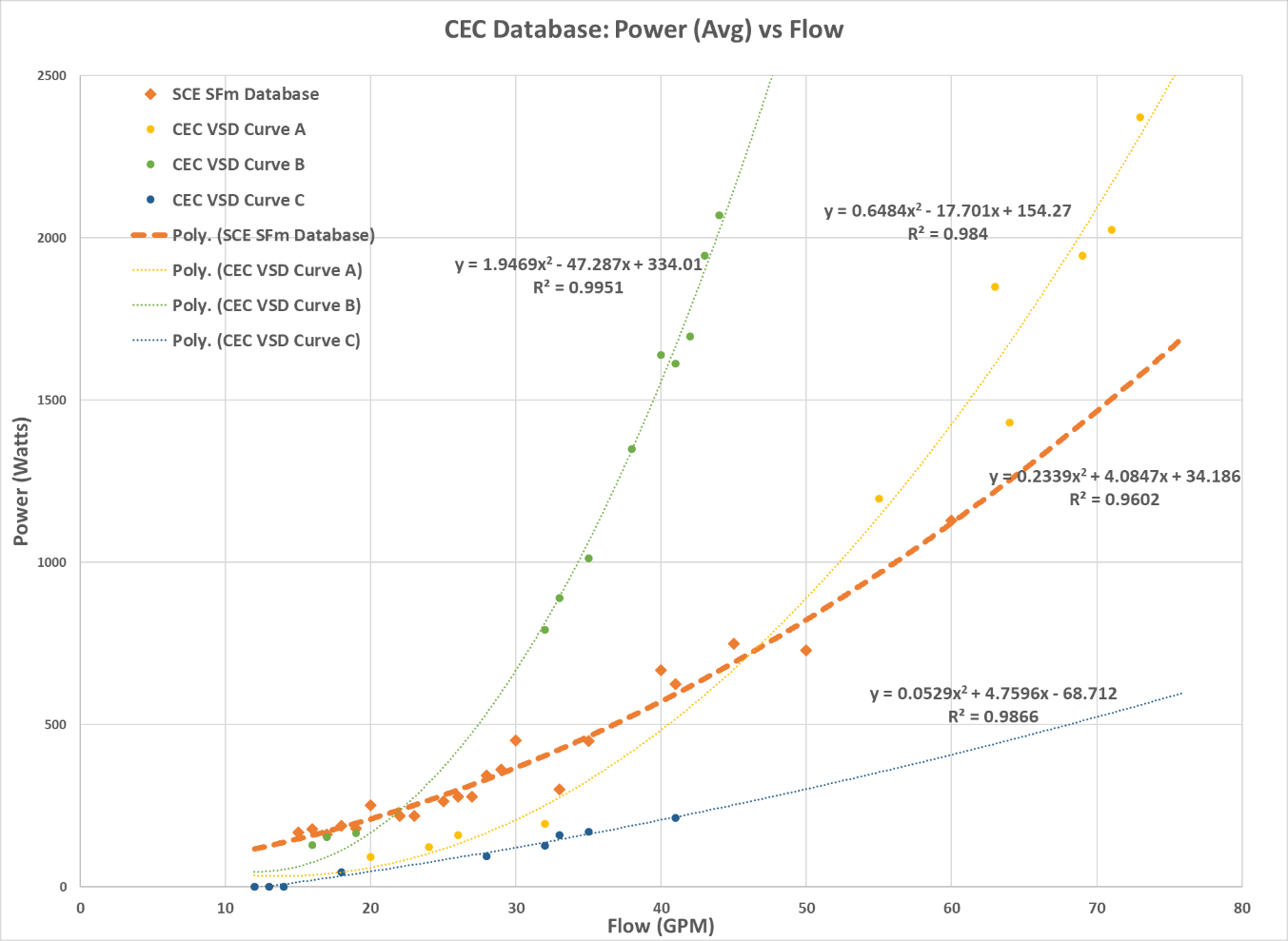
|  |  |  |
| --- | --- | --- |
| **System Curve A** | **System Curve B** | **System Curve C** |
| The hydraulic performance of a typical swimming pool (i.e., a pool with two-inch PVC plumbing and a diatomaceous earth filter) is represented by Curve A. Curve A is defined by a mathematical relationship between the flow rate and system head. | Curve B shows a higher dynamic head pressure and is suited for older pools (e.g., 1.5” copper piping). | Curve C shows the lowest dynamic head pressure and is suited for the most efficiently designed pools. |
| **H = 0.0167 × F2** | **H = 0.05 × F2** | **H = 0.0082 × F2** |
| *H= Total system head, ft of water F = Flow rate, gpm* | | |



Two-speed and variable speed pool pump values were exported from the CEC database in 2018; the single-speed pump data was drawn from the 2008 CEC database because the 2018 CEC database only included single-speed pool pumps < 1 hp. The CEC database includes motor horsepower, service factor, full capacity, flow (gpm), power (W) and EF for each CEC system curve. For each database, only pumps between 1 hp and 3 hp were included for the analysis.

The CEC variable speed pump data was compared to the installed power and flow data from the SCE single-family installation database.[[26]](#footnote-27) 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 six or more data points were used for the CEC curves A, B and C. For the installed single-family data, only averages with ten or more points were used.

As demonstrated in the figure below, the single-family data does not fit to any curve perfectly. This is due to the variety of pool, pump, and piping configurations in the dataset. The single-family data intersects the CEC Curve B at roughly 23 gpm and with Curve A at roughly 47 gpm. This correlates well to the low-speed and high-speed average flows from the single-family database.[[27]](#footnote-28) *Thus, to estimate pump performance it is assumed that at, Curve B can be used for lower (filtering) speeds and Curve A can be used for higher speeds.* It was determined that CEC Curve C did not fit the data well at any flow, and therefore was not used in this analysis.



***Pool Pump Energy Factor Calculation.*** The energy factor of a pool pump defined as the water flow rate divided by power:

*EF = F × C2 / P*

*EF = Energy factor, gallons/W-hr*

*F = Flow rate, gpm*

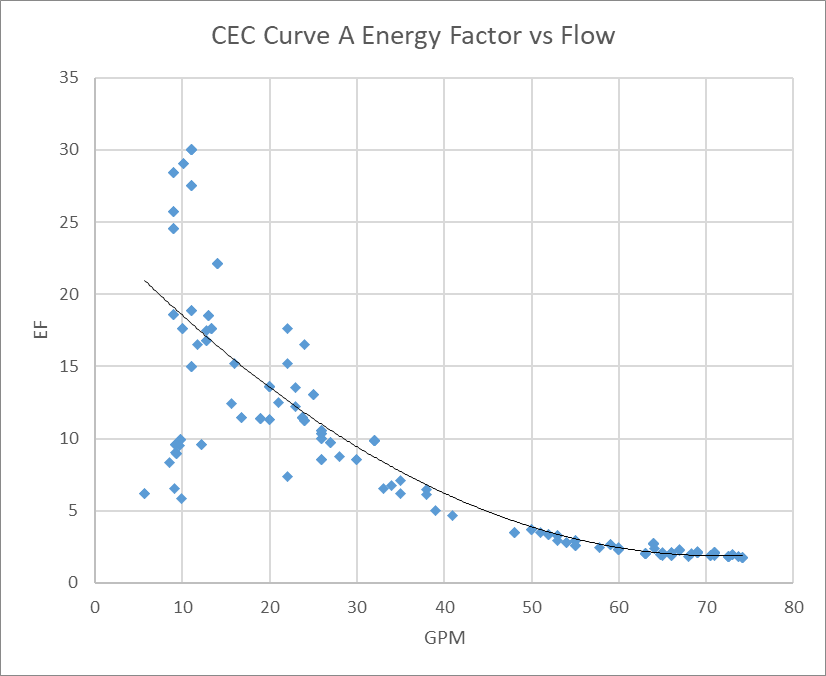
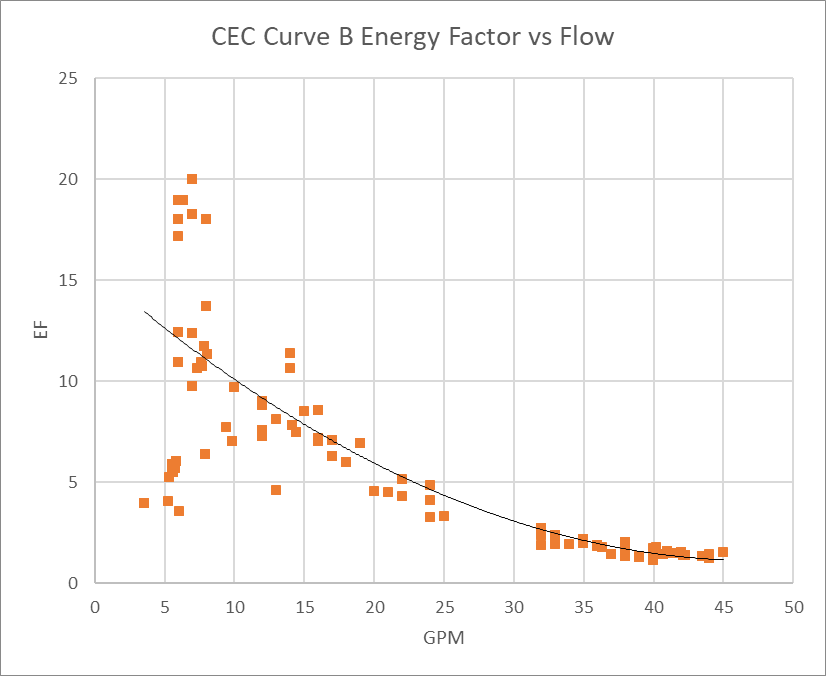
*C2 = Conversion constant, 60 min/hr*

*P = Power, W*

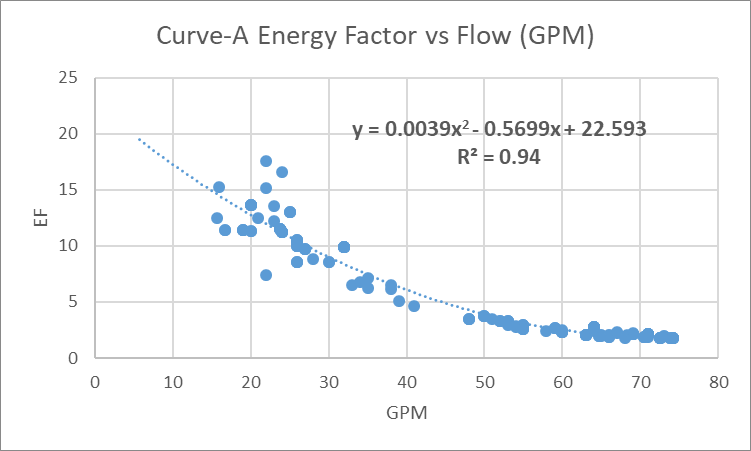
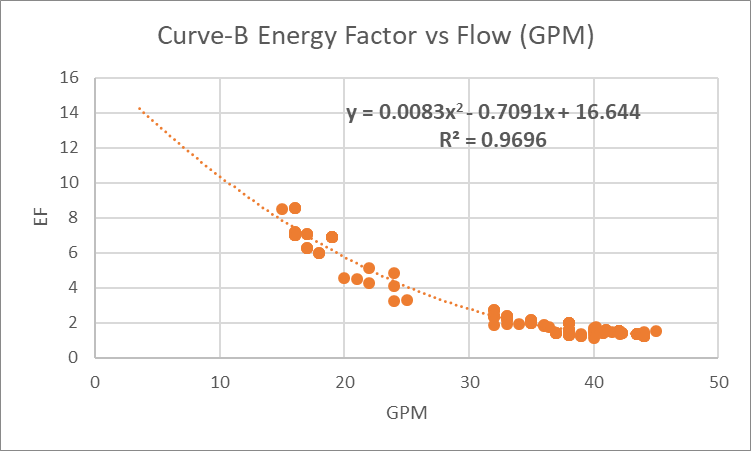
The energy usage can be obtained by dividing the volume of pumped water by the EF, as shown above in general form of the UEC calculation. Efficiency (i.e., the EF value) and energy consumption are inversely related and thus a higher EF value is preferred from an energy efficiency perspective. This figure of merit is posted on the CEC web site for (121) single-speed, (171) two-speed, and (147) variable speed pumps.[[28]](#footnote-29) Note, however, that, because these EF values 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.*** Using the 2018 CEC database of variable speed pumps, a correlation for EF and flow was found for Curves A and B. The average flows described above were used to calculate EFs based on the best fit lines from the correlation for various modes and pool types.[[29]](#footnote-30)

The EF ratings for variable-speed pool pumps were derived from a regression analysis of EF versus flow rate (gpm) from the CEC database; the dataset was filtered to include only pool pumps of 1 hp to 3hp. The data reveal that at low flow rates (< 15 gpm) the EF rating became independent of flow (see graphs below); thus, 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.[[30]](#footnote-31)

Thus, database entries less than 15 gpm were removed from the dataset. The resulting dataset provided the following EF versus flow (gpm) curves. A polynomial regression curve was created for Curve A and Curve B to estimate the 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.

. 

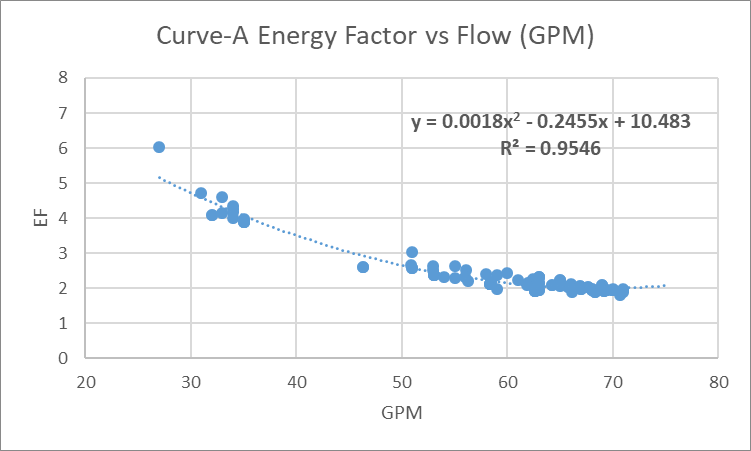
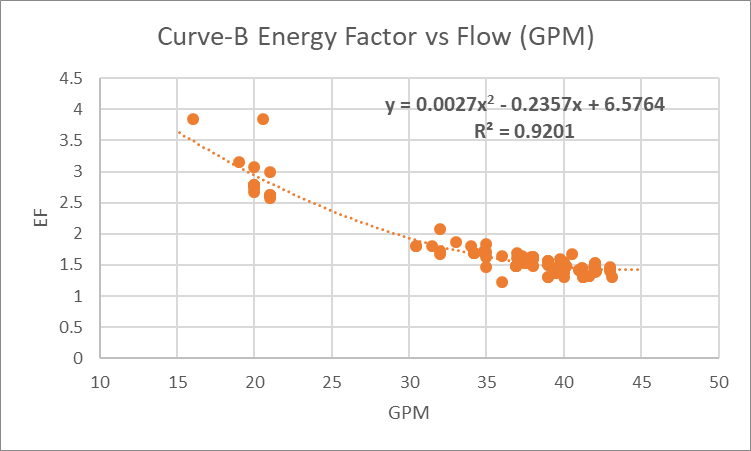
|  |  |  |
| --- | --- | --- |
| **CEC Curve** | **Variable Speed Pump EF Equation** **[[31]](#footnote-32)**  EF = Energy Factor, F = Flow (gpm) | **Coefficient of Determination** |
| Curve A | EF = 0.003922 x F2 - 0.569902 x F + 22.592557 | 0.94 |
| Curve B | EF = 0.008254 x F2 - 0.709072 x F + 16.643590 | 0.97 |

Flows for measure and base case systems were used to estimate EF values 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.

| **Building Type** | **Pool Type/Mode** | **Flow (gpm) [[32]](#footnote-33)** | **Curve Selected** | **Calculated Energy Factor (gal/W-hr)** |
| --- | --- | --- | --- | --- |
| SFm | Mode 1: Filtering Only | 22 | Curve B | 5.04 |
| SFm | Mode 2A: Filtering | 18 | Curve B | 6.55 |
| SFm | Mode 2B: Pool Sweeps | 48 | Curve A | 4.27 |
| MFm | Swimming Pool (High Speed) | 54 | Curve A | 3.33 |
| MFm | Swimming Pool (Low Speed) [[33]](#footnote-34) | 32 | Curve A | 8.44 |
| MFm | Spa Pool | 47 | Curve A | 4.47 |
| MFm | Wading Pool [[34]](#footnote-35) | 15 | Curve B | 7.86 |

***Energy Factors for Two-Speed Pumps.*** Using the two-speed pump data from the 2018 CEC database, a correlation for EF and flow was found for Curves A and B. The average flows described above were used to calculate EFs based on the best fit lines from the correlation for various modes and pool types.[[35]](#footnote-36)

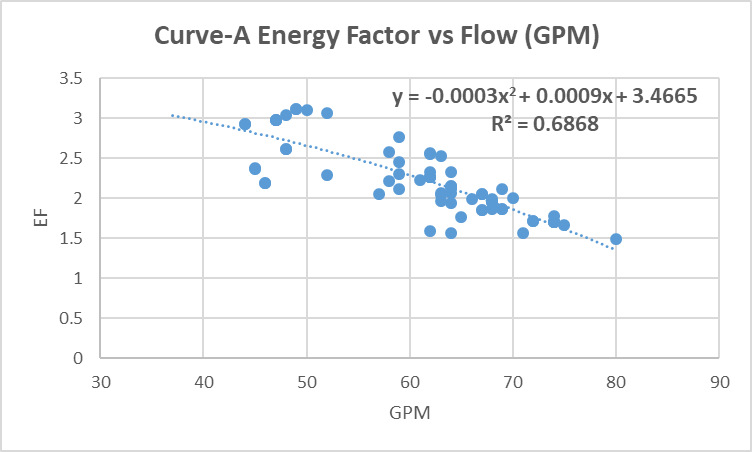
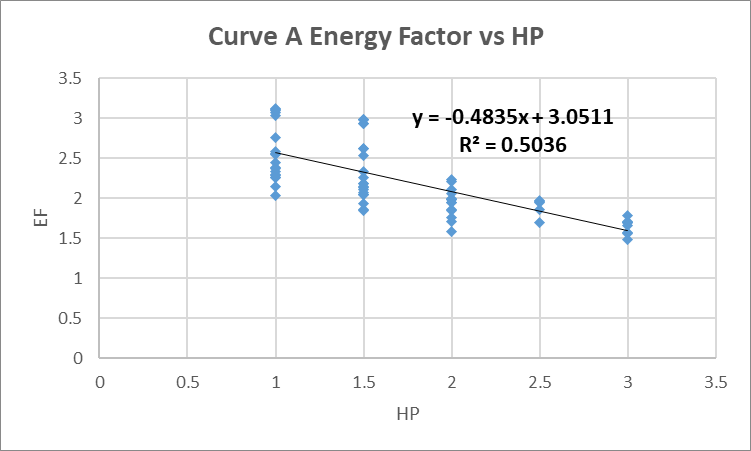
The EF rating for two speed pumps was calculated in a similar way as the EF for variable speed pumps. The EF ratings for two-speed pool pumps were obtained from a regression analysis of EF versus flow from the CEC database. The dataset was filtered so that only pool pumps of 1 hp to 3 hp were included. The resulting dataset provided the following EF versus 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 System Curve** | **Two-speed Pump Energy Factor Equation[[36]](#footnote-37)**  EF = Energy Factor, F = Flow (gpm) | **Coefficient of Determination** |
| --- | --- | --- |
| Curve A | EF = 0.0018 x F2 - 0.2455 x F + 10.483 | 0.95 |
| Curve B | EF = 0.0027 x F2 – 0.2357 x F + 6.5764 | 0.92 |

***Energy Factor Rating for Single-Speed Pumps.*** Based on the average pump size (hp) described above (approximately 1.5 hp), an average of EF value was calculated with the single-speed pump data from the 2008 CEC database.[[37]](#footnote-38)

The EF 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 EF for Curve A (R-Squared = 0.69). An analysis showing the correlation between EF and horsepower 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, horsepower, 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 horsepower equal to 1.5 hp was adopted for the analysis. This horsepower was chosen because the average baseline horsepower from the single-family installation data and the 2016 multifamily pump study were 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 Horsepower (hp)** | **Chosen Horsepower (hp)** | **Average CEC Curve A Energy Factor  (gal/W-hr)** |
| --- | --- | --- | --- |
| SCE database of single-family installations, 2008-2009 [[38]](#footnote-39) | 1.56 | 1.5 | 2.38 |
| 2016 multifamily pump study [[39]](#footnote-40) | 1.53 |

The final flow rates for measure and base case systems used to estimate EF values for each pool type/mode of operation are specified below.

Calculated Energy Factor Values

| **Building Type** | **Pool Type/Mode** | **Flow (gpm)** | **Curve Selected** | **Calculated Energy Factor (gal/W-hr)** |
| --- | --- | --- | --- | --- |
| SFm | Mode 1: Filtering Only | 22 | Curve B | 2.70 |
| SFm | Mode 2A: Filtering | 18 | Curve B | 3.21 |
| SFm | Mode 2B: Pool Sweeps | 48 | Curve A | 2.85 |
| MFm | Swimming Pool (High Speed) | 54 | Curve A | 2.50 |
| MFm | Swimming Pool (Low Speed) [[40]](#footnote-41) | 32 | Curve A | 4.50 |
| MFm | Spa Pool | 47 | Curve A | 2.92 |
| MFm | Wading Pool [[41]](#footnote-42) | 15 | Curve B | 7.21 |

Market Percent of Modes of Operation

The estimates of the market percent of each mode of operation for single family pool pumps were derived from the SCE database of single-family installations spanning 2008-2009.[[42]](#footnote-43)

Estimates of Market Percent by Mode of Operation – Single Family

|  |  |  |
| --- | --- | --- |
| **Statewide Measure Offering ID** | **Market Percent - Mode 1 (%)** | **Market Percent - Mode 2 (%)** |
| A | 71.70% | 28.30% |
| B | 71.70% | 28.30% |
| C | 71.70% | 28.30% |

Days of Operation per Year

As shown below, this analysis assumes 365 days of pump operation per year for all measure offerings.

Assumed Days of Operation per Year

|  |  |
| --- | --- |
| **Statewide Measure Offering ID** | **Days per Year** |
| A | 365 |
| B | 365 |
| C | 365 |
| D | 365 |
| F | 365 |
| G | 365 |
| J | 365 |
| K | 365 |
| L | 365 |

Deviations from the 2017 Disposition

Note that some calculation inputs for this analysis deviate from the 2017 disposition values because new data was available after the disposition was issued. 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 updated inputs and reasons for such changes are explained in the Derivation of Inputs and Assumptions below.

* *Single family offerings.* Single family measure offering A and C methodologies were revised to better align with the measure offering B methodology, using the general form of the UEC calculation (see Methodology above) and the CEC pool pump database efficiency assumptions. This deviates from the approved savings from the disposition because SCE has updated data sources with the CEC database data from 2008 and 2018. The updated methodology uses inputs from 750+ installed single family pool projects and updated CEC database efficiency assumptions.[[43]](#footnote-44) Additionally, the single-family pool volume was reduced from 20,341 gallons to 15,700 gallons, and 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.
* Multifamily measure offerings. Swimming pool volume and turnovers for multifamily pools were updated from 31,000 gallons and four turnovers per day, to 27,527 gallons and 1.9 per day in high mode and 0.5 per day in low mode, respectively. The 2016 multifamily pool pump study was used to update these inputs. The EF values for multifamily pools were changed to be dependent on the corresponding average flow rates, rather than simply mimicking the EF rating for the single family measure offering B. This was done because multifamily pool volumes, flows, and turnover requirements vary from single family pools that are shown to impact the EF value.

Sample Calculations

**Residential Single-Family Pool – Single Speed Pool Pump*.*** Below is a sample calculation of the UEC for a single-family pool with a single-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

UEC2-spd:M-1 = (15,700 gal)(1.052 turnover)(365 day/yr) /(2.38 gallons/W-hr)(1,000 W/kW)= 2,531.13kWh/yr

**Residential Single-Family Pool – Variable Speed Pool Pump*.*** Below is an example calculation of the weighted UEC of a single-family swimming pool variable speed pool pump with the following inputs:

W%\_M1 = 71.7%

W%\_M2 = 28.3%

UEC\_SFm, VS: M1 = 1,188.42

UEC\_SFm, VS: M2A = 910.12

UEC\_SFm, VS: M2B = 597.96

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

UEC\_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)[[44]](#footnote-45)** | **Market %, [W%][[45]](#footnote-46)** |
| --- | --- | --- | --- |
| 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,  Non-Programmed | EU\_SFm, VS: M1, NPr | 1,236.12 | 71.7% |
| EU\_SFm, VS: M2A, NPr | 946.72 | 28.3% |
| EU\_SFm, VS: M2B | 597.96 |
| EU\_SFm, VS: Wtd, NPr | **1,323.49** | |

The example below shows the calculation of a 1st and 2nd baseline UES for single family Measure C, which is an *accelerated replacement installation*.

UES\_1st BL = UEC\_SFm, 1-spd – UEC\_SFm, VS: Wtd

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

UES\_2nd BL = UEC\_SFm, 2-spd: Wtd – UEC\_SFm, VS: Wtd

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

Derivation of Inputs for Commercial Measure Offerings

The data to develop the UEC inputs for the residential measure offerings were drawn from the following sources.

* Commercial Variable Speed Pool Pump Market Characterization and Metering Study (SCE, 2015), referred to as the “2015 commercial pool pump emerging technologies (ET) study”.***[[46]](#footnote-47)***
* 2018 CEC pool pump database.

The analysis presented herein follows the same methodology of the 2015 commercial pool pump ET study, except that it utilized pump data from the 2018 the CEC database and includes a two-speed industry standard practice (ISP) baseline.

The following table provides sources of the inputs for the UEC calculations for commercial measure offerings (H and I), with notation if the data was measured or obtained via a survey.[[47]](#footnote-48)

Summary of Commercial Measure Offering Inputs and Data Sources

| **Input (Unit)** | **Source** |
| --- | --- |
| Flow rates, multispeed (gpm) | 2015 commercial pool pump ET study (calculated) |
| Power, single-speed (kW) |
| Pool volume (gal) | 2015 commercial pool pump ET study (measured) |
| Filter pressure Drop (ft) |
| Electrical conditions (V, A, Phase) |
| Pool Annual Hours | 2015 commercial pool pump ET study (surveyed) |
| Ex. Pump Annual Hours |
| Pool pump motor size (hp) |
| Turnover Rate |
| Single Speed Flow Rate |
| Two-speed High and Low Speed Power (kW) | 2018 CEC pool pump database (calculated values)  2018 CEC pool pump database |
| Variable speed High and Low Speed Power (kW) |

To support development of a deemed measure under a “single speed” pump baseline, only “typical” pump operation and system characteristics were used from the 2015 commercial pool pump ET study. From the (50) sites that were surveyed for Hotels and Motels for that study, (25) sites were removed based on the following conditions: (reasons for removal from dataset are noted in the calculations.[[48]](#footnote-49)

* 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 a 3-hp motor.

Note that measure savings estimates for *normal replacement* under two-speed baseline, were supported using the CEC Database.

Once the UEC and demand were calculated per site, the 1st and 2nd baseline savings were calculated as the average of the 1st and 2nd baseline energy savings and coincident demand for the 25 sites.

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 the analysis datasets and calculation as long as (and only if), the subject commercial building type has operating characteristics consistent with Hotel/Motel buildings and meet all the criteria listed in Program Requirements.

Unit Energy Consumption and Demand Calculation

The UEC 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.[[49]](#footnote-50)

**Motel Example, Site #5**

The characteristics of a sample motel site are provided below. Data from this site will be used to for sample calculations in this section. This site will be used in all following examples.[[50]](#footnote-51)

Building type: Motel

Pool hours: 7:00 a.m. to 7:00 p.m.

Pump run hours: 24 hours per day, 365 days per year

Pump: Single-speed, 1.5 hp

Pool Volume: 26,393 gallons

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

***Unit Energy Consumption - Single Speed Base Case.*** 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 the power factor was not available, a value of 0.8 was assumed (from the Handbook of Pumps and Pumping,[[51]](#footnote-52) full load for 0.75‒7.5 kW; see figure below).



Typical Power Factors by Motor Size [[52]](#footnote-53)

The annual UEC is calculated as:

**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 UEC for this measure is the average across 25 sites:

**Unit Energy Consumption - Two-Speed and Variable Case.**

The multispeed pump power consumption is determined from regression analysis of data from the 2018 CEC database of residential pool pumps. In Title 20 code,[[53]](#footnote-54) there is no significant distinction between residential and commercial pool pumps, 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: [[54]](#footnote-55)

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

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.*[[55]](#footnote-56)*

The Los Angeles County Department of Public Health guidelines for the installation of variable speed pumps state:

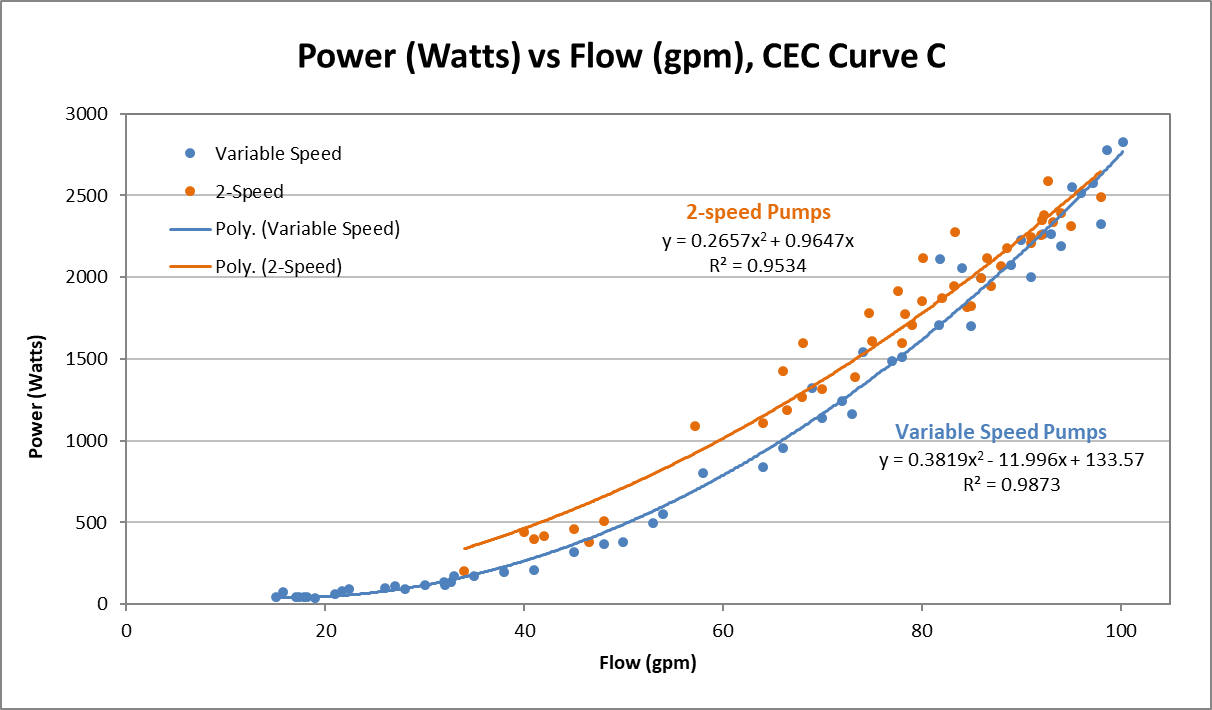
“For existing pools, installation will be allowed only when plumbing and equipment is sized to accommodate the maximum flow of the pump at 60 feet of head at the highest rpm.”

The guidelines also include specific requirements for a particular variable speed 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 all counties, and while many other variables such as filters and piping configuration will influence head losses, for this measure 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 measure.

The figure below displays the power versus flow polynomial regressions for two-speed and variable speed pumps.[[56]](#footnote-57)



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.[[57]](#footnote-58)

***Unit Energy Consumption - Pool Open Hours.*** The Title 24 six-hour turnover requirement for public pools is used to determine the minimum flow rate (Qopen) during pool open hours. Note that some counties may require a turnover rate greater than the six- hour turnover required by Title 24, so the watt draw may be greater in those cases.

**Motel Example, Site #5**

Pool skimmers require a minimum of 25 gpm to function adequately,*[[58]](#footnote-59)* 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.*[[59]](#footnote-60)* 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.

Using the regression results for both variable speed and two-speed, the expected watt draw of each type of pump providing 73.31 gpm is:

***Unit Energy Consumption - Pool Closed Hours.*** 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.[[60]](#footnote-61) 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,58 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.

**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.[[61]](#footnote-62)

***Annual Average Unit Energy Consumption.*** The following assumptions are used in the annual UEC 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 six-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 the operation time of a pool pump is for non-filtration tasks.[[62]](#footnote-63) Therefore, the open hours are extended by applying a factor of 1.1:

**Motel Example, Site #5**

Pool Open Hours: 7:00 a.m. to 7:00 p.m. (12 hours)

However, the UEC for this measure is the average across 25 sites as found to be:

***Motel Example, Site #5 – UES Calculations***

The UEC values calculated for this site (in above examples) are:

UEC1-speed = 14,184.19 kWh

UEC2-speed = 7,971.10 kWh

UECVS = 6,769.09 kWh

The 1st baseline accelerated replacement UES is calculated as the difference between the base case (1-speed pump) UED and the measure case (variable speed pump) UEC.

The 1st baseline UES for this measure is the average across 25 sites is found to be:

The 2nd baseline accelerated replacement and 1st baseline normal replacement UES is the difference the ISP case (two-speed pump) and the measure case (variable speed pump) UEC.

The UES for this measure is the average across 25 sites is found to be:

Peak Electric Demand Reduction (kW)

Methodology

The coincident peak demand reduction represents the degree to which the demand reduction coincides with the DEER peak demand, defined as average demand between 4:00 p.m. and 9:00 p.m. during a three-day summer heat wave.

The *coincident peak demand* was calculated as the electric demand multiplied by a peak coincident demand factor (CDF), for both the base case and measure case of each measure offering. The CDF is the ratio of coincident demand to maximum demand.

Since only *single family one-speed pumps* and *multifamily* pool systems are assumed to operate during peak period, the methodology to calculate the electric demand for such systems are presented herein.

*PC = P × CF*

*PDR = PC measure – PC base*

*PC = Peak coincident demand, kW (measure or base)*

*P = Electric demand, kW*

*CDF = Coincident demand factor (CDF), no units*

*PDR = Peak demand reduction, kW*

The *peak demand reduction* for each measure offering was calculated as the difference between the base case (single-speed or two-speed pump) and the measure case (variable speed pump) coincident peak demand. Thus, using the calculated coincident demand for each case, the 1st baseline and 2nd baseline demand reduction can be calculated for each measure as follows.

*DR\_1st BL = CD\_1BL – CD\_M*

*DR\_2nd BL = CD\_2BL – CD\_M*

*DR = Demand reduction*

*CD\_1BL and CD\_2BL = Coincident demand of the single- or two-speed baseline*

*CD\_M = Coincident demand of the variable speed baseline.*

For the *single-family measure offerings* A, B, and C (2nd baseline) the base case and measure case are assumed to be programmed outside of peak hours, per 2019 Title 24,[[63]](#footnote-64) thus have zero demand reduction.

For Measure C, the 1st baseline, demand reduction is realized from programming the variable-speed pump to not operate during peak hours (4 p.m. to 9 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 the best fit curve for the two speed pumps dips below the single speed pump, and for some flows is slightly less efficient.[[64]](#footnote-65)

Derivation of Inputs for Residential Measures Offerings

Coincident Demand Factors (CDF)

The coincident demand factor (CDF) is the ratio of coincident demand to maximum demand; the CDF represents the degree to which the peak demand of a particular site coincides with the utility system peak demand. The California Public Utility Commission (CPUC) peak demand reduction is represented as the average demand across the nine hours that fall between 4:00 p.m. and 9:00 p.m. during a three-day summer heat wave. Pool pumps are non-weather sensitive, and thus are expected to operate during the same hours each day (on average).

The baseline and measure case CDFs computed for this analysis are provided in the tables below, followed by a discussion of the CDF analysis.

Coincident Demand Factors, Baseline

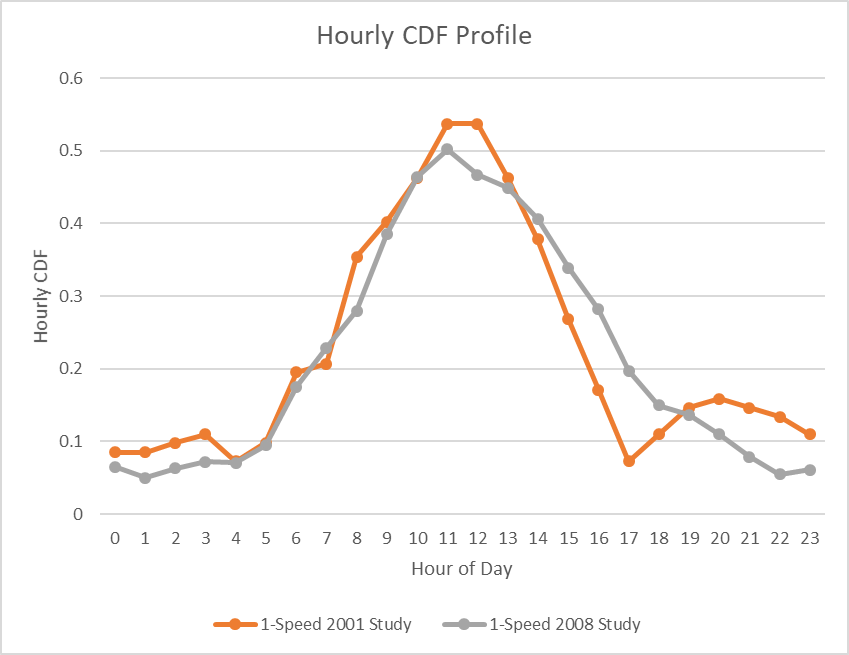
| **Statewide Measure Offering ID** | **Coincident Demand Factor (CDF)** | **Coincident Demand Factor (– 2nd Baseline (kW)** |
| --- | --- | --- |
| A | 0.00 |  |
| B | 0.00 |  |
| C | 0.34 | 0.00 |
| D | 0.97 | 0.93 |
| F | 0.97 | 0.93 |
| G | 0.97 | 0.93 |
| J | 0.93 |  |
| K | 0.93 |  |
| L | 0.93 |  |

Coincident Demand Factors, Measure Case

| **Statewide Measure  Offering ID** | **Coincident Demand Factor (CDF)** |
| --- | --- |
| A | 0.00 |
| B | 0.00 |
| C | 0.00 |
| D | 0.93 |
| F | 0.93 |
| G | 0.93 |
| J | 0.93 |
| K | 0.93 |
| L | 0.93 |

***Coincident Demand Factors – Single-Family Pools.*** The 2019 California Building Energy Efficiency Standards (Title 24)[[65]](#footnote-66) stipulates that residential pool pumps cannot operate during the peak electric demand period. *Thus, for single family measures, the code baseline two-speed pump and the measure case variable speed pump are expected to not operate during the peak periods of 4:00 p.m. and 9:00 p.m. and thus have a CDF equal to zero.*

However, for *accelerated replacement installations* (that use single-speed pumps) and *multifamily installations* (that are required to run during occupied periods to satisfy local health codes), operating hours are expected during the peak period. The CDF values for single speed pool pumps were derived from the *Pool Pump Demand Response Potential Demand and Run-Time Monitored Data* study conducted by SCE in 2008.[[66]](#footnote-67) This study monitored the hourly electric demand of 146 pool pumps in the SCE service area and compared the resultant load shapes with monitored data from a 2001 study that similarly monitored several pools. The CDF calculated from the 2008 data, and comparison of load shapes from both studies are shown below.



Load Shapes for Single Speed Pumps in 2001 and 2008 (SCE service area)

Coincident Demand Factors for Single-Speed Pool Pumps [[67]](#footnote-68)

| **Max Demand (kW)** | **Average Peak Demand (kW)** | **CDF** |
| --- | --- | --- |
| 0.691 | 0.234 | 0.338 |

***Coincident Demand Factors – Multifamily Pools.*** The CDF for multifamily pools is based upon the *Metering and Measuring of Multi-Family Pool Pumps, Phase 2* study (referred to as the “2016 multifamily pool pump study”).[[68]](#footnote-69) The resultant hourly profiles, measured from 84 variable speed pumps installed across all four IOU service areas, reveal that most variable speed pumps operate at full speed during peak periods.

The CDF for each pool was calculated as the ratio of the average demand during peak hours and the maximum demand (kW) of all hours. Thus, a CDF was calculated for the base case single-speed pools and the measure case variable speed pools. The weighted average CDF values (shown below) were calculated based on the quantities of pumps from each IOU in the study.[[69]](#footnote-70) *Note that the CDF for both the two-speed and variable speed cases are assumed to be equal.*

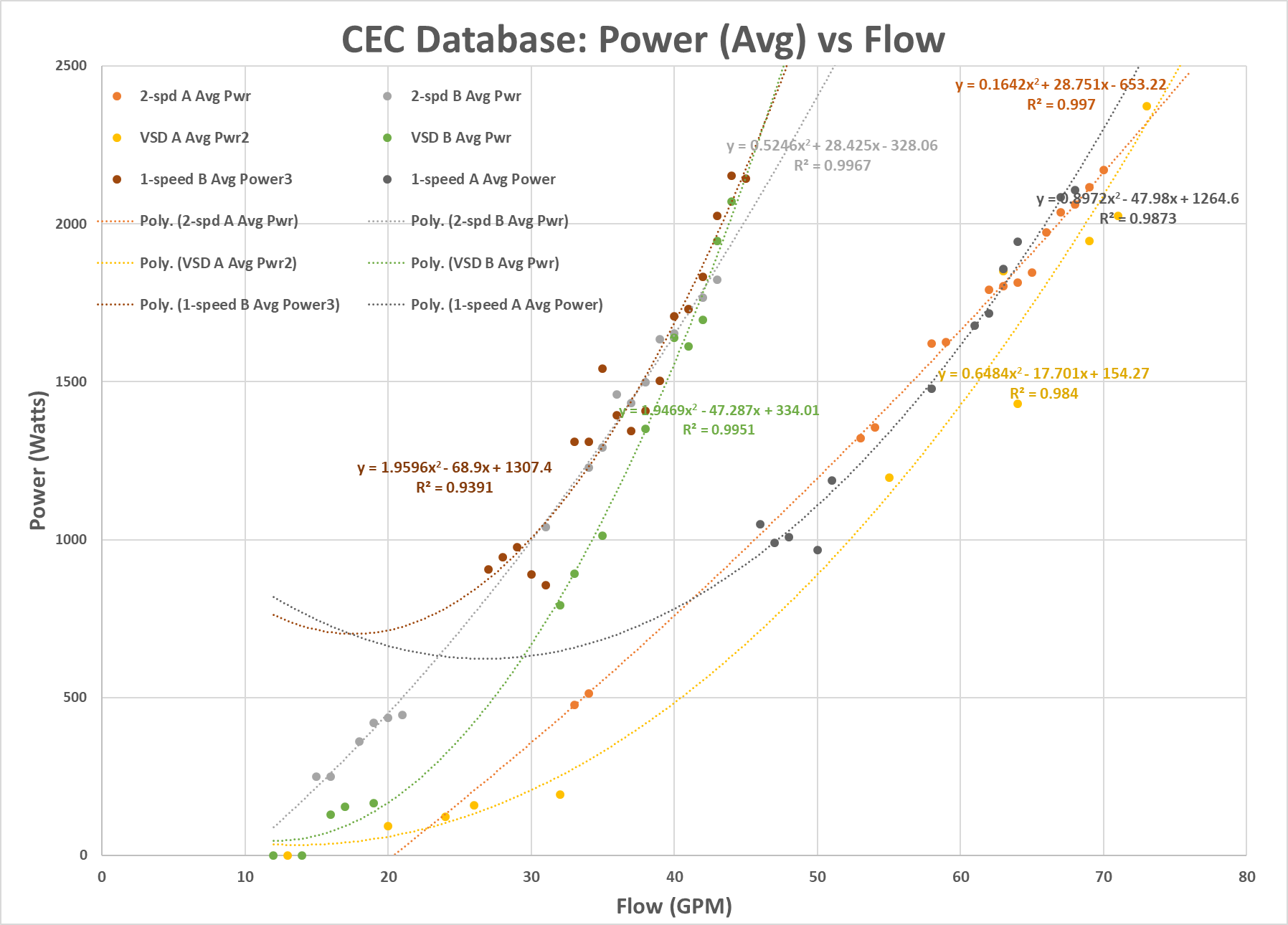
Derivation of Average Weighted Coincident Demand Factors [[70]](#footnote-71)

| **Avg. Pump Type and CDF** | **SCE** | **SDG&E** | **SCG** | **PG&E** | **Weighted Average** |
| --- | --- | --- | --- | --- | --- |
| Count (Qty) | 53 | 22 | 5 | 4 | n/a |
| Average CDF – Single Speed | 0.99 | 0.93 | N/A | 0.83 | 0.965 |
| Average CDF – Variable Speed | 0.97 | 0.83 | 1.00 | 0.86 | 0.931 |

Electric Demand

The electric demand for each case was 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 database. Single speed pump data was taken from a previous workpaper for this workpaper, which used the 2008 CEC database. This was necessary because the CEC database currently only includes single-speed pool pumps less than 1 hp. The database exports include relevant data such as motor horsepower, service factor, full capacity, flow (gpm), power (W), and EF value for each CEC curve. For each database, only pumps between 1 hp 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 six or more data points were used for the CEC curves A and B for single speed, two speed, and variable speed databases. [[71]](#footnote-72) The figure and table below show the curves applicable to this analysis and the corresponding regression formulas.



CEC Performance Curve Demand Equations

| **Pump Type** | **CEC Curve** | **CEC Curve Demand Equation** **[[72]](#footnote-73)**  D = Demand (W), F = Flow (GPM) | **Coefficient 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 | 0.9970 |
| 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 | 0.9840 |
| Variable Speed | Curve B | D = 1.9469\*F2 - 47.287\*F + 334.01 | 0.9951 |

The flows for measure and base case systems were used to estimate the electric demand for each case based on the CEC Curve demand equations. Note that Curve A was used for higher speeds, while Curve B was used for lower speeds. As indicated below, the flow of 54 gpm was used for the multifamily two-speed and variable speed measures because the pumps are operating in the high mode during the peak demand hours.

Calculation of Electric Demand [[73]](#footnote-74)

| **Building Type** | **Pool Type** | **Pump Type** | **Flow  (gpm) [[74]](#footnote-75)** | **CEC Curve Selected** | **Electric Demand (kW)** |
| --- | --- | --- | --- | --- | --- |
| Single Family | Swimming | 1-Speed | 41 | Curve A | 0.806 |
| Multi-Family | Swimming | 1-Speed | 63 | Curve A | 1.822 |
| Multi-Family | 2-Speed | 54 | Curve A | 1.355 |
| Multi-Family | Variable Speed | 54 | Curve A | 1.063 |
| Multi-Family | Spa | 1-Speed | 47 | Curve A | 0.991 |
| Multi-Family | 2-Speed | 47 | Curve A | 1.061 |
| Multi-Family | Variable Speed | 47 | Curve A | 0.755 |
| Multi-Family | Wading [[75]](#footnote-76) | 1-Speed | 15 | Curve B | 0.715 |
| Multi-Family | 2-Speed | 15 | Curve B | 0.216 |
| Multi-Family | Variable Speed | 15 | Curve B | 0.063 |

The final baseline and measure case coincident demand calculated for this analysis are provided in the following tables.

Peak Electric Demand, Baseline

| **Statewide Measure Offering ID** | **Peak Electric Demand (kW)** | **Peak Electric Demand – 2nd Baseline (kW)** |
| --- | --- | --- |
| A | 0 | - |
| B | 0 | - |
| C | 0.81 | 0 |
| D | 1.82 | 1.3549 |
| F | 0.99 | 1.0608 |
| G | 0.71 | 0.2164 |
| J | 1.3549 |  |
| K | 1.0608 |  |
| L | 0.2164 |  |

Peak Electric Demand, Measure Case

| **Statewide Measure Offering ID** | **Peak Electric Demand (kW)** |
| --- | --- |
| A | 0.0000 |
| B | 0.0000 |
| C | 0.0000 |
| D | 1.0632 |
| F | 0.7546 |
| G | 0.0628 |
| J | 1.0632 |
| K | 0.7546 |
| L | 0.0628 |

***Single Family Example (Measure offering C)***

The example below shows the calculation of a 1st and 2nd baseline demand reduction for single family Measure C, an accelerated replacement installation.

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

*DR\_1st BL = 0.27230 – 0.00 = 0.27230 kW*

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

*DR\_2nd BL = 0.00 – 0.00 = 0.00*

Derivation of Inputs for Commercial Measure Offerings

The measure case variable speed measure offering 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 measure case variable speed pump is assumed to produce a small energy savings and on-peak demand reduction.

Electric Demand

The non-coincident demand was derived as the difference between the power values obtained from either the baseline measurements or the CEC database curves. Because the pools were shown to operate at full speed during peak hours, the full speed demand was used to estimate demand reduction.

Coincident Demand Factors

Most lodging sites are open year-round, but several only open during summer or winter. Nearly all sites operate their pools between 4 p.m. and 9 p.m. The CDF values for the commercial measure offerings were calculated by averaging the number of open hours during 4 p.m. to 9 p.m. and dividing by the number of hours in the peak period. The number of coincident hours per site was derived from the *Commercial Variable Speed Pool Pump Market Characterization and Metering Study* (SCE, 2015), referred to as the “2015 commercial pool pump emerging technologies (ET) study”.[[76]](#footnote-77)

**Coincident Demand Factors**

|  |  |  |
| --- | --- | --- |
| **Building Type** | **CDF** | **Source** |
| Lodging (Hotel and Motel) | 0.98 | Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” See “Calculations” tab. |

***Motel Example, Site #5***

Continuing the motel example in Electric Savings, the following demand values are:

P1-speed = 1.61920 kW

P2-speed,Open = 1.49884 kW

PVS, Open = 1.30678 kW

The 1st baseline accelerated replacement energy demand reduction is the difference the base case (single-speed pump) and the measure case (variable speed pump).

The demand reduction for this measure was calculated as the average across 25 sites is found to be:

The 2nd baseline accelerated replacement and 1st baseline normal replacement peak demand reduction was calculated as the difference of the ISP base case (two-speed pump) and the measure case (variable speed pump), multiplied by the CDF.

The peak demand reduction for this measure was calculated as the average peak demand reduction across 25 sites.

Gas Savings (Therms)

Not applicable.

Life Cycle

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.”[[77]](#footnote-78) This approach provides a reasonable RUL estimate without requiring any prior knowledge about the age of the equipment being replaced.[[78]](#footnote-79) Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on equipment so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component.”[[79]](#footnote-80)

The EUL specified below is based upon the estimated lifetime of a high-efficiency pool pump, the EUL was derived from a Codes and Standards Enhancement (CASE) initiative study[[80]](#footnote-81) that assessed the impact of proposed revisions to the California Appliance Efficiency Regulations (Title 20) relating to pools and spas.

Effective Useful Life and Remaining Useful Life

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| EUL (yrs) | 10.0 |
| RUL (yrs) | 6.67 |

Base Case Material Cost ($/unit)

The base case material cost for the single-speed and two-speed pumps was derived from cost data obtained come from online retailers. Various online sources including 2019 retail equipment costs were used to search for each of the base case equipment between 1 hp and 3 hp. The base case material cost was calculated as the average cost of each equipment type.[[81]](#footnote-82)

In addition to equipment costs, the base case material cost includes the average permit fee incurred for the installation for public pools. 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 and commercial measure offering.

Average Permit Fee

| **Jurisdiction** | **Permit Fee** | **Unit** |
| --- | --- | --- |
| 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 single gated 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 |  |

Measure Case Material Cost ($/unit)

Due to the similarity in pump size (and pump performance characteristics) and installation requirements, it is estimated 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 Southern California Edison (SCE) Multifamily Program data (1.84 hp)[[82]](#footnote-83) is close to the average horsepower estimated from the *Commercial Variable Speed Pool Pump Market Characterization and Metering Study* (1.78 hp).[[83]](#footnote-84)

The total measure case material and labor cost per pump was derived from data collected from the installation of (101) pumps from the SCE Multifamily programs during 2016 and 2017. To account for increased costs between 2016 and the present, RSMeans historical cost indexes[[84]](#footnote-85) for Los Angeles were used to convert the cost to 2019 dollars. (This resulted in an increase the total installation cost by roughly 7%.) Furthermore, because the program costs did not separate out the material and labor costs for the installation, material costs for several variable speed pumps ranging from 1 hp to 3 hp were obtained from online retailers in 2019.

In addition to equipment costs, the base case material cost includes the average permit fee incurred for the installation for public pools. 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 and commercial measure offering.

Average Permit Fee

| **Jurisdiction** | **Permit Fee** | **Unit** |
| --- | --- | --- |
| 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 single gated 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 |  |

Base Case Labor Cost ($/unit)

Because the base case equipment will not require any programming to operate, the 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.

Measure Case Labor Cost ($/unit)

The measure case labor cost was calculated as the total measure case installation cost (determined from the SCE Program data, see Measure Case Material Cost) less the average material cost per pump calculated from 2019 online retailer data.[[85]](#footnote-86)

To calculate the measure case cost of the self-installed measure offering, one labor hour by an electrician at the rate of $67.55 was obtained from RSMeans 2019 Residential Labor Rates.[[86]](#footnote-87) This was subtracted from the estimated labor for the programmed pump installation, to account for the absence of programming in the measure.

Net-to-Gross (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The NTG values are based upon the average of all NTG ratios for all evaluated 2006 – 2008 commercial residential programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. These sector average NTGs (“default NTGs”) are applicable to all energy efficiency measures that have been offered through commercial and residential sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| NTG – Commercial | 0.60 | Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3. |
| NTG – Residential | 0.55 |

Resolution E-4952[[87]](#footnote-88) (Section 5.4) determined that a NTG adjustment factor for below-code savings for accelerated replacement measures are necessary. The “Energy Efficient Potential and Goals Study for 2018 and Beyond” (Potential Study) notes that savings for equipment has below-code savings are already captured through codes and standards. In addition, the 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. It was established that an adjustment for accelerated replacement measures be applied to the below-code portion of savings.

In conformance with Resolution E-4952, an adjustment factor (below) is applied to the “above-code” NTG ratio specified above to the “below-code” savings of an *accelerated replacement installation*.

Net-to-Gross Ratio Adjustment Factor for Accelerated Replacement

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Source** |
| NTG adjustment factor | 0.75 | California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Op 1. Pp 58 – 59. |

Gross Savings Installation Adjustment (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. The GSIA rate specified for the VSD pool and spa pump measure is specified below. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rate

|  |  |  |
| --- | --- | --- |
| **Parameter** | **GSIA** | **Source** |
| GSIA | 1.0 | California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 31. |

Non-Energy Impacts

Non-energy impacts for this measure have not been quantified.

DEER Differences Analysis

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER does not include a measure for variable speed drive pool pumps. DEER 2005 did have a measure for two-speed swimming pool pumps (D03-967). This measure used an inefficient 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 VSD pump compared to a two-speed pump and the application has differing operation than a residence. Note that DEER 2020 does not include pool, spa, and wading pool pump measures.

DEER Difference Summary

| **DEER Item** | **Comment / 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 |
| NTG | Source: DEER. The NTG of 0.55 is associated with NTG ID: *Res-Default>2.* The NTG of 0.60 is associated with NTG ID: *Com-Default>2* |
| GSIA | Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA* |
| EUL/RUL | Source: DEER. The value of 10 years is associated with EUL ID: *OutD-PoolPump*. |

Revision History

Measure Characterization Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision Number** | **Revision Complete Date** | **Primary Author, Title, Organization** | **Revision Summary and Rationale for Revision** |
| 01 | 06/30/2018 | Jennifer Holmes  Cal TF Staff | Draft of consolidated text for this statewide measure is based upon:  SCE17WP008, Revision 1 (January 12, 2018)  SCE17WP001, Revision 0 (October 12, 2017)  Consensus reached among Cal TF members. |
| 03/08/2019 | Lake Casco,  TRC | Revised calculation methodology, eligibility and implementation writeups for both residential and commercial measures based upon:  SCE17WP001, Revision 1 (July 13, 2018   * Updated peak demand reduction values to correspond with DEER2020 peak period. * Updated turnover adjustment and energy savings for Measure B, based on DEER2020 peak period * Updated costs for 2020 based on new online retailer material searches and RSMeans adjustment factors * Updated code references for T20 2020, T24 2019 and future 2021 Title 10 Federal Code |
| 03/29/2019 | Jennifer Holmes  Cal TF Staff | Updates for submittal of version 01 |
| 10/01/2020 | Jesse Manao | Updated package to include:   * Updated EAD table (1. Added expiration date in implementation tab due to federal code effect, 2. Savings for SWRE002I was copied incorrectly from the MeasDataSpec, it is now corrected in energy impact tab) * Updated workpaper text to match CalTF document formatting. * Updated cover sheet to reflect confirmed expiration date. |

1. Worth, C., E. Ludovici, E. Joyce (Energy Solutions), and G. Fernstrom (PG&E). 2013. Pools & Spas – Codes and Standards Enhancement (CASE) Initiative for PY2013: Title 20 Standards Development, Analysis of Standards Proposal for Residential Swimming Pool & Portable Spa Equipment. July 29. [↑](#footnote-ref-2)
2. Hillis, R., and D. Rowan (ASWB Engineering). 2014. Commercial Pool Pump Market Characterization Study: Intermediate Report. July 22.  [↑](#footnote-ref-3)
3. Hunt, A., and S. Easley (Building America Retrofit Alliance). 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. U.S. Department of Energy (DOE). May. [↑](#footnote-ref-4)
4. California Energy Commission. 2019. *California Code of Regulations Title 20*. CEC-140-2019-002 [↑](#footnote-ref-5)
5. California Energy Commission (CEC). *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)*. CEC-400-2018-020-CMF. [↑](#footnote-ref-6)
6. California Code of Regulations. Title 22, Section 65501. 2016 [↑](#footnote-ref-7)
7. California Building Code, Part 2, Volume 2. Chapter 31B - Public Pools. 2016. [↑](#footnote-ref-8)
8. . Centers for Disease Control and Prevention (CDC), and U.S. Department of Housing and Urban Development (HUD). 2006. *Healthy Housing Reference Manual*. [↑](#footnote-ref-9)
9. Track 1 Working Group. 2016. *T1 Working Group Report.* Version 2.0. Prepared for the California Public Utilities Commission. December 7. Appendix B. [↑](#footnote-ref-10)
10. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-11)
11. ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25. [↑](#footnote-ref-12)
12. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “MFm Report Values” tab. [↑](#footnote-ref-13)
13. California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition for Workpapers Covering Residential Variable Speed Pool Pumps." March 1. [↑](#footnote-ref-14)
14. Southern California Edison (SCE), Customer Service, Emerging Products. 2015. *Commercial Variable Speed Pool Pump Market Characterization and Metering Study.* ET13SCE1170/ET13SCE1171. February. [↑](#footnote-ref-15)
15. Hunt, A., and S. Easley (Building America Retrofit Alliance). 2012. *Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings.* U.S. Department of Energy (DOE). May. [↑](#footnote-ref-16)
16. DNV GL. 2016. *Impact Evaluation of 2013-2014 SDG&E Residential VSD Pool Pump Program.* Prepared for the California Public Utilities Commission (CPUC)*.* CALMAC Study ID: CPU0132.01. April 1. [↑](#footnote-ref-17)
17. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “Data Base” tab for raw data, and Analysis tabs for calculations. [↑](#footnote-ref-18)
18. ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25. [↑](#footnote-ref-19)
19. “Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “Analysis” tab.

    California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition for Workpapers Covering Residential Variable Speed Pool Pumps." March 1. [↑](#footnote-ref-20)
20. California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition for Workpapers Covering Residential Variable Speed Pool Pumps." March 1. [↑](#footnote-ref-21)
21. *Single family flow values* derived from the SCE Single-family Pump Installation Data, 2008-2009. See:  
    Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.”

    *Multifamily flow values* derived from:  
    ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25.

    *Spa pool flow value* stipulated in:  
    California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition for Workpapers Covering Residential Variable Speed Pool Pumps." March 1. [↑](#footnote-ref-22)
22. Although the 2017 disposition calculated the average flow for a wading pool equal to 12 gpm based on the turnovers, the analysis of EF values for variable speed pumps showed that at low flows (approximately 15 gpm), the EF 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. [↑](#footnote-ref-23)
23. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.”. [↑](#footnote-ref-24)
24. ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25. See “MFm Report Values” tab. [↑](#footnote-ref-25)
25. California Energy Commission (CEC). 2019. California Code of Regulations Title 20. CEC-140-2019-002. [↑](#footnote-ref-26)
26. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “1-Spd CEC Data (2008)”, “2-Spd CEC Data (2018)”, and “VS CEC Data (2018)” tabs. [↑](#footnote-ref-27)
27. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-28)
28. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-29)
29. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “VS CEC Data (2018)”. [↑](#footnote-ref-30)
30. Pentair. (n.d.) “INTELLIFLO® Variable Speed Ultra Energy Efficient Pump. Installation and User’s Guide.” [↑](#footnote-ref-31)
31. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-32)
32. *Single family flow values* derived from the SCE Single-family Pump Installation Data, 2008-2009. See:  
    Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.”

    *Multifamily flow values* derived from:  
    ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25.

    *Spa pool flow value* stipulated in:  
    California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition for Workpapers Covering Residential Variable Speed Pool Pumps." March 1. [↑](#footnote-ref-33)
33. 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. [↑](#footnote-ref-34)
34. Although the 2017 disposition calculated the average flow for a wading pool equal to 12 gpm based on the turnovers, the analysis of EF values for variable speed pumps showed that at low flows (approximately 15 gpm), the EF 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. [↑](#footnote-ref-35)
35. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “2-Spd CEC Data (2018)” tab. [↑](#footnote-ref-36)
36. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “2-Spd CEC Data (2018)” tab. [↑](#footnote-ref-37)
37. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “1-Spd CEC Data (2008)” tab. [↑](#footnote-ref-38)
38. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “1-Spd CEC Data (2018)” tab. [↑](#footnote-ref-39)
39. ADM Associates, Inc. 2016. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Prepared forSouthern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25. [↑](#footnote-ref-40)
40. 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. [↑](#footnote-ref-41)
41. Although the 2017 disposition calculated the average flow for a wading pool equal to 12 gpm based on the turnovers, the analysis of EF values for variable speed pumps showed that at low flows (approximately 15 gpm), the EF 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. [↑](#footnote-ref-42)
42. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “Data Base” tab for raw data, and Analysis tabs for calculations. [↑](#footnote-ref-43)
43. “Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-44)
44. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Savings Calculations.xlsx.” [↑](#footnote-ref-45)
45. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Savings Calculations.xlsx.” [↑](#footnote-ref-46)
46. Southern California Edison (SCE), Customer Service, Emerging Products. 2015. *Commercial Variable Speed Pool Pump Market Characterization and Metering Study.* ET13SCE1170/ET13SCE1171. February. [↑](#footnote-ref-47)
47. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” [↑](#footnote-ref-48)
48. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” See “Calculations” and “Summary” tabs. [↑](#footnote-ref-49)
49. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” [↑](#footnote-ref-50)
50. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” See Row #7. [↑](#footnote-ref-51)
51. Nesbitt, Brian. "10.1.3.1 Power Factor." Handbook of Pumps and Pumping: Pumping Manual International. 1st ed. Burlington: Elsevier, 2006. 263. Web. 25 Aug. 2014. [↑](#footnote-ref-52)
52. Nesbitt, Brian. "10.1.3.1 Power Factor." Handbook of Pumps and Pumping: Pumping Manual International. 1st ed. Burlington: Elsevier, 2006. 263. Web. 25 Aug. 2014. [↑](#footnote-ref-53)
53. California Energy Commission. (January 2019). California Code of Regulations Title 20 (2019). CEC-140-2019-002 [↑](#footnote-ref-54)
54. Pentair. 2014. "Commercial Pool Pump Savings Calculator." August 25. <http://www.pentairpool.com/dealer-resources/calculators/commercial-pump-calc/standard.html>.

    NSF International. 2010. "NSF/ANSI 50 Equipment for Swimming Pools, Spas, Hot Tubs, and Other Recreational Water Facilities." Issue 57, Draft 2. May. [↑](#footnote-ref-55)
55. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” [↑](#footnote-ref-56)
56. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” See “CEC VS (Curve C)” and “CEC 2S (Curve C)” tabs. [↑](#footnote-ref-57)
57. Southern California Edison (SCE). 2018. “SWRE002-01 Com Pool VFD Savings Calculations.xlsx.” See “CEC VS (Curve C)” and “CEC 2S (Curve C)” tabs. [↑](#footnote-ref-58)
58. Hunt, A., and S. Easley (Building America Retrofit Alliance). 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. U.S. Department of Energy (DOE). May. [↑](#footnote-ref-59)
59. Pentair. 2014. "Commercial Pool Pump Savings Calculator." August 25. http://www.pentairpool.com/dealer-resources/calculators/commercial-pump-calc/standard.html. [↑](#footnote-ref-60)
60. Information & Energy Services, Inc. 2012. Multi-Family Residential Variable Speed Swimming Pool/Spa Pump Retrofit. [↑](#footnote-ref-61)
61. Pentair. 2014. "Commercial Pool Pump Savings Calculator." August 25. http://www.pentairpool.com/dealer-resources/calculators/commercial-pump-calc/standard.html. [↑](#footnote-ref-62)
62. Hunt, A., and S. Easley (Building America Retrofit Alliance). 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. U.S. Department of Energy (DOE). May. [↑](#footnote-ref-63)
63. California Energy Commission (CEC). *2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24).* CEC-400-2018-020-CMF. [↑](#footnote-ref-64)
64. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-65)
65. California Energy Commission (CEC). 2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24). CEC-400-2018-020-CMF. [↑](#footnote-ref-66)
66. Southern California Edison (SCE), Design & Engineering Services. 2008. *Pool Pump Demand Response Potential Demand and Run-Time Monitored Data.* DR 07.01. June 1. [↑](#footnote-ref-67)
67. Southern California Edison (SCE), Design & Engineering Services. 2008. *Pool Pump Demand Response Potential Demand and Run-Time Monitored Data.* DR 07.01. June 1.

    Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Savings Calculations.xlsx.” See “Peak Demand” tab. [↑](#footnote-ref-68)
68. ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25. [↑](#footnote-ref-69)
69. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “MFm CDF” and “SFm CDF” tabs. [↑](#footnote-ref-70)
70. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “MFm CDF” and “SFm CDF” tabs. [↑](#footnote-ref-71)
71. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “Peak Demand” tab. [↑](#footnote-ref-72)
72. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” See “Peak Demand” tab. [↑](#footnote-ref-73)
73. Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.” [↑](#footnote-ref-74)
74. *Single family flow values* derived from the SCE Single-family Pump Installation Data, 2008-2009. See:  
    Southern California Edison (SCE). 2018. “SWRE002-01 Res Pool VFD Database Analysis.xlsx.”

    *Multifamily swimming pool flow values* derived from:  
    ADM Associates, Inc. *Metering and Measuring of Multi-Family Pool Pumps, Phase 2.* Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, and Pacific Gas and Electric Company. April 25.

    *Spa pool flow value* stipulated in:  
    California Public Utilities Commission (CPUC), Energy Division. 2017. “Disposition for Workpapers Covering Residential Variable Speed Pool Pumps." March 1. [↑](#footnote-ref-75)
75. Although the 2017 disposition calculated the average flow for a wading pool equal to 12 gpm based on the turnovers, the analysis of EF values for variable speed pumps showed that at low flows (approximately 15 gpm), the EF 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. [↑](#footnote-ref-76)
76. Southern California Edison (SCE), Customer Service, Emerging Products. 2015. *Commercial Variable Speed Pool Pump Market Characterization and Metering Study.* ET13SCE1170/ET13SCE1171. February. [↑](#footnote-ref-77)
77. California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32. [↑](#footnote-ref-78)
78. KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc. [↑](#footnote-ref-79)
79. California Public Utilities Commission (CPUC). 2016. Resolution E-4807. December 16. Page 13.   [↑](#footnote-ref-80)
80. Davis Energy Group and Energy Solutions. 2004. Codes and Standards Enhancement Initiative for PY2004: Title 20 Standards Development - Analysis of Standards Options for Residential Pool Pumps, Motors, and Controls. Prepared for Pacific Gas and Electric (PG&E). May 12. [↑](#footnote-ref-81)
81. Southern California Edison (SCE). 2018. “SWRE002-01 Cost Calculations.xlsx.” [↑](#footnote-ref-82)
82. Southern California Edison (SCE). 2018. “SWRE002-01 Cost Calculations.xlsx.” [↑](#footnote-ref-83)
83. Southern California Edison (SCE), Customer Service, Emerging Products. 2015. *Commercial Variable Speed Pool Pump Market Characterization and Metering Study.* ET13SCE1170/ET13SCE1171. February. [↑](#footnote-ref-84)
84. Gordian. (n.d.) "RSMeans Cost Index.pdf." [↑](#footnote-ref-85)
85. Southern California Edison (SCE). 2018. “SWRE002-01 Cost Calculations.xlsx.” [↑](#footnote-ref-86)
86. Gordian. 2019. RSMeans Online, "Residential Labor Rates.pdf". March 6. [↑](#footnote-ref-87)
87. California Public Utilities Commission (CPUC). 2018. Resolution E-4952. October 11. O.P 1, pp 58 – 59. [↑](#footnote-ref-88)