Metering and Measuring of Multi-Family Pool Pumps, Final Report - Phase 1 & 2

Prepared for:

Southern California Edison Company
San Diego Gas and Electric Company
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Disclaimer

1. Executive Summary

This report contains the results of field measurements for multi-family swimming pool equipment for the investor owned utilities (IOU)s in California. The collection of data from multi-family pool pumps will support the IOUs when updating work papers. Pools located in four IOU areas; Southern California Edison Company (SCE), San Diego Gas and Electric Company (SDG&E), Southern California Gas Company (SCG), and Pacific Gas and Electric (PG&E) have field measurements completed and included in this report. The final report is inclusive of the Phase 1 report which did not include PG&E results and the Phase 2 report which did include PG&E results.

The main objectives for this study are:

- To conduct pre and post measurements of pool pump usage via onsite visits to a sample of 50 multi-family pools receiving variable speed drive (VSD) pool pumps in SCE service area and monitor the power profile of the baseline and new pool pumps;
- To conduct baseline or post-measurements of pool pump usage via onsite visits to a sample of 27 multi-family swimming pools (22 for SDG&E and 5 for SCG);
- To conduct same-day pre- and post-measurements of pool pump usage on a sample of 5 multi-family pools receiving variable speed drive pool pumps in PG&E service area;
- To implement a telephone survey with the local enforcement agencies in the targeted counties of the IOU service territories, and retrieval of other documentation in order to collect information regarding the regulatory requirements of county guidelines for pool-turnover and pump operation;
- To characterize pools and to inventory other pool equipment such as spas, water features, filters, heaters, in-pool lighting, pool area lighting, and associated controls.

The results of these activities will be used by the IOUs to update statewide work papers on variable speed drive pool pumps in the multi-family space and LED pool lighting.

The most significant portion of this study is the pre and post metering of pool pump energy use for SCE sites. The analysis of the field data showed that the average energy savings for early replacement is 6,408 kWh per pump. This is a 48.5 % energy savings. The savings is even higher when two negative saving pumps are excluded[1]. The demand savings is 0.58 kW per pump which is a reduction of 33.1 %. Energy and demand savings developed for the single visit sites for SDG&E and SCG utilized savings characterizations from the SCE sites. Energy and demand savings for the PG&E sites were conducted on VSD installations not recruited as part of a utility incentive program. The savings are lower for these sites in part due to non-operation of the pumps

[1] Additional detail is provided in section 4.2

during the overnight hours. The savings results are summarized in Table 1-1. The last row is the weighted average by number of pumps across all IOUs.

Table 1-1 Absolute and Relative Energy Savings and Demand Reduction per Pump by IOU

IOU	***Energy Savings, kWh***	***Demand Reduction, kW***	***Energy Savings, %***	***Demand Reduction, %***	***Approach***
SCE	6,408	0.58	48.5%	33.1%	Pre/Post with 52 Pumps (51 Pools)
SDG&E	6,901	0.58	48.5%	31.7%	On-Site audits for 8 VSD and 17 SS Pumps, savings projected from SCE results
SCG	9,203	0.83	48.5%	37.0%	On-Site audits for 6 VSD Pumps, savings projected from SCE results
PG&E	3,051	0.59	34.0%	32.6%	One-time Pre/Post readings for 4 pools
Average	6,448	0.57	46.2%	31.5%	Weighted averages

The average multi-family pool size for the SCE study sample is 26,250 gallons. In the San Diego area, the average pool size for the sample is slightly higher at 28,210 gallons. The SCG pools averaged 37,200 gallons and the PG&E pools averaged 28,467 gallons. The average baseline single speed pump motor for the SCE sample is 1.46 horsepower (hp), 1.72 hp for the SDG&E sample, and 1.50 hp for the PG&E sample. New VSD pumps are larger and average 1.74 hp for SCE, 3.00 hp for SDG&E, and 2.85 hp for PG&E. Flow data from the pool equipment was not consistently available and is subject to unknown accuracy, particularly at lower flow rates. However, for the data collected from the SCE pools the average turnover[2] rate was 6.6 hours for the single speed pumps and 8.6 hours for the VSD pumps. For the four PG&E pools, the average pool turnover rate was 7.8 hours for the single-speed and 8.2 hours for the VSD pumps. Natural gas pool heaters are in use in less than 30 % of the multi-family pools. An additional 5 % to 10 % of the pools have natural gas pool heaters that are no longer in use. The average pool heater size has an output rating of 350 kBtu/hr for SCG, and 410 kBtu/hr for SDG&E, and 275 kBtu/hr for PG&E.

Approximately 65 % of the pools have incandescent lighting in them, whereas only about 18 % of the pools have LED lighting in them. The average incandescent lamp wattage ranges from 250 to 400 watts. The typical in-pool LED lamp has a wattage of 50 to 65 watts. The annual in-pool lighting energy use ranged from a low of 1,054 kWh for SDG&E to a high of 2,264 kWh for the five pools designated as SCG sites.

Interviews were conducted with 10 county environmental health departments that oversee the periodic inspections of public pools. The interviews were intended to identify how each county interrupts and applies Title 22 and Title 24 codes as they pertain to the commissioning and inspection of public swimming pools. Every respondent indicated that they were open to allowing energy and demand saving equipment or controls for the operation of public pool recirculation

[2] A turnover occurs when the pump has pumped the volume of water the pool contains.

systems provided that the use of such equipment was not in direct conflict with public swimming pool code enforcement. When asked whether there were sections of the public pool code that could be open to more than one interpretation the answers varied. One-third of the respondents answered "No" while the remaining respondents indicated that yes, all codes have some interpretation involved in their application. Every county respondent indicated that they strive for consistency in code enforcement among all inspectors in the county.

2. Introduction

This study was initiated to collect field data in support of creating or updating work papers associated with multi-family swimming pools. In particular, the replacement of single speed pumps for VSD pumps.

SCE offers rebates for pump replacement for multi-family pools through their Multifamily Energy Efficiency Rebate (MFEER) Program. The savings values currently in use are based on case studies from pump replacements at two pools part of an SDG&E emerging technology report.[3] PG&E offers a MFEER program which is based on savings from the single family pool pump VSD work paper.

A study was initiated to collect statewide data for all four IOU service areas. Rather than develop a uniform approach to the data collection, each utility opted for a different data collection approach. The approach applied to the SCE data collection effort is the most consistent with conventional pre- and post-measurement strategies.

2.1 Study Objective

The main research objectives for this study are:

- To conduct pre and post measurements of pool pump usage via onsite visits to a sample of 50 multi-family pools receiving variable speed drive pool pumps in SCE service area and monitor the power profile of the baseline and new pool pumps;
- To conduct baseline or post measurements of pool pump usage via onsite visits to a sample of 27 multi-family swimming pools (22 for SDG&E and 5 for SCG);
- To conduct same-day pre and post measurements of pool pump motor usage on a sample of five multi-family pools receiving variable speed drive pool pumps in PG&E service area.;
- To implement a telephone survey with the local enforcement agencies in the targeted counties of the IOU service territories, and retrieval of other documentation in order to collect information regarding the regulatory requirements of county guidelines for pool turnover and pump operation; and
- To characterize pools and to inventory other pool equipment such as spas, water features, filters, heaters, in-pool lighting, pool-area lighting and associated controls.

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[3] The "Multi-Family Residential Variable Speed Swimming Pool /Spa Pump Retrofit" study report can be found at: http://www.etcc-ca.com/sites/default/files/OLD/images/vfd_pump_mfr_swim_pool_spa_mv_report_final_rev28.pdf

2.2 The Technology and Background

For years, pools have been designed and built to provide a water circulation system that keeps the pool water clean and safe for swimming. Traditionally, a single speed pump motor has been used for the circulation system. The circulation system typically pulls water from the bottom of the pool and skims some from the top. The water goes through a straining basket to catch large debris such as leaves and sticks, and then through a filter for finer particles and contaminants. Chemicals may be added before the water is returned to the pool. As more water is filtered, the filter becomes dirty and creates additional backpressure the pump must work against. Proper maintenance will minimize the backpressure and improves the pumping efficiency of the system.

Sizing of the pump for a system usually includes a safety margin for the condition of an especially dirty filter. Additionally, single speed motors only come in discreet sizes. Building and health codes require the system to be capable of turning over the water from the pool at a certain rate. A turnover occurs when the pump has pumped the volume of water the pool contains. The current code requires that the system be operated whenever a public pool is open for use, and that the pool's volume of water pass through the filter system every six hours. Pools built prior to 1982 are only required to turn over the pool water volume in eight hours. Typically, the pumps are turned on a couple hours prior to opening to the public. The pool maintenance staff may operate the pump for longer hours after a public pool closes just to insure the water quality is maintained and they do not receive complaints about cloudy or dirty water.

Energy savings can be achieved by turning over the water at just the prescribed amount the code requires. The control to allow such commissioning of a system is provided by variable speed drive pumps. The pump speed can be programmed to deliver just the required flowrate provided a flowmeter exists. The installer must adjust the speed of the VSD pump to match the required flowrate. Once the ideal speed is determined it will be programmed into the schedule of operation. Figure 2-1 shows a VSD pump with a keypad and display which can be set to any schedule and speed combination the operator determines will provide the optimum operation of the pump for both energy conservation and health code requirements.

Figure 2-1 Variable Speed Pool Pump

3. Methodology

This chapter provides a discussion of our overall methodology including sample selection. We describe our approach and methodology for performing the tasks to address the project objectives.

3.1 Sample and Site Selection

3.1.1 Sample Size

The target number of samples required to meet the study objectives was designed as part of the research plan. A site for this study is defined as a pool.

Specifications for the onsite data collection portion of the sample design include site visit quantities for each participating IOU as shown below in Table 3-1. It should be noted that as there is overlap between SCE and SCG service territories, a portion of the SCE site visits will collect data relevant to SCG. The sample size shown for SCG is exclusive of the sample size shown for SCE.

Table 3-1 Pool Visit Sample Sizes by IOU

Approach	*SCE*	*SCG*	*SDG&E*	*PG&E*	*Total*
Type 1: Pre and Post	50	0	0	0	50
Type 2: Baseline or post-only	0	5	22	0	27
Type 3: Baseline and post with new VSD	0	0	0	6[4]	6
Target Total	**50**	**5**	**22**	**6**	**83**
Actual Total	**53**	**5**	**23**	**6**	**87**

Three types of site visits were conducted in order to collect the most cost-effective data while accommodating the specific needs of each IOU. Refer to section 3.2 for the measurement approaches. The three types of site visits are as follows:

- Type 1: Onsite instantaneous measurements and characterization data collection visits including both current (amperage) pre metering of pool pump usage prior to variable speed drive installation and current post metering of pool pump usage following variable speed drive installation. Only sites for SCE fall into this category.
- Type 2: Onsite measurement and data collection visits including either baseline characterization of pool pump usage **or** "post"-only characterization of pool pump usage with variable speed drive pumps, for SDG&E and SCG sites; and

[4] Only four of six pools were included in the analysis of the PG&E pools as explained elsewhere in the report.

- Type 3: A single onsite measurement and data collection visit to measure power and record the operating schedule of both the outgoing single-speed pool pump and the incoming variable speed pool pump. These were conducted for PG&E.

Additional pool and characterization data were collected for all three types as described in section 3.2.

3.1.2 Sample Selection

SCE has offers rebates for pump replacement for multi-family pool pumps through their MFEER Program. Within SCE territory the recruitment of sites was limited to program participants. This limitation was based on the requirement to collect metered data on the pool pumps before and after the installation of a VSD. The sample selection for the SCE sites was limited to participants of the pump replacement program and those sites that could be recruited for data collection within the time constraints of the project. No climate zone distinction is made since pump energy use is dictated primarily by California codes for health and safety. The sites were a combination of apartments, condominiums, and home-owner associations. During 2015 there were two primary program implementers.

ADM worked with the two program implementers to get advance notice of the sites that were planning to receive VSD installations to allow a visit to be scheduled to collect pre-installation (baseline) data on the existing pool pump. Despite being provided contact information for the sites it was difficult to get past the gatekeepers to schedule appointments. A gift card was offered to the person at the facility most helpful with our data collection effort. Generally, that meant the person that had the key to open up the pool pump area for access and measurements. Exceptions were where we were told it was against company policy to accept any form of gift. Additional leverage was gained when two large apartment management companies provided specific names of site managers and also sent emails encouraging their assistance in helping to schedule appointments.

For SDG&E and SCG, IOUs that do not have a multi-family VSD pool pump replacement program, ADM used Type 2 visits to collect baseline or post-only data. Post referring to sites with VSD pool pumps. Within this approach, the distribution between baseline and post-only site is strictly based on sites that could be scheduled for a data collection visit. These were primarily cold calls and the success rate was low. Again, a $50 gift card was offered to whomever at the facility could provide assistance with our data collection effort. The sample selection process for the San Diego region was as random as could be provided the recruitment difficulties. A list of all public pools from the San Diego environmental health department was obtained. From that list hotel, motel, and community pools were culled. Of the remaining pools, those with email addresses were invited to participate in the study and those that followed up were contacted. An additional recruitment effort was conducted through pool maintenance services. Sometimes once we found one service contractor they offered other apartments where they maintained the pool equipment. No systematic sampling approach was used for the SCG sites.

PG&E requested ADM to pursue Type 3 site visit options for their territory. PG&E used another consultant to recruit sites for the replacement of VSDs at multi-family facilities. A total of six pools had VSD installed, three pools were visited by ADM and three by PG&E's consultant. Of the original six pools with VSD replacement, two pools were dropped from the analysis after it was determined they did not meet code compliance for turnover rate of the baseline conditions. PG&E plans to conduct more comprehensive research of VSD pool pump installations in its territory at a later date. The prequalification criteria included: the climate zone for the pool, the pool was actively being used and maintained, and the pool was not of abnormal size (investigated using satellite images.) Although not having a VSD on the existing filter pump was also a requirement, this could not be verified until a site visit was made.[5] The recruitment offered a VSD pump or motor at no cost to the customer.

Despite plans for the sample sites to have a variety of values for parameters such as pool size, pump size, quantity of pool pumps, climate zone, and pool operating hours, we were restricted to sites that were participating in the SCE program in SCE territory and those sites that would agree to participate in the other areas.

The third subset consisting of four reported pools in PG&E service area, which received new VSD pool pump motors, had instantaneous measurements of baseline and VSD conditions. The premises for this subset was selected based on geographical distribution by climate zones. The target distribution is shown in .

Table 3-2.

Table 3-2 Target Pool Locations by Climate Zone for PG&E

CA Climate Zone	***Combined Target Number of Pools[6]***	***ADM Target Number of Pools***	***Number of Pools Used***
1	0	0	0
2	1	0	1
3	2	0	0
4	6	0	1
5	1	0	0
11	1	1	1
12	3	3	0
13	2	2	1
16	0	0	0
Total	16	6	4

[5] At least three recruited sites already had VSD on the filter pumps, so were not included in the sample.

[6] Original target of 6 by ADM and 10 by PG&E contractor.

3.2 Metering and Measuring

A primary activity of this project was to conduct metering and measuring of pool pumps and pool equipment in order to obtain data on pump power measurements, pool size, flow rate, pool pump specifications, operating hours, LED lighting, gas heaters, and other characterization data.

3.2.1 Data Collection

To obtain data regarding pool pumps, pool heater, and pool lighting, schedules and characteristics, ADM created a universal data collection form that addressed the issues raised in the planning. The data collection form can be found in Appendix A. Data collection procedures and interviews with facility maintenance staff assisted in our efforts to collect the data inputs at each pool. Flow and pressure measurements listed on the data collection form relied on gauges that are part of the existing pool equipment. According to Title 24 code (3125.B.3) all public pools must have a flow meter installed which is capable of measuring the flow rate with accuracy within 10 % of actual flow. We used these flowmeters to document the flow rate for each pump for each state of operation independent of the type of site visit. These flow meters may not be able to measure or register the flow when the pump is operated at very low speeds. Although according to county environmental health department code requiring the flowmeters to be maintained in working order we found a significant number of them did not register flow when the pump was on.

For the SCE sites the pumps were monitored using current (amps) logging recorders that could be fit within the small confines of electromechanical time-clock boxes. The loggers used were Onset's HOBO® model U12-006[7] which had a 20 amp CT, and were used to collect baseline data and post retrofit data (see Figure 3-1). It was intended that the baseline period would be two weeks and the post period would be one month. Because of time constraints toward the end of the field work caused delays in installing the VSD pool pumps, not all sites have this much post VSD data. However, based on the daily repetitive cycle it was judged to be sufficient. The current data was logged at five-minute intervals. The logger clock was synchronized to the NIST[8] clock available on the web. At the end of monitoring the loggers were removed and the data downloaded for analysis.

[7] The U12-006 has an accuracy of ±2.5% of reading, and clock accuracy of ±1 minute per month.

[8] National Institute of Standards, time widget: http://time.gov/widget/widget.html

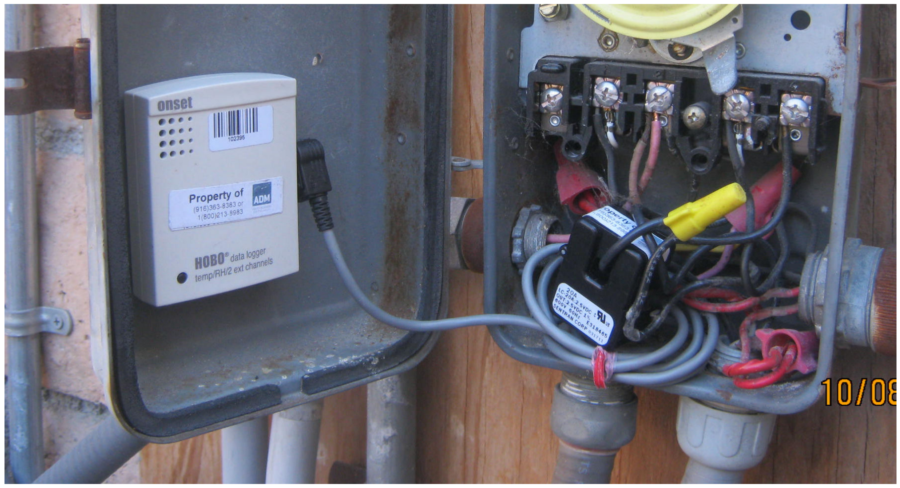

Figure 3-1 Data Logger with Current Transducer inside Timeclock Box

A power meter was used to measure true RMS voltage, current, power and power factor. The model used was an AEMC 3910 power meter.[9] In PG&E territory, PowerSight PS3000 meters[10] were used to make the instantaneous measurements.[11] For all utility areas instantaneous measurements for existing single speed pool filter pump motors included volts, amps, power (watts), and power factor. For the baseline pump motors, the measurements were made at typical steady state conditions. For the VSD pump motor the measurements were taken at the speeds the pumps were scheduled to operate. Typically, this was either one or two speeds. For the cases with two speed the second speed was used to operate the pump during non-occupied hours (during the night). Any special conditions for the operation of the pump were noted. For a couple VSD pumps, one-time power measurements were made at additional speed settings.

Data on discharge pressure, suction pressure, and flow rate were gathered from gauges that were part of the pool system. Visual reading from the existing analog gauges were documented and pictures were taken. In PG&E service area, FlowVis® inline flow meters were installed to insure the accuracy of the flow measurements for the VSD settings.

3.2.2 Data Collection Site Types

[9] The AEMC has a current range from 0 to 500 amps, and power range from 30 W to 300 kW. The current accuracy is ±2% of full scale, the voltage accuracy is ±0.3%, and the power accuracy is the sum of the current and voltage accuracy (or ±2.3%). The voltage resolution is 1 Vac, and the current resolution is 0.1 amps.

[10] PowerSight PS300 has current range from 0.1 to 100 amps, and power range from 1 W to 6 MW. The current accuracy is ±0.5% of full scale, the voltage accuracy is ±0.5%, and the power accuracy is the sum of the current and voltage accuracy (or ±1.0%).

[11] At PG&E's request, ADM coordinated with the Pacific Energy Center's tool lending library to borrow a PowerSight power meter to make power measurements in their service area.

The data collection needs for each utility were defined by input from each and defined to be different from each other. The metering and measuring procedure involved three types of site visits accommodating the specific needs of each IOU. The three types of site visits are as follows:

- **SCE (Type 1)**: Two onsite measurement and data collection visits.
  - 1.1. Instantaneous power measurements for existing baseline pool pump(s);
  - 1.2. Set of instantaneous power measurements for new VSD pool pump(s) at various speed settings and each water piping conditions;
  - 1.3. Current (amps) monitoring start from baseline existing baseline pool pump(s) and continuing for up to one month of VSD;
  - 1.4. Collect characteristics data for baseline conditions using the data collection form common to all pools;
  - 1.5. Collect characteristics data for VSD pumps using page 1 & 2 on the data collection form.
- **SDG&E and SCG (Type 2)**: One onsite measurement and data collection visit.
  - 2.1. Instantaneous power measurements for existing baseline pool pump(s) or VSD pool pump(s);
  - 2.2. Collect characteristics data using the data collection form common to all pools.
- **PG&E (Type 3)**: One onsite measurement and data collection visit[12].
  - 3.1. Instantaneous power measurements for existing baseline pool pump(s);
  - 3.2. Replace existing pool pump motor with VSD pool pump;
  - 3.3. Set of instantaneous power measurements for new VSD pool pump(s) at various speed settings;
  - 3.4. Collect characteristics data for baseline conditions using the data collection form common to all pools;
  - 3.5. Collect characteristics data for VSD pumps using page 1 & 2 on the data collection form.

The methodology for Type 1 sites was to monitor the time series load profile for the pool pump motors for a period of time prior to the pump replacement and continue through for a period after the VSD pump has been installed. At least two visits were conducted for each site with pre and post metering. No intermediate visit was planned to accompany the contractors, which replace the original single speed pump with a VSD pump. Type 2 sites involve instantaneous power measurements of either baseline usage or post-VSD installation usage. Type 3 sites involve

[12] The sites were required to be visited by the installer prior to the installation visit in order to determine sizing of the piping and relevant information and to be able to complete the county permit process.

instantaneous power measurements of the baseline pump demand and a set of post-VSD installation demand measurements during a visit coordinated with a contractor that replaces the pump with a VSD.

For Types 1, 2, and 3 site visits operating schedules for the pumps were documented. For the baseline visits, pictures of the daily electromechanical time clock were taken. The position of the ON and OFF trippers was noted on the data collection form. Any variance of the time clock to local time was also noted. For the VSD pumps the programmed operating schedule was viewed on the digital display and documented.

Type 3 site visits conducted for PG&E include VSD pump installation for measurement purposes. The initial part of the visit is to document the time clock settings for the baseline pool pump operation and make instantaneous measurements of the pool pump operating at a steady state condition. ADM hired local pool or mechanical contractors who replace the pump with a VSD pump. After waiting onsite for the contractor to replace the pump we make sets of instantaneous measurements at pump speed settings that the unit is programmed. The time schedule and speed setting programmed into the VSD is documented to characterize the post installation operation profile.

Although not specifically investigated, pool equipment, including filter pumps for multi-family properties, are serviced by the same meter that services all common area loads on the property. This makes it difficult to use whole premise meter data to analyze the savings results and supports the end use measurement approach.

3.3 Analysis Approach

3.3.1 Types of Data Analyses for Determining Pump Energy Usage

In this work we use two methods to estimate pool pump annual energy usage and peak demand. One method involves metering pool pump current at five-minute intervals, and another method involves taking spot measurements of pool pump kW, and reconstructing the pump operation schedule by checking the pool pump time clock and (for VFD pool pumps) the programmed pump schedule. Each method is briefly described below.

Load Reconstruction Through Spot Measurements

In this approach, the pool pump power is established through spot measurements while the pump is operating. For variable speed pumps, power measurements are taken at the programmed operation set points, and for a few extra operation points to span the likely range of pump operation (typically 750 RPM to 3450 RPM). The pool pump operating schedule is determined by inspection of the time clock for single speed pumps, and by inspection of the pool pump's program in the operator control panel for variable speed pumps, see Figure 3-2. Lastly, the contact person for the pool (typically the pool maintenance agent), is interviewed to inquire whether the daily operation schedule has any seasonality.[13]

Figure 3-2 Typical Dial Timer used to Control Pool Pumps (left) and a Variable Speed Pump Control Panel (right)

Load Reconstruction Through Metering

In this approach, the pool pump operation is determined by monitoring the pump's current draw at five-minute intervals. The monitoring duration was highly variable, in part due to the availability of advanced notice from installation contractors and in part due to departures from expected installation dates. The average monitoring period was 38 days for the pre-installation period and 25 days for the post-installation period, although the monitoring durations ranged from two to 99 days. As with the spot measurement approach, the contact person for the pool (typically the pool maintenance agent), is interviewed to inquire whether the daily operation schedule has any seasonality.

The pool pump power is also reconstructed from the monitoring data. Although the monitoring data provides information only on the pumps' AC current draw, the current draw is converted to

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[13] According to our interviews, most pool pumps do not have seasonal operation schedules, but a small fraction of pumps (particularly in SDG&E and PG&E service territory) tend to run slightly shorter hours in the winter.

kW in a two-step process. The pump kW is reconstructed as the product of the average voltage on site (as measured through several spot measurements), the current, and a power factor. The power factor for single speed pool pumps is taken to be 0.96, which is the average value for 68 spot measurements on single speed pool pumps. The power factor for variable speed pumps is reconstructed from a fit of 202 measurement points.[14] The curve fit is given by the following equation, and shown in below in Figure 3-3. This can be done since the VSDs are virtually all the same horsepower rating.

$$Power\ Factor = 0.99\ e^{-\left(\frac{Amps}{1.14664}\right)}$$

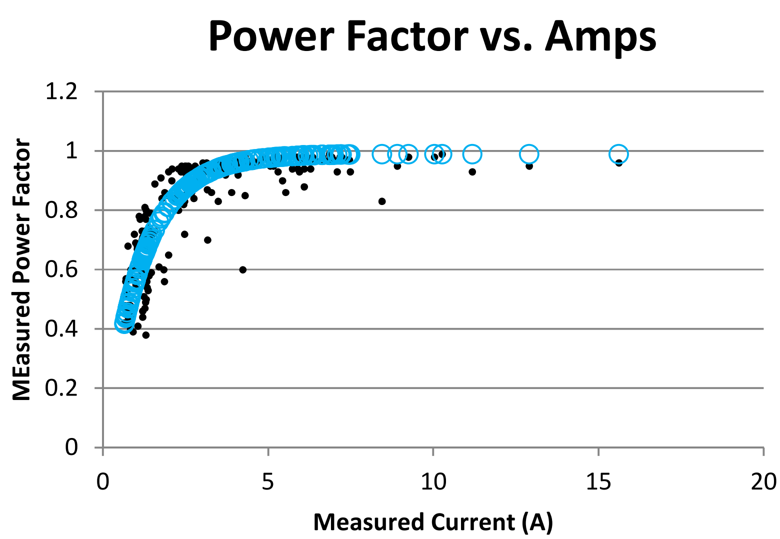

Figure 3-3 Distribution (black dots) and Fit (blue circles) of Power Factor vs. Amps for Variable Speed Pool Pumps

Although voltages and power factors are required to convert amps to kW, our calibration methodology supplants the nominal voltage and power factor values with ones that are more specific and appropriate for each pump. The calibration process involves comparing the nominal power construction from the metering data to actual power measurements taken onsite. Since pump power can vary over time according to factors such as filter resistance, we prefer to compare the pump power estimates from the metering data on the same day as the onsite power measurement. Whenever possible, we calibrate pre-retrofit data to the pre-retrofit measurement and post-retrofit data to the post-retrofit onsite measurement. One reason for the dual calibration is that the pool pump current can vary significantly as a result of the pump retrofit. Often, the current in the post-retrofit period has harmonics that the current in the pre-retrofit period does not have. This can cause the current transformer (CT) to output a different DC potential per AC current in the post

[14] Three measurement points were identified as gross outliers and were removed from the fit.

retrofit period than in the pre-retrofit period.[15] While the difference may not be dramatic, a dual-calibration methodology enhances the accuracy of the metering effort.

3.3.2 Counts by Climate Zone and Utility

The distribution of pools sampled was reasonably dispersed by climate zone considering population distribution. There were restrictions on the sample selection, particularly for SCE, but recruitment difficulties in SCG and SDG&E also played a factor in location of the pools visited. Table 3-3 shows the distribution of pools by California climate zones and utility served. The SCG listed pools are also SCE customers. There were other large areas of SCE that were not represented, namely CA climate zones 13, 14, & 16, which have lower densities of multi-family facilities.

Table 3-3 Pool Location by Climate Zone and Utility

CA Climate Zone	SCE	SCG	SDG&E	PG&E
2	-	-	-	1
4	-	-	-	1
6	11	-	-	-
7	-	-	12	-
8	22	3	-	-
9	5	-	-	-
10	12	1	10	-
11	-	-	-	1
13	-	-	-	1
15	3	1	-	-
Total	53	5	22	4

3.3.3 Counts by Pump Type and Utility

Type 2 site visits observed either a single speed pump or a VSD pump depending on what happened to exist at the site at the time of the visit. Table 3-4 lists the distribution of sites by single speed versus VSD pool pumps. For SCE the quantities are equal because the sites were visited twice, once for the baseline and once with the new VSD.

[15] We have accumulated indirect evidence that the response of typical current transformers may not be completely linear as the overall current drops to or below 10% of the CT's rated current. The typical outcome is that the current for the efficient pool pump can be understated by a few percent. This motivated our dual calibration effort. As a result of the more robust calibrations, the average energy savings for the 52 SCE pool pumps was reduced by almost 6%.

Table 3-4 Pool Visit Sample Size by IOU and Pump Type

Service Area	Single Speed	VSD	Total
SCE[16]	53	53	53
SCG	0	5	5
SDG&E	14	8	22
PG&E	4	4	4
Total	71	70	83

3.3.4 Counts by Data Analysis Type for SCE Pools

Of the 53 pools in the initial sample, 2 pools did not yield useful baseline or post pool pump power data. The remaining 51 pools contributed to the data analysis. Ideally, each pump would have both spot measurements and monitoring data from the pre-retrofit and post-retrofit periods. Of 52 VSD pumps in our final dataset for SCE, all 52 contain spot measurements for the pre-retrofit and post-retrofit periods. Post-retrofit metering data is available for 49 pumps, and pre-retrofit meter data are available for 40 pumps.

Some reasons for metering data loss include:

- Apparent high frequency electromagnetic interference from other sources (three occurrence);
- Data logger ran out of batteries during post period (one occurrence);
- Amps in the post-period are much lower than 10% of the rated CT amps (one occurrence).
- CT was found to be disconnected upon retrieval, with no usable data on logger (one occurrence);
- Baseline pool pump failed within one day of logger installation (one occurrence); and
- Other irrecoverable data loss observed upon return visit (eight occurrences).

In cases where metering data are not available, we construct the hourly pump loads by coupling the onsite power measurements with a detailed operation schedule as determined from inspection of the pump timer, the variable speed pump control panel, and onsite interview regarding any possible seasonality in pump operating schedules. Whenever available, we compare the annual energy usages as estimated by metering and by spot measurements and pump timer schedule inspections. On average, the two methods agreed within 1% for the post period and within 8% for the baseline period. The primary reason for disagreements in the baseline period was that metering

[16] The 53 single speed pumps for SCE and the 6 single speed pumps for PG&E are the baseline pumps.

occasionally bore out longer hours of operation than the hours of operation determined through pump timer inspections. This may be due to pump timers being manually bypassed.[17]

For each of the 52 pumps in the SCE sample, we have constructed an hourly annual load profile (an 8,760-element array with a kW value for each hour of the year) for both the baseline and post-retrofit conditions. The energy savings result as the difference between the sums of these arrays. This is the energy savings for early retirement using existing conditions as the baseline. The demand reductions result as the difference between the peak demands of the two pool pumps, with the peak demand calculated as the average pump loads between 2 PM and 5 PM on weekdays.

3.3.5 Counts by Data Analysis Type for PG&E Pools

Of the four pools in the sample, one had reduced operating hours in the winter[18] compared to the summer. The pool is located in climate zone 4.

3.4 County Regulations Data Collection

This section addresses the data collected from county regulatory agencies that enforce health codes for public pools. A survey with a structured set of questions and open ended response format was developed (see Appendix A for an imbedded copy). An interviewer with a technical background conducted telephone interviews.

Telephone surveys with the local enforcement agencies in each of the targeted counties of the IOU service territories were conducted. The survey instrument objective was to address the following topics:

- The agency's specific interpretation of the California Department of Public Health regulations;
- The agency's enforcement practices for the California Department of Public Health regulations;
- The agency's specific regulations regarding "off-peak" pool pump turnover;
- The agency's definition of "clear and disinfected" condition, as related to "off-peak" pool pump turnover; and
- The agency's stance on use of variable speed drive pumps for filtration in public pools.

[17] This is not a material issue with the 12 sites that had baseline energy usages determined through spot metering and timer schedules because eight of the sites had 24/7 operation in the baseline period, and two of the remaining four sites had post schedules that were identical to the baseline schedules, and were subsequently validated through metering.

[18] October 1 to May 1.

From August to November 2015 ADM conducted telephone surveys with county public health departments to better understand the regulatory environment and potential impact of regulatory enforcement on the implementation of VSD-equipped pool pumps for multi-family pools. The department names vary some from county to county but they all have "Environmental Health" as part of the department name. Any county within California that oversees at least one percent of statewide multi-family pools was targeted for contact. Fourteen county health departments (see Table 3-5) were contacted by emails and followed by phone calls in order to find the appropriate contact for in-depth interviews.

Table 3-5 List of County Environment Health Departments Targeted

CA County	***IOU Service Area***
Alameda	PG&E
Contra Costa	PG&E
Fresno	PG&E, SCE, SCG
Kern	PG&E, SCE, SCG
Los Angeles	SCE, SCG
Orange	SCE, SCG, SDG&E
Riverside	SCE, SCG
San Bernardino	SCE, SCG
San Diego	SDG&E
San Francisco	PG&E
San Mateo	PG&E
Santa Barbara	PG&E, SCE, SCG
Santa Clara	PG&E
Ventura	SCE, SCG

This information will be used to determine whether there is variation among the local enforcement agencies and how it may impact utility programs. The pool filtration pumps are required to operate any time the public pool is open or available for use. Operation of the pumps during hours the pool is closed is at the discretion of the pool operator as long as water clarity and chemical balance are maintained.

Title 24 dictates public pool pumping system flowrate capacity. This is enforced by county building inspectors at the time of construction. Title 22 dictates water turnover rates in public pools. This is enforced by local county environmental health and safety (EH&S) departments. The EH&S conducts periodic inspections of public pools to ensure public health and safety. The EH&S departments inspect for water quality, pump flow and turnover are maintained and can issue citations for infractions or have the authority to close the pool.

4. Results

Information presented in this section is the result of analysis of data collected from the field and through interviews.

4.1 Characteristics of Pools and Systems

One characteristic of pools is the size, normally expressed by volume in gallons of water the pool nominally holds. For some of the sites the volume was obtained from pool maintenance staff who need to know this critical information when adjusting chemical balance in the pool. At other sites the dimensions of the pool were measured and the volume calculated. A distribution of pool sizes in gallons by IOU is provided in Figure 4-1. The majority of multi-family pools are in the 10,000 to 40,000 gallons range. The average multi-family pool size for the SCE study sample is 26,250 gallons. In the San Diego area, the average size for the sample is slightly higher at 28,210 gallons. The designated SCG sample pools were larger, but were based on only five pools and are within the SCE area so are not necessarily a true representation of SCG service area. The four PG&E pools averaged 28,467 gallons. The range of pool sizes for the study sample is provided in Table 4-1.

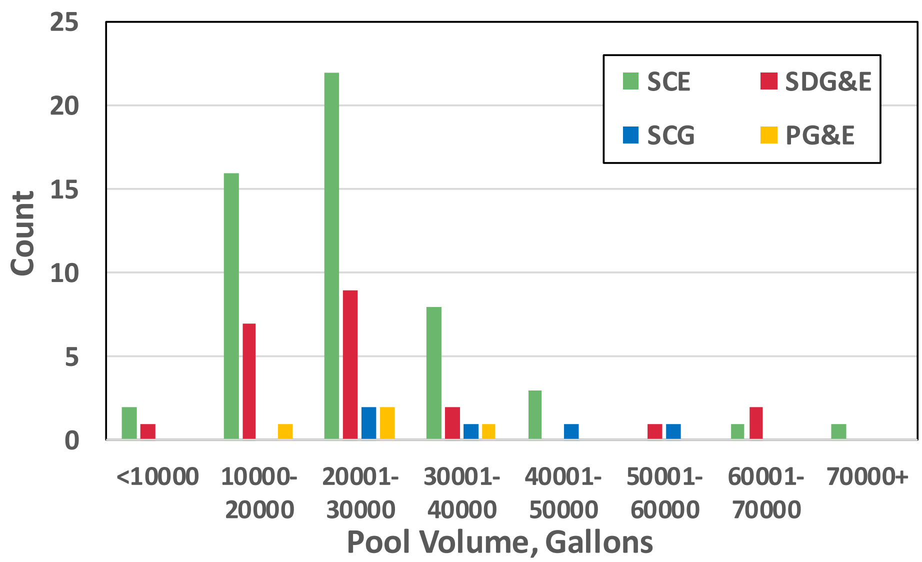

Figure 4-1 Multi-Family Pool Size Distribution by IOU

Table 4-1 Pool Size by IOU

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

4.1.1 Pump Size

Pump size as rated in horsepower (hp) is another characteristic for classifying pools. Figure 4-2 shows the horsepower rating count distribution by IOU. There were nine distinct horsepower ratings for the baseline single speed pool pump motors. The most common sizes in the study sample were 1, 1.5, and 2 horsepower for the single speed pumps. There were three different horsepower ratings for the VSD pumps, with most being either 1 or 3 hp.

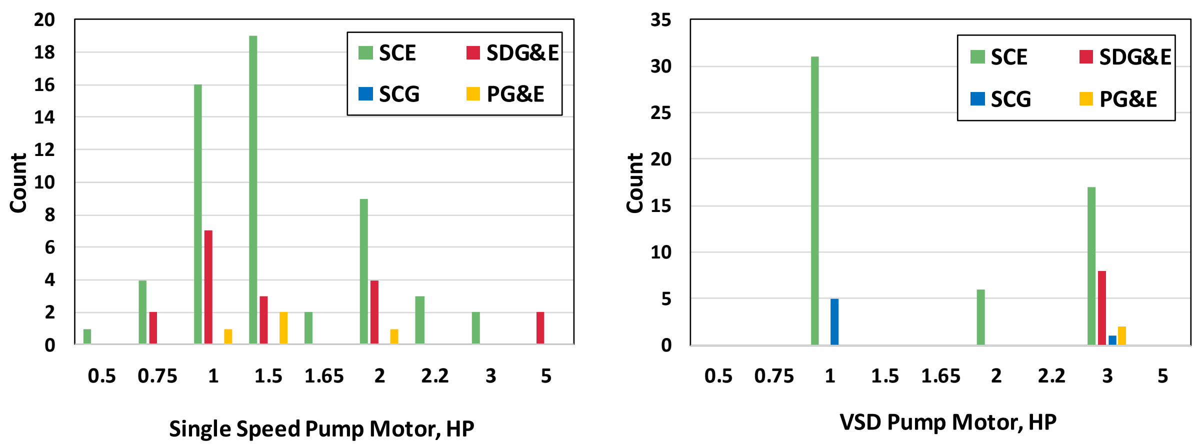

Figure 4-2 Pool Pump hp Size Distribution for Single Speed and VSD Pumps by IOU

Motors also have a service factor (sf) rating. The service factors for the single speed motors ranged from 1.0 to 2.6. The service factors for the VSDs ranged from 1.32 to 3.95. When the hp and sf are multiplied together the result is the service factor horsepower (sfhp). This is the maximum short-term power the motor can supply. Figure 4-3 shows the sfhp rating count distribution by IOU charted in range bins. There is a somewhat normal distribution of sfhp around 2 for the single speed pumps. However, almost universally the VSD are all rated at 3.95 SFHP whether the pumps are rated as 1, 2, or 3 hp. The difference between them is the impeller size.

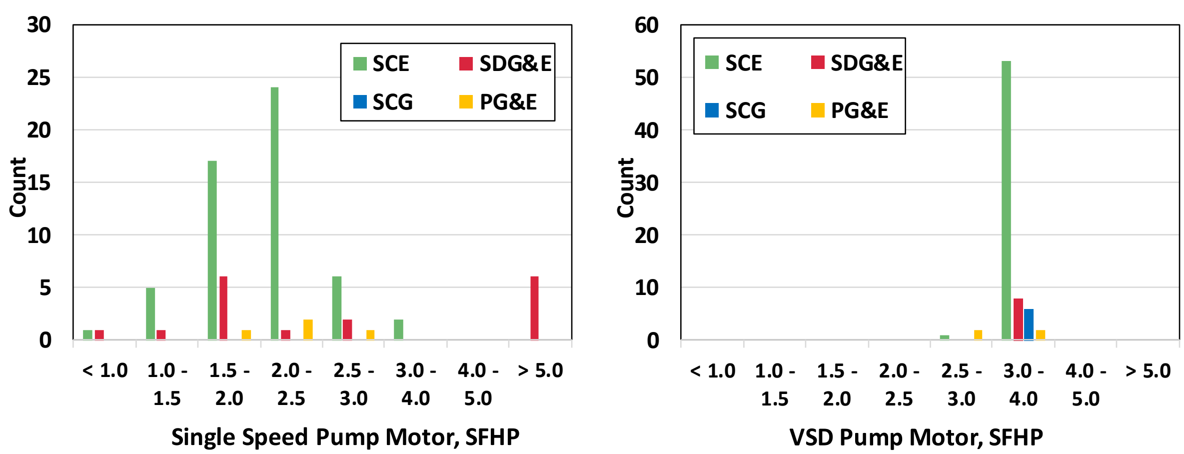

Figure 4-3 Pool Pump Service Factor hp Distribution for Single Speed and VSD Pumps

The average pump rating is for horsepower and service factor horsepower by speed type and IOU are provided in Table 4-2. Despite the SCG pumps having the lowest average horsepower rating they have just as high of an sfhp rating.

Table 4-2 Average Pump Rating by IOU

Pump Type	*Rating*	*SCE*	*SDG&E*	*SCG*	*PG&E*
Single Speed	hp	1.46	1.72	na	1.50
VSD	hp	1.74	3.00	1.33	2.85
Single Speed	sfhp	2.04	2.95	na	2.19
VSD	sfhp	3.93	3.96	3.95	3.33

Large volume pools can accommodate higher flow rate by either using one large pump or two typical size pumps. A total of six pools visited have two pumps and these are larger than average size pools. There are two SCE pools with two pumps, one SCG pool, and three SDG&E pools with two filtration pumps. One of the SCE sites with two[19] single speed pumps were replaced with one 3-hp VSD pump.

4.2 Savings Results

The energy usages of the SCE baseline single-speed pumps and the post-retrofit variable speed pumps are plotted against pool volume in Figure 4-4.[20] The distribution in Figure 4-4 indicates that the pump installers and pool maintenance technicians tend to specify pump capacities and operating schedules according to pool volume. This amounts to indirect evidence of pump "sizing" for both the baseline and post-retrofit cases. The plot also indicates that in most cases, the variable speed pumps result in significant energy savings. In the sample of 52 pumps, the average energy savings was 6,408 kWh, or 48% of the baseline pump energy usage. Commissioning would require proper knowledge of flow rates, which we were not able to get for a significant number of sites. But it is presumed that properly commissioned VSD pumps should result in energy savings and not an increase in energy use. There were two instances that showed negative savings and when excluding those two sites from the analysis the average energy savings for the SCE sites was 6,709 kWh per year. For one of the two pumps with negative savings the VSD pump was drawing more power and circulating water at a higher rate than the baseline single speed pump. The VSD could have been set to run at a slower speed but was not. The other negative saving pump operated three fewer hours for the baseline than the hours the pool was open and also the VSD runs throughout

[19] One was 1.65-hp pump and the other was a 2-hp pump.

[20] Note that the two largest pools in the plot had two pool pumps each. A 67,000 gallon pool had two single speed pumps replaced with one VSD pump, and is characterized in the plot as one 67,000 gallon pool. A 100,000 gallon pool had two single speed pumps replaced with two VSD pumps. This pool is plotted as two separate 50,000 gallon pools in the plot. This is done to plot all data on equal footing: each open circle represents the annual energy usage of one VSD pump, each red star shows the annual energy usage that is the baseline for one VSD pump, and the location on the horizontal axis shows the volume of water that is filtered by one VSD pump.

the night but at a very low (35%) speed. These constitute real situations that will be encountered during the implementation of an energy efficiency program and should be taken into account.

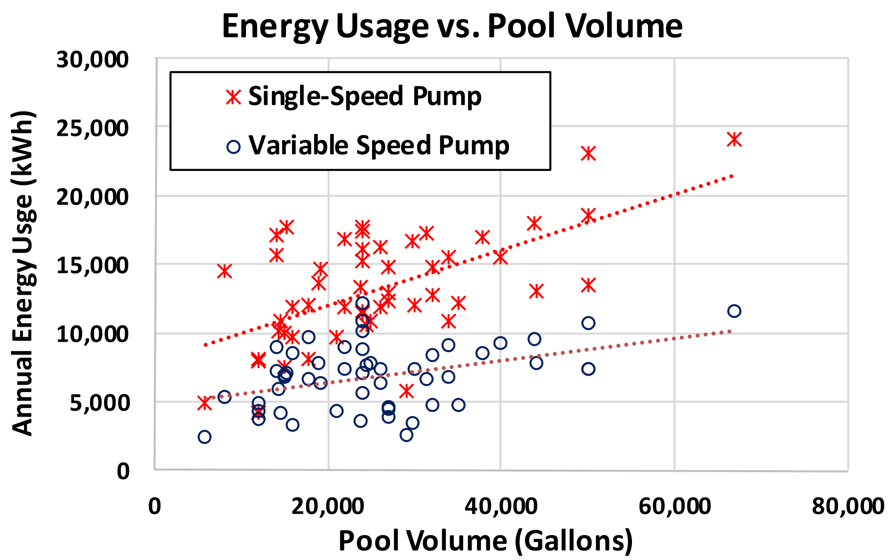

Figure 4-4 Pool Pump Energy Usage vs. Effective Pool Volume

Energy savings and demand reduction impacts are measured directly for the 51 pools in SCE service territory. A second row for SCE is provided in the table that shows the results if the two negative savings were excluded. Energy savings and demand reductions are also estimated for the pools in the type 2 data collection groups for SDG&E and SCG. Energy savings and demand reductions are estimated for the pools in the type 3 data collection group for PG&E. The average PG&E savings is below the SCE savings and is discussed in one of the following sections (4.2.4). The per pump energy savings and demand reductions are summarized in Table 4-3 and discussed below. The last row is the weighted average by number of pumps across all IOUs.

Table 4-3 Absolute and Relative Energy Savings and Demand Reduction per Pump by IOU

IOU	Energy Savings, kWh	Demand Reduction, kW	Energy Savings, %	Demand Reduction, %	Approach
SCE	6,408	0.58	48.5%	33.1%	Pre/Post with 52 Pumps (51 Pools)
SCE	6,709	0.60	49.7%	34.5%	Pre/Post with 50 "Commissioned" Pumps (49 Pools)
SDG&E	6,901	0.58	48.5%	31.7%	On-Site audits for 8 VSD and 17 SS Pumps, savings projected from SCE results
SCG	9,203	0.83	48.5%	37.0%	On-Site audits for 6 VSD Pumps, savings projected from SCE results
PG&E	3,051	0.59	34.0%	32.6%	One-time Pre/Post readings for 4 pools
Average	6,448	0.57	46.2%	31.5%	Weighted averages (using 52 SCE pumps)

4.2.1 Energy Savings Estimates for SCE

The distribution of energy savings for the 52 pumps included in the SCE retrofit isolation study is shown in Figure 4-5 below.

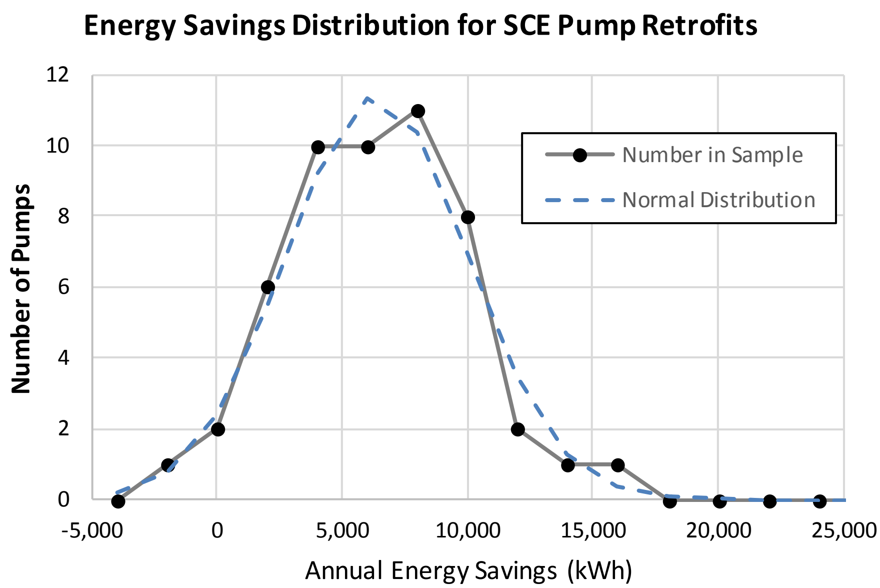

Figure 4-5 Energy Savings Distribution for 52 Pump Retrofits in SCE Service Territory

The distribution is fairly homogeneous, with a coefficient of variation of 0.57. If one were to use a single-point estimate for energy savings attributable to VSD pump retrofits in SCE service territory, the estimate would be 6,408 kWh ± 829 kWh per pump, where the second term represents the 90% confidence band around the estimate. The estimate would be slightly higher (6,697 kWh) if the estimated savings (discussed in the next section) for the six SCG pumps were combined with the 52 SCE measurements. Most of the SCG pools were actually participants in SCE's 2015 Multifamily Energy Efficiency Rebate Program. The energy savings would also be approximately 5% higher if the two retrofits that had negative energy savings were excluded from consideration. We note that the two retrofits with negative energy savings were included in the average because they were representative of SCE's Multifamily Energy Efficiency Rebate Program. The dashed profile in Figure 4-5 corresponds to a normal distribution with the mean and standard deviation of the 52 observations. A simple visual inspection reveals that the retrofits with savings below zero, or above 15,000, are not unexpected. These are naturally occurring within the program, On the other hand, two of the six retrofits from PG&E territory were excluded from analysis. Exclusion of the two PG&E sites is not motivated by statistical tests (the sample size of six was too small, and not normally distributed), but rather by the following considerations:

- For those two installations, the contractor needed to increase the pumping level in order to meet code requirements.

- With the small sample size in PG&E service territory, there is a greater need to address outliers or non-representative sites, since there are not enough projects from PG&E service territory to absorb the impacts of a non-representative site.
- The offering of the VSD pump at no cost may have enticed customers that may otherwise not had sufficient financial incentive to participate in the program. In other words, the significant customer co-pay in other service territories may naturally screen out customers (such as the two discarded retrofits for PG&E) that do not have significant savings potential for this measure.

Based on the trends apparent in Figure 4-4, it may be possible to devise a parametric, or "partially deemed" savings estimate based on pool volume. This may enhance accuracy, although in practice the pool volume is sometimes difficult to determine. We also investigated the possibility of devising a parametric savings estimation, based on the single speed pump nameplate horsepower. Figure 4-6 shows the average annual energy savings for five horsepower bins. It appears that there is not much utility in a parametric construction for baseline pumps in the one to two horsepower range. However, the energy savings for replacement of fractional horsepower pumps is significantly lower than average, while the savings for retrofits of three horsepower pumps were twice as high as the average energy savings.

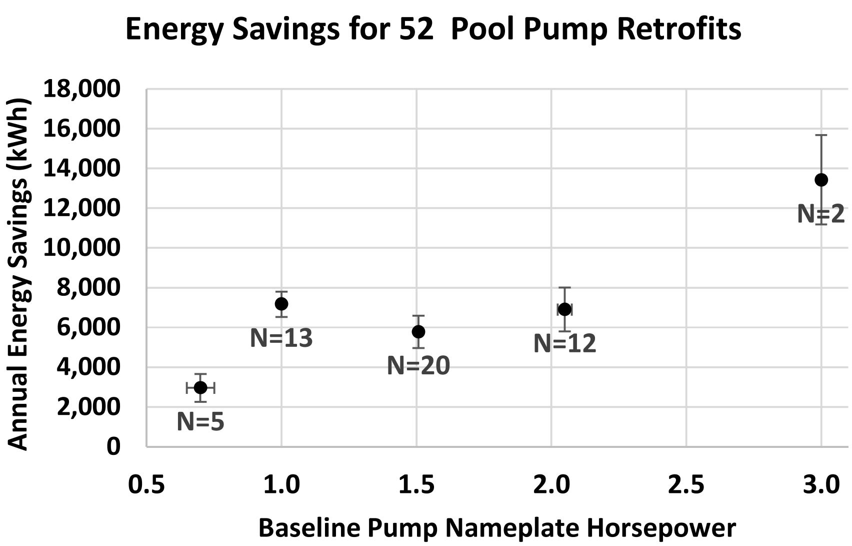

Figure 4-6. Annual Energy Savings vs. Baseline Nameplate Horsepower

4.2.2 Energy Savings Estimates from Type 2 Site Visits for SDG&E and SCG

In the Table 4-3, annual energy savings for single speed pumps from SDG&E are estimated as the product of the baseline pump's annual energy usage, and the relative savings of 48.5% as measured from 52 pre-post comparisons in SCE service territory, as summarized in

$$\text{Equation 4-1:} \quad Energy\ Savings_{VSD} = Energy_{SS} \times (\%\ Savings)_{SCE}$$

Where,

- $Energy\ Savings_{VSD}$ is the annual energy savings that has likely resulted from the upgrade of the single-speed pump to the VSD pump,
- $Energy_{SS}$ is the annual energy usage of the single speed pump, as determined by the Type 2 visit, and,
- $(\%\ Savings)_{SCE}$ is 48.5%, as determined through the 52 Type 1 measurements in SCE service territory.

The energy savings for VSD pumps in SDG&E and SCG service territories are estimated by the Equation 4-2:

$$\text{Equation 4-2:} \quad Energy\ Savings_{VSD} = Energy_{VSD} \times \frac{(\%\ Savings)_{SCE}}{(1-(\%\ Savings)_{SCE})}$$

Where,

- $Energy_{VSD}$ is the annual energy usage of the VSD pump, as determined by the Type 2 visit, and other terms occur in Equation 4-1and are defied above.

The energy savings for SDG&E service territory, then, are informed by site-specific data related to pump energy usage, but secondary data for the relative energy savings achievable by VSD pool pumps. ADM conducted several checks to verify that the above data imputation process is reasonable and appropriate. As a first check, the swimming pool volumes for SCE and SDG&E are not materially different. Noting that all five pools listed under SCG in Table 4-1 are also in SCE service territory, one can estimate the average pool volume in SCE service territory as 27,199 gallons ± 1,952 gallons, and he average pool volume in SDG&E service territory as 28,218 gallons ± 3,436 gallons. According to Table 4-2, the average baseline pump horsepower for SDG&E is 1.72, while the average baseline pump horsepower for SCE is lower, at 1.46. However, one can assume that if baseline pump horsepower were available for the six SCG pumps (all were VSDs), the average for SCE would increase somewhat, given that the five pools in the SCG sample were much larger than the average pool in the SCE sample. These considerations may imply that the potential energy savings in SDG&E service territory are similar to, or perhaps slightly higher, than the energy savings observed in SCE service territory.

As another check, we aggregated all single speed pumps into five horsepower bins and plotted for each bin the average annual energy use against the average horsepower. The SCE and SDG&E distributions were quite similar, and were well described by a single linear model, as shown in Figure 4-7.

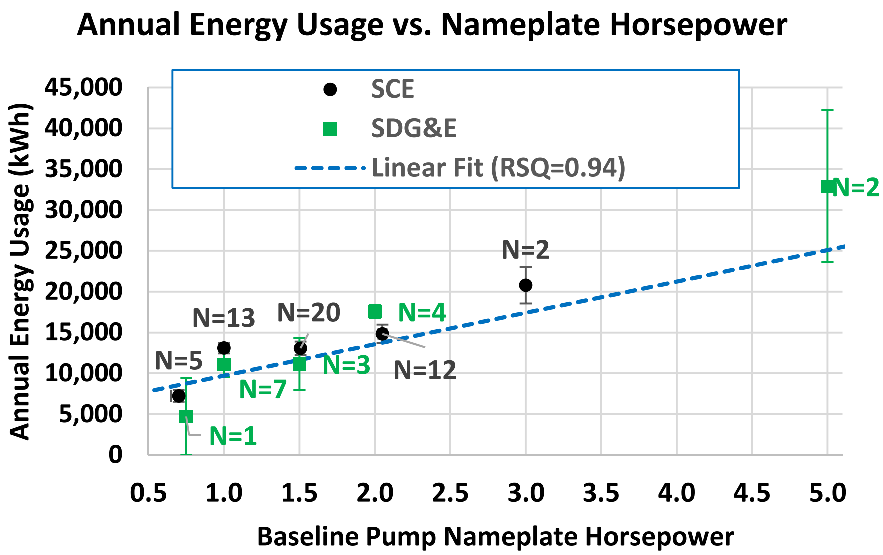

Figure 4-7 Annual Energy Usage against Baseline Nameplate Horsepower

As a final check, we confirmed that the relative energy saving (e.g., the 48.5% as measured from the 52 SCE retrofits) does not have a strong dependence on baseline horsepower. As such, the application of a single-point estimate is appropriate.

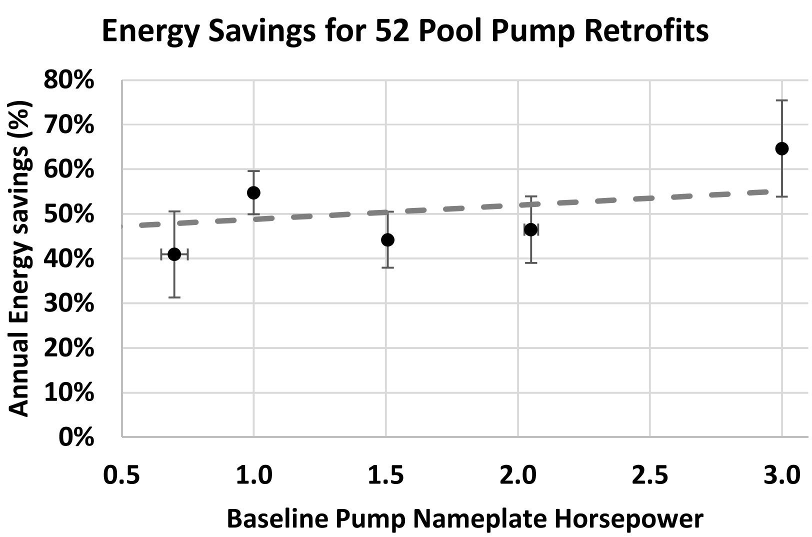

Figure 4-8. Relative Energy Savings versus Baseline Pump Horsepower

4.2.3 Energy Savings Estimates from Type 3 Site Visits for PG&E

There were four pools reported for the PG&E area that had baseline power measurements made and VSDs installed and additional power measurements made. Of the original six pools with VSD replacement, two pools were dropped from the analysis after it was determined that they did not meet code compliance for turnover rate of the baseline conditions. The analysis of the measurements shows that one of the remaining four had very low savings. If this site was initially visited as part of the recruitment and the pool equipment was audited for energy savings potential and code compliance, it may not have been selected. If a customer is required to cover some of the installation costs they will only want to participate if there will be a payback in a reasonable amount of time.

The primary reason for low savings for one site was that the water flow rate of the existing pump just barely met the flow rate necessary for the required turnover rate by code. A secondary reason was the pump only operated for the hours the pools was open for use or only slightly longer. Often the pumps are operated many additional hours than the pool is open for use and during those hours the pump speed can be reduced for significant savings.

4.2.4 Pool Pump Hourly Load Curves and Demand Reductions

Public pools are almost universally open during the day especially during peak period hours. This generates a load profile that is very flat during the day. Since the clock schedules are 24 hour, there is no weekday versus weekend distinction in the operation of the pool pumps. We also did not find any deviation between summer and winter operation hours or pump schedules for the SCE and SCG pools.

Figure 4-9 shows the average hourly load profile for single speed and variable speed pool pumps in SCE service territory across all the pumps, and also for six variable speed pumps in SCG service territory. Figure 4-10 shows the average hourly load profile for 17 single speed and eight variable speed pool pumps in SDG&E service territory. Figure 4-11 shows the average hourly load profile for the four PG&E pools. There is no operation of the pumps during many of the night time hours. These are hours where on average the pools in other service areas still operate. One explanation could be that the pool operators in the PG&E area are already conserving energy where they can with the existing time clock controls already on the system.

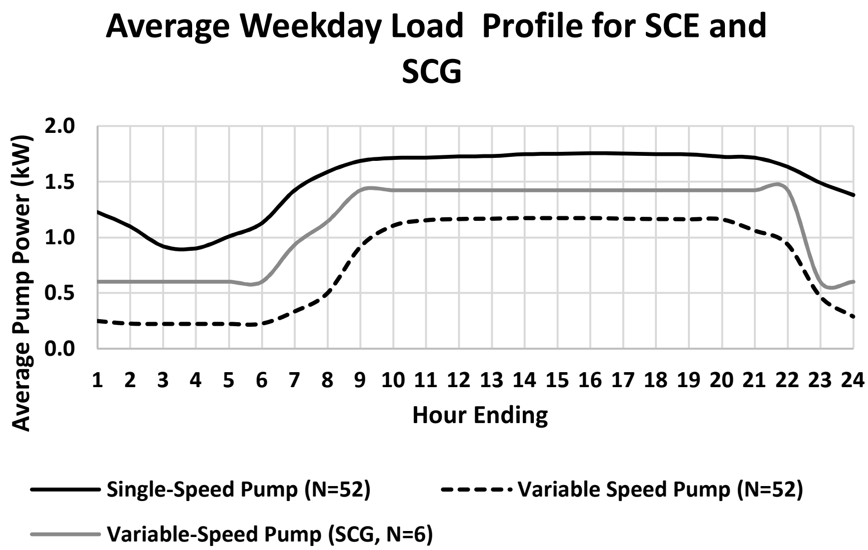

Figure 4-9 Average Weekday Pool Pump Load Profiles for SCE and SCG

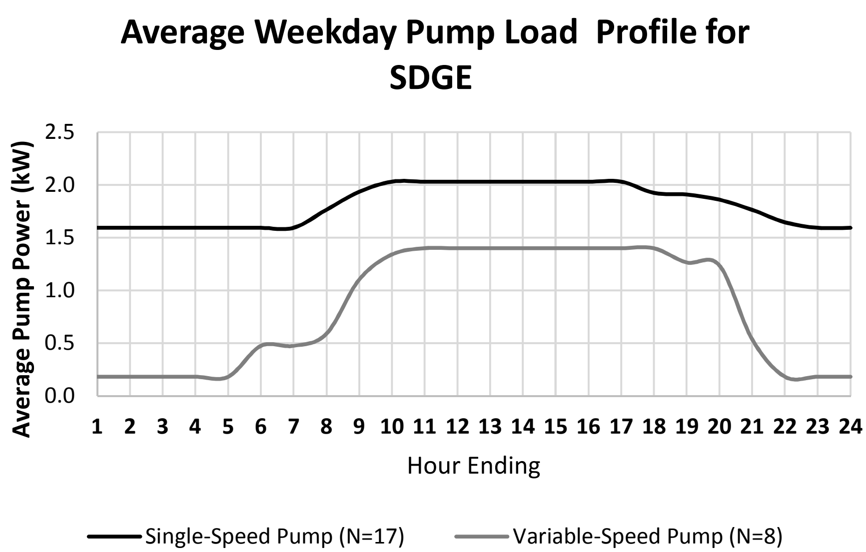

Figure 4-10 Average Weekday Pool Pump Load Profiles for SDG&E

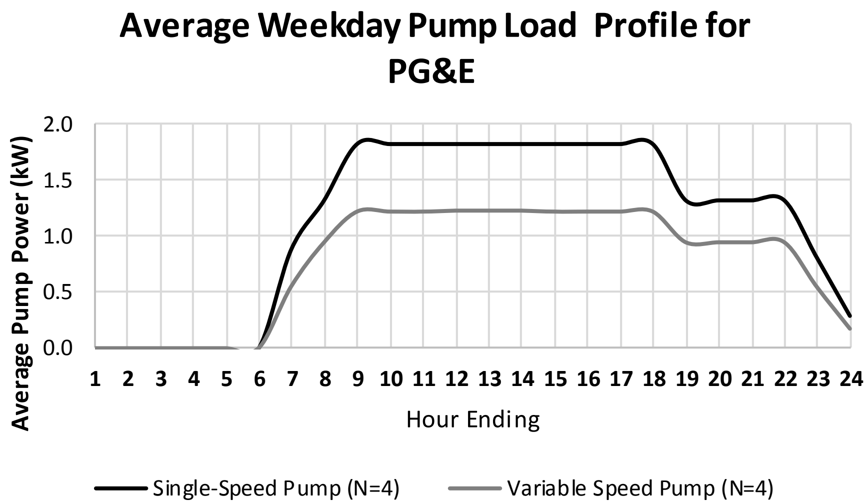

Figure 4-11 Average Weekday Pool Pump Load Profiles for PG&E

Demand reductions are defined as the average demand difference between single speed and VSD pumps during the period 2 PM to 5 PM on summer weekdays. For the 52 pump retrofits in SCE service territory, the demand reduction is measured directly. For the 25 pumps in SDG&E territory, the demand reductions are estimated in the fashion as described for annual energy usage, except at the hourly, rather than annual level. That is, Equation 4-1 and Equation 4-2 are applied, but instead of one value of the parameter $(\%\ Savings)_{SCE}$, there is a unique value for each hour of the day. This approach is not used to peak demand reductions for the six SCG pumps because the loads for the six SCG pumps differ significantly from the average for SCE. Presumably, this is attributable to statistical fluctuations associated with the small sample size. The SCG hourly savings are taken to be similar to the SCE savings, but are scaled to the larger average load for the six SCG pool pumps (0.83 kW for SCG vs. 0.58 kW for SCE and 0.58 kW for SDG&E). For the four PG&E pools the demand savings is calculated based on the summer weekdays period of 2 PM to 5 PM. The peak period demand savings is the average measured base load minus the average measured VSD load. For PG&E the average peak demand savings is 0.59 kW. The resulting energy savings curves are shown in Figure 4-12 below. The demand reductions attributable to pool pump retrofits are essentially constant from 10 AM to 6 PM (8 PM in southern California). The average savings for the PG&E pools is the same as the majority of the southern California pools during the middle of the day. The annual energy savings difference for the PG&E pools is mostly a result of the pool pumps being turned off at night for the baseline conditions and this does not allow any savings for the VSD to occur when the pool is not open.

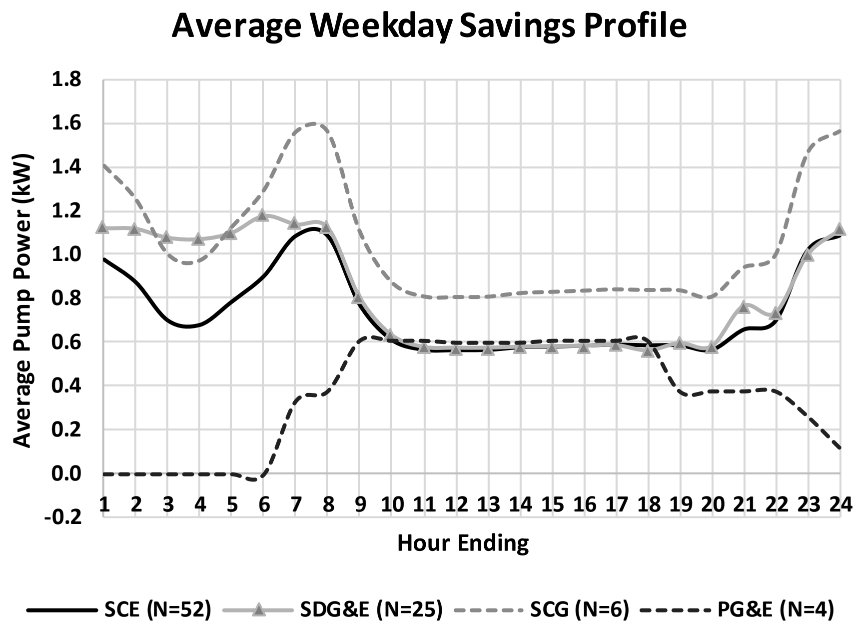

Figure 4-12 Energy Savings by Hour by IOU.

4.3 Pump Flow Data, Pool Turnover Time, and Turnovers per Day

Based on information gathered during our onsite visits, approximately one in three pools does not have a functional flow meter. Of the 52 SCE pool pumps, 34 had functioning flow meters in the baseline case, and 34 had functioning flow meters in the post-retrofit case. However, there was not 100% overlap between the two sets of 34 pool pumps; 28 had both pre-retrofit and post-retrofit flow available.

Based on the two sets of 34 pumps that had available flow data, we have determined that the average flow rate for single speed pumps is 63.3 Gallons Per Minute (GPM), while the average flow for variable speed pumps is 53.5 GPM in high mode, and 31.8 GPM in low mode. The average pool "turnover rate," or the time it takes to pump the entire pool volume, was 6.6 hours for the single-speed pumps, and 8.6 hours for the variable speed pumps. The average daily number of turnovers was 3.4 for the single speed pumps, and 2.8 for the variable speed pumps. Therefore, the pool pump retrofits yielded approximately 19% savings from a reduction of overall pumping work, and another 29% savings due to the efficiency enhancements associated with the variable speed pumps.

For the four PG&E pools, the average pool turnover rate, was 7.8 hours for the single-speed pumps and 8.2 hours for the VSD pumps.

4.4 VSD Power Characteristics

A sample of instantaneous power measurements made at various speed settings are plotted for all VSD pumps with two or more measurements in Figure 4-13. The chart is accumulative across SCE, SCG, and SDG&E service areas. Three different size (horsepower) motors are represented in the chart. The load motors experience is dependent on the system it is connected. A polynomial curve fit trend line is included in the plot for each pump motor for reference.

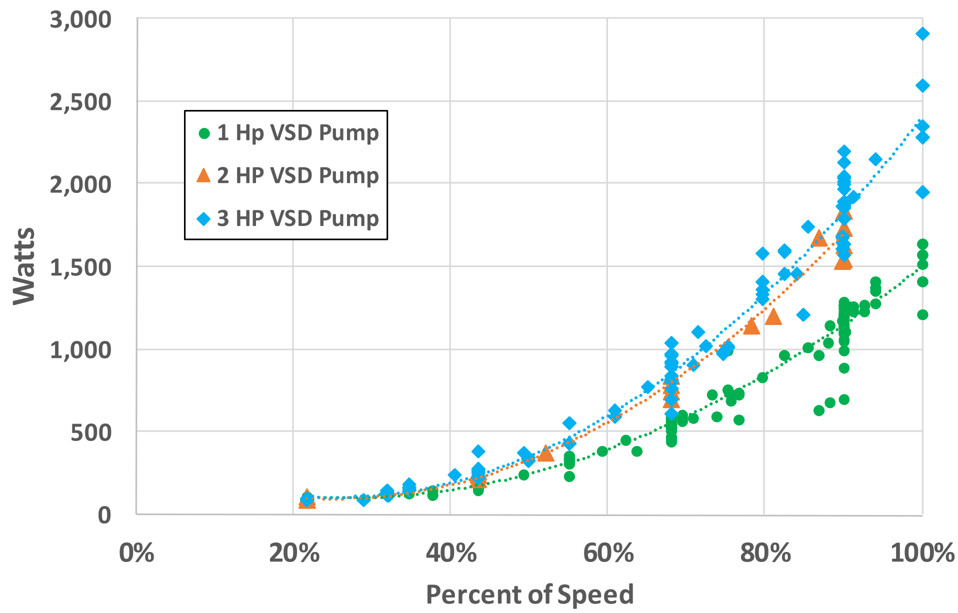

Figure 4-13 VSD Pump Power versus Percent Speed for 3 Motor Sizes

4.5 Pool Heaters

The majority, over 60%, of multi-family swimming pools, are not heated. Natural gas is used to heat from 22% to 33% of multi-family pools. Figure 4-14 shows the percentage distribution of pool heating by type and IOU. The SCE and SCG pools were combined since they are all served by SCG. Of those that are heated, less than 5% of the overall sample use solar thermal water heating. Some natural gas heaters are no longer used or have been decommissioned.

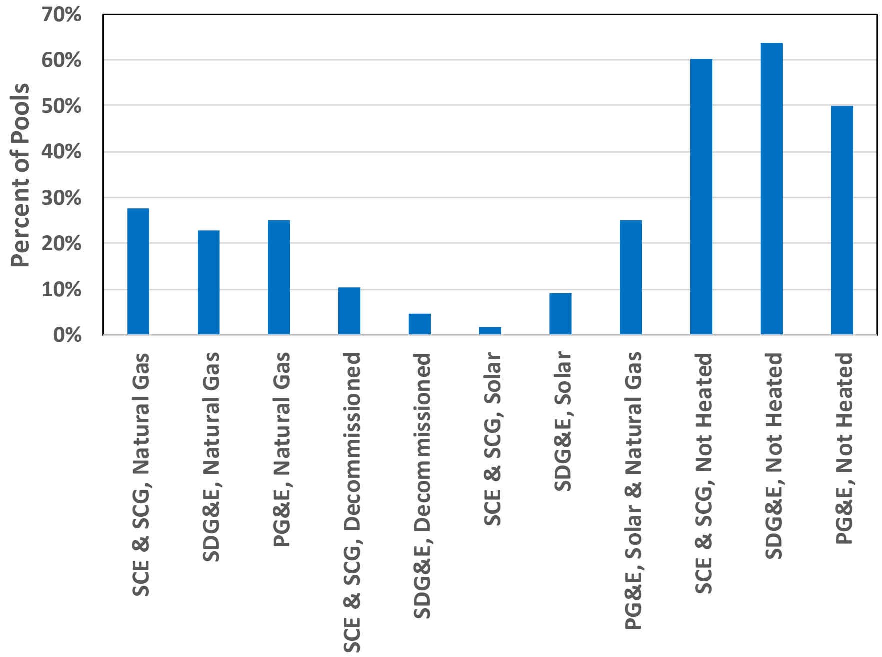

Figure 4-14 Multi-Family Pool Heater Type by IOU

The natural gas heaters that are used range in output size from 272 kBtu/hr to 811 kBtu/hr as shown in Table 4-4.

Table 4-4 Natural Gas Pool Heater Output Rating

IOU	***Average, BTU/hr***	***Min, BTU/hr***	***Max, BTU/hr***
SCE & SCG	354,293	272,650	405,000
SDG&E	410,162	272,650	811,800
PG&E	282,750	253,500	312,000

When pools are heated, the temperature set point ranges from 75 ºF to 87 ºF and is an average of 81 ºF. Of the pools that are heated, 70% are heated year round or at least have the ability to heat year round. Approximately 30% of the pool are only heated for about six of the winter months.

We do not expect any significant impact of pool heating as a result of installation of VSD pumps.

4.6 Pool Lighting

This section reports on the data collected for the pool lighting. One other area of pool energy use investigated was lighting. Both in-pool and around the pool lighting was documented to the best the information could be collected. Incandescent lighting is still the most common in-pool lighting used. However, SDG&E is making headway in LED lighting for pools. Annual lighting energy use was calculated based on rated wattage and hours of operation. Pool lighting is split between use of time clocks and photocells to control the operating hours for lighting. In our analysis, when photocells were used to control the lighting we based the operating hours on 4,100 hours per year. Pool or pool area lighting is not on during the day so there is no opportunity for peak demand savings. Lighting wattage was obtained from either, direct observation of the lamp, verbal inquiry of pool maintenance staff, or one-time power measurement of the lighting circuit. A table of the in-pool annual lighting energy use is provided in Table 4-5. Only a small percentage of pools had area lighting specific to the pools. Observations of non-working lamps were taken into account when developing the average wattage and energy use. On average the SCG pools were larger and therefore would require more lamp fixtures.

Table 4-5 In-Pool and Pool Area Lighting Average Wattage and Energy

IOU	Average In-Pool Lighting, Watts	Average Pool Area Lighting, Watts	Pool Lighting Hours	Annual In-Pool Lighting Energy Use, kWh	Annual Pool Area Lighting Energy Use, kWh
SCE	314	10	4,097	1,303	42
SCG	553	-	4,216	2,264	-
SDG&E	292	125	3,796	1,054	590
PG&E	620	100	4,013	2,263	547

A breakdown of the lighting audit information for in-pool and pool area lighting are provided in Table 4-6 and Table 4-7. Approximately 65 % of the pools have incandescent lighting in them whereas only about 18 % of the pools have LED lighting in them. The average incandescent lamp wattage ranges from 250 to 400 watts. The typical in-pool LED lamp has a wattage of 50 to 65 watts. NA in the tables signify that wattage was not available because there were no lamps in that category.

Table 4-6 In-Pool Lighting Types and Wattages

Description	Lamp Type	SCE	SCG	SDG&E	PG&E
Number of Pools in Sample with In-Pool Lighting	LED	3	1	10	1
	Incandescent	36	4	10	3
	Halogen	2	1	0	0
	HPS	2	0	0	0
	Other	7	0	1	0
Total Number of In-Pool Lamps in Sample	LED	4	1	37	4
	Incandescent	56	7	12	4
	Halogen	6	5	0	0
	HPS	3	0	0	0
	Other	7	0	1	0
Average In-Pool per Lamp Wattage	LED	52.7	65	50.6	170
	Incandescent	256	388	395	420
	Halogen	165	250	NA	NA
	HPS	384	NA	NA	NA
	Other	153	NA	250	NA

The following table is provided for completeness. It does not provide detail that are particularly useful other than to address the limited applicability of lighting measures to pool area lighting.

Table 4-7 Pool Area Lighting Types and Wattages

Description	Lamp Type	SCE	SCG	SDG&E	PG&E
Number of Pools in Sample with Pool Area Lighting	LED	1	0	3	0
	Incandescent	0	0	0	1
	Halogen	1	0	0	0
	HPS	0	0	0	0
	Other	2	1	1	0
Total Number of Pool Area Lamps in Sample	LED	1	0	108	0
	Incandescent	0	0	0	1
	Halogen	3	0	0	0
	HPS	0	0	0	0
	Other	4	6	4	0
Average Pool Area per Lamp Wattage	LED	NA	NA	25.7	NA
	Incandescent	NA	NA	NA	400
	Halogen	150	NA	NA	NA
	HPS	NA	NA	NA	NA
	Other	32	NA	11	NA

4.7 County Regulation Interviews

This section reports on the data collected through phone interviews from county regulatory agencies that enforce health codes for public pools.

Fourteen county health departments (see Table 4-8) were contacted by emails followed by phone calls in order to find the appropriate contact for in-depth interviews. Of the 14 selected counties in-depth interviews were completed by nine, one partial response, and four non-respondent counties. A non-respondent indicates that the county health department both did not respond to any email contact and failed to respond to at least six call attempts made at various times of the day. Each unsuccessful call attempt was left with a detailed message. Interviews were considered fully complete if the interviewee answered each of the questions. The length of each interview ranged from 30 to 60 minutes as the interviewees frequently expanded into details beyond the question prompt. A summary of interview responses, interviewee titles, and estimation of the size and scope of each county pool inspection program is in the table below.

Table 4-8 County Environment Health Departments Contacted for Survey

County	***Response***	***Title of Interviewee***	***Inspectors***	***Offices***	***Pools Inspected***	***Annual Inspection Frequency***
Alameda	No	-	-	-	-	-
Contra Costa	Yes	REHS[21]	20	1	1500-1600	Once per year, twice for year-round
Fresno	Yes	REHS	20	1	1300	Twice per year
Kern	Yes	REHS II	12	1 main, 3 aux	800 permits	Once per year
Los Angeles	Yes	REHS III	12	6 or 7	16000	1, 2, or 3 time per year by risk category
Orange	Partial	Plan Check Supervisor	-	-	Over 20000	-
Riverside	Yes	Lead Inspector, REHS IV	45	6	7600	Twice per year
San Bernardino	Yes	Supervisor	35	3	2800	Twice per year
San Diego	Yes	REHS III	40	2	not sure	Once per year required, twice allowed
San Francisco	No	-	-	-	-	-
San Mateo	Yes	REHS	12	1	1300	Twice per year
Santa Barbara	No	-	-	-	-	-
Santa Clara	No	-	-	-	-	-
Ventura	Yes	REHS, Pool Plan Check Specialist	18	2	1500	Goal of twice per year, once is required

The interviews focused on interpretation of Title 24 Building Standards Code and Title 22 Social Security Code as they pertain to the commissioning and inspection of public swimming pools utilizing energy and demand saving equipment or controls. Every respondent indicated that they were open to allowing energy and demand saving equipment or controls for the operation of public pool recirculation systems provided that the use of such equipment was not in direct conflict with public swimming pool code enforcement. Contra Costa and Los Angeles counties responded that the public health department actively encourages energy saving technology while the remaining counties held a more neutral stance typically responding that energy-saving equipment was "allowed but not encouraged."

[21] Registered Environmental Health Specialist.

Per Title 24, Section 3124B, the turnover time for public pools shall be six hours or less (8 hours or less for pools built prior to 1982). About a third (33%) of the interview responses indicated that they would not allow the flow rate of the recirculation system to vary during the hours that the pool is open to the public. Upon further questioning all recognized the provision in Title 22, Division 4, Chapter 20, section 65525 that states "the variation in the flow rate of an operating recirculation system shall be such as not to reduce the flow below 75% of the rate required in 3124B of Title 24." However, a few respondents indicated that this flow rate provision was intended to account for inefficiencies in the recirculation system, such as dirty filters, and not applicable to the use of energy-saving devices. Once respondent indicated that application of the 75% flow rate rule in such a manner would be a policy decision, not a technical decision.

When asked whether there were sections of the public pool code that could be open to more than one interpretation the answers varied. One-third (33%) of the respondents answered "No" while the remaining respondents indicated that yes, all codes have some interpretation involved in their application. Every county respondent indicated that they strive for consistency in code enforcement among all inspectors in the county. The respondent from San Diego County informed the interviewer that an annual meeting of the health departments from each county called the Recreational Health Advisory Committee occurs to discuss policy and standardize application of codes. This technical committee is split into two divisions, northern and southern California counties.

Each county respondent indicated that they had a uniform policy on pool recirculation system turnover and enforcement; however, that this enforcement only occurs during the plan check phase for new pool or new pool equipment commissioning. Further questioning for how turnover rate is enforced yielded a variety of answers. During plan check, the volume of the pool and sizing calculations for the recirculation are checked to ensure code compliance. During routine pool inspection inspectors will often not know the volume of the pool and typically will inspect to ensure that the recirculation equipment is in good working order. A common issue on inspection was a broken or stuck flow meter. Inspectors may perform rough calculations of pool volume to determine the six-hour turnover rate if needed.

All county respondents indicated that there are no special provisions for pool pump turnover during the electric utilities peak demand period, from 2 PM to 6 PM. The respondents were also consistent in their definition of the conditions that qualify a pool as "clear and disinfected." Clear means the pool bottom is visible to the inspector and disinfected means that the pool meets the required chemical levels on startup.

According to Title 24 code (section 3125.B.3) all public pools must have a flow meter installed which is capable of measuring the flow rate with accuracy within 10 % of actual flow. Two-thirds (66%) of the county respondents indicated that they will read the flow meter as absolute. One-third (33%) indicated that the 10% variation is allowable when inspecting the pool for required flow rate. Some further discussion on the subject of flow meters yielded a variety of insights. The respondent from San Bernardino County answered that the 10% variation in the code is simply the precision of the flow meter itself and is intended to be read as an absolute value. Many other responses indicated that the issue is often with an improperly installed or malfunctioning flow meter in which case the pool operator will be tasked with repairing the meter to be checked on a subsequent inspection.

All respondents answered that any change to the pool equipment will be subject to the code based on the year the pool was built unless the change to pool equipment entails change to the pool plumbing. Further questioning revealed that most pools build prior to 1982 used 2” diameter piping in their recirculation systems. Modern pools typically use 2.5” or 3” piping and therefore the flow velocity required to generate the required volumetric flow is much lower. Regarding the Virginia-Graeme Baker Act (VGB) and the related Assembly Bill 1020 (AB1020), all respondents indicated that all pools must comply with the maximum flow velocities set forth. However, per AB1020, a one-time check was mandated on all pools. Post implementation of AB1020, all pool equipment sold in California will comply with VGB. Any discrepancies will be caught in plan review.

When each county respondent was asked about records that list information about public pools all maintained that record do exist, but a formal records request is required to obtain anything. Upon further inquiry no county maintains a digital database of pool information that includes the size, in gallons, of each public pool. Most plan reviews are performed with hard copies of the documents and are stored for two years. At times attempts have been made to gather more complete records; however, the information gathered is typically incomplete.

Overall the counties showed consistency in their application of the Title 24 and Title 22 codes. Los Angeles County indicated that they have a specialized subdivision for pool inspections and maintains a county-specific list of approved equipment. The majority of the pools are multi-family residential pool and as the inspection of these pools is considered “low-risk” most of the inspection is subcontracted out. Some respondents indicated that most pool pumps are sized at approximately double the required size in order to meet the recirculation minimums and that there may be ample room for variable speed in typical applications without going below flow minimums. As mentioned earlier the Recreational Technical Advisory Committee (RecTAC) makes policy decisions regarding the inspection and commissioning of public pools. Each county health department receives guidance from RecTAC and RecTAC maintains contacts with policy-makers thus making RecTAC an excellent point of contact for further questions.

5. Conclusions

This study provides energy and demand savings results that are significant because it contains field data collected from more multi-family pools than any previous study in California. The original target number of sites for the study was based on pools. The savings analysis is conducted per pump. Large pools may use more than one pump for the water filtration system. The pre and post metering conducted for the SCE pools was crucial to establish reliable baseline and post installation data from which energy savings was calculated.

Analysis of the field data showed that the average energy savings for the SCE VSD pool pump is 6,408 kWh per pump. This is a 48.5 % energy savings. The savings is even higher when two negative saving pumps are excluded. This is shown in Table 5-1 which also summarizes the projected savings for the other IOUs using single site visits. The SCE VSD pool pump peak demand savings is 0.58 kW per pump which is a reduction of 33.1 %. Energy and demand savings developed for the single visit sites for SDG&E and SCG utilized savings characterizations from the SCE sites. The savings for the SCG pools is higher than the SCE sites while the PG&E pools have lower savings. The recruitment approach was different for the PG&E pools than for the SCE pools which may impact the comparative savings. The last row is the weighted average by number of pumps across all IOUs.

Table 5-1 Absolute and Relative Energy Savings and Demand Reduction per Pump by IOU

IOU	***Energy Savings, kWh***	***Demand Reduction, kW***	***Energy Savings, %***	***Demand Reduction, %***	***Approach***
SCE	6,408	0.58	48.5%	33.1%	Pre/Post with 52 Pumps (51 Pools)
SCE	6,709	0.60	49.7%	34.5%	Pre/Post with 50 "Commissioned" Pumps (49 Pools)
SDG&E	6,901	0.58	48.5%	31.7%	On-Site audits for 8 VSD and 17 SS Pumps, savings projected from SCE results
SCG	9,203	0.83	48.5%	37.0%	On-Site audits for 6 VSD Pumps, savings projected from SCE results
PG&E	3,051	0.59	34.0%	32.6%	One-time Pre/Post readings for 4 pools
Average	6,448	0.57	46.2%	31.5%	Weighted averages (using 52 SCE pumps)

The average demand savings during the day for the PG&E pools is approximately the same as the SCE and SDG&E pools. The annual energy savings difference for the PG&E pools is mostly a result of the pool pumps being turned off at night for the baseline conditions and this does not allow any savings for the VSD to occur when the pool is not open. The conclusion is that energy savings for installation of VSDs can be maximized by targeting pools that run the pumps a significant portion of the time the pools are closed. Any further research by PG&E into the characteristics of multi-family pools in their territory should include hours the pumps run and hours the pool is open.

The average multi-family pool size for SCE is 26,250 gallons. In the San Diego area, the average pool size is slightly higher at 28,210 gallons. The average pool size for the designated SCG sites was 37,200 gallons and for PG&E 28,467 gallons. All the SCE and SCG pools are located in congruent service areas and the average across all 58 pools is 27,199 gallons, which is close to the average for the SDG&E multi-family pools. The baseline single speed pumps ranged in horsepower from 0.5 hp to 5.0 hp. The average single speed pump for SCE is 1.46 horsepower (hp), 1.72 hp for the SDG&E sample, and 1.50 hp for the PG&E sample. New VSD pumps are larger and average 1.74 hp for SCE, 3.00 hp for SDG&E, and 2.85 hp for PG&E. For the SCG VSD pumps the average size is 1.33 hp which is smaller, even though the pool sizes are larger.

Flow data from the pool equipment was not consistently available and is subject to unknown accuracy, particularly at lower flow rates. However, for the data collected the average turnover rate was 6.6 hours for the single speed pumps and is 8.6 hours for the VSD pumps for the southern California pools. For the four PG&E pools, the average pool turnover rate was 7.8 hours for the single-speed and 8.2 hours for the VSD pumps. Proper commissioning of installed VSD pump should require a proper functioning flow meter and should even require an in-line flow meter that can accurately measure low flow rates that may be present when the VSD is programmed.

Natural gas pool heaters are in use in less than 30 % of the multi-family pools. Five to 10 % of the pools have natural gas pool heaters that are no longer in use. The average pool heater size has an output rating of 350 kBtu/hr for SCG, 410 kBtu/hr for SDG&E, and 282 kBtu/hr for PG&E. We do not expect any significant impact of pool heating as a result of installation of VSD pumps.

Approximately 65 % of the pools have incandescent lighting in them whereas only about 18 % of the pools have LED lighting in them. The average incandescent lamp wattage ranges from 250 to 400 watts. The typical in-pool LED lamp has a wattage of 50 to 65 watts. The annual in-pool lighting energy use ranged from 1,054 kWh for SDG&E to 2,264 kWh for the five pools designated as SCG sites. Significant energy savings can be achieved by replacing conventional in-pool lighting with LED lighting.

Interviews were conducted with 10 county environmental health departments that oversee the periodic inspections of public pools. Every respondent indicated that they were open to allowing energy and demand saving equipment or controls for the operation of public pool recirculation systems provided that the use of such equipment was not in direct conflict with public swimming pool code enforcement. When asked whether there were sections of the public pool code that could be open to more than one interpretation the answers varied. One-third of the respondents answered “No” while the remaining respondents indicated that yes, all codes have some interpretation involved in their application. Every county respondent indicated that they strive for consistency in code enforcement among all inspectors in the county. Despite striving for consistency, the field inspectors generally do not have the pool volume information with them nor calculate the turnover rate based on the flow meter reading. They tend to make the assumption that if the flowmeter shows flow the pump is providing sufficient flow for the required turnover because they are accustomed to single speed pumps which had to pass a plan check and building inspection when originally installed.

6. Appendix A

The on-site data collection form that was used is provided as an embedded document.

VSD PoolPump Form v5.docx

The county interview survey form that was used is provided as an embedded document.

County Health Department Intervie