Connected Pool Pump Market Assessment

INTERIM REPORT

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About Energy Solutions

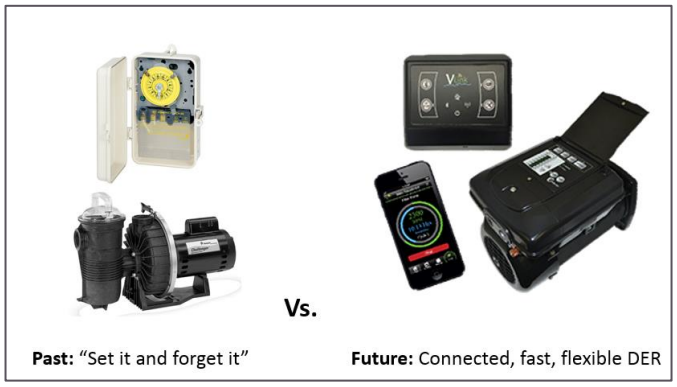
Energy Solutions is a mission-driven clean energy implementation firm that specializes in programs that align with the market to deliver significant resource impacts. For 25 years we've been pioneering end-to-end, market-driven solutions that deliver reliable, large-scale and cost-effective savings to our utility, government, and private sector clients across North America. Our passionate, smart employee-owners are committed to excellence and to building long-lasting, trusted relationships with our clients.

1. Introduction

Energy Solutions, under contract to Southern California Edison (SCE) has been issued a Consultant Work Assignment (CWA) for SCE's Emerging Markets and Technology (EM&T) program for the development and delivery of a Connected Pool Pump (CPP) Market Assessment to better understand the market potential for the flexible control of residential pool pumps. This report is an interim deliverable incorporating a literature review of previous pool pump demand response (DR) programs, an assessment of current pool manufacturer technologies, and a characterization of the pool pump supply chain. Also included is an estimation of the flexible resource potential of residential pools in SCE territory. The complete scope of work (SOW) also includes a field-testing component where equipment will be purchased, installed and tested at four residential pools in SCE territory. The final deliverable will be a completed market assessment report to be published in Q4 of 2020, including descriptions of field installations and next steps to realize the opportunity from connected pool pumps.

According to the U.S. Environmental Protection Agency (EPA) ENERGY STAR® program a "connected pool pump" must have smart grid functionality involving the capability to receive, interpret, and act upon certain types of control signals. Additionally, more consumer-oriented features must also be included, such as the ability to report energy consumption data, operational statuses, adjust pump/user settings, and transfer messages. This Market Assessment explores connected pool pumps extensively, however, it is important to understand that connected pool pumps build upon two decades of pool pump efficiency innovation, much of which occurred in California.

In the early 2000s, in response to the energy crisis, California utilities and the California Energy Commission (CEC) began exploring residential pool pump energy efficiency opportunities that ultimately resulted in the development of energy saving variable-speed pumps up to 4 horse-power (HP) for residential size pools. Since then, energy efficiency efforts throughout the country have moved much of the pool pump market from single-speed to variable-speed through incentive programs, state level efficiency standards, and a national pool pump efficiency standard set to take effect in on July 19, 2021. This new Department of Energy (DOE) national standard will effectively require all in-ground pool pumps over roughly 1 horsepower to be variable-speed, significantly expanding the number of variable-speed pool pumps nationally. Furthermore, in April 2020 the Energy Commission adopted complementary standards for replacement pool pump motors sold in CA that will require variable-speed capability for all replacement pool pump motors over 0.5 HP. National standards requiring variable-speed capability for replacement pool pump motors are currently under consideration at DOE.



Starting in 2016 as the national saturation of variable-speed pool pumps grew, many pool pump and replacement motor manufacturers began offering connected capabilities for their variable-speed pool pumps and motors where users can change motor speed, flow, turn on/ off, modify schedules, and control auxiliary loads instantaneously through a Wi-Fi or other remote connection, creating a significant opportunity for load flexibility.

Figure 1: Past and Future of Pool Pump Technology

This opportunity is significant in SCE territory as each residential in-ground pool may have up to 1.3 kW of year-round flexible load. There are an estimated 486,000 residential in-ground swimming pools in SCE territory and 1.2 million in California, each with at least one filtration pump between 1-4 HP (CEC 2009). With new connected capabilities now available on the market, in-ground variable-speed pool pumps alone (excluding above-ground pool pumps) have a significant opportunity to become a flexible distributed energy resource (DER) with up to 750 MW of technical potential in SCE territory.

The Market Assessment is divided into five activities summarized below, with this interim report documenting Activity 1, 2, and 3:

Activity 1: Literature Review. Numerous technology assessments, field demonstrations and other published studies are reviewed and summarized in this activity. Additionally, the limited existing DR programs for pool pumps in the U.S. are reviewed and summarized.

Activity 2: Technology Review. In this activity market available pool pump products with connected technology are reviewed and their capabilities compared. Between 2016 and 2018, most major pool pump and pool pump motor manufacturers introduced connected capabilities their variable-speed pool pumps, allowing homeowners, pool contractors, pool service companies, and/or manufacturers to change motor speed, flow, turn on/off, modify schedules, and control auxiliary loads through a Wi-Fi or other remote connection.

Activity 3: Supply Chain and Market Potential. This activity quantifies pool pump equipment stock and shipments, distribution channels, and other market factors unique to the Southern California pool market. Additionally, based on upcoming DOE standards and other available data, this review discusses the connected DR potential, use cases, business models for deployment and utility intervention strategies. The flexible demand technical potential for common backyard in-ground pool pumps is large, at nearly 750 MW in SCE territory. However, realizing this potential is a function of appropriate market interventions and consumer protections to create a strong value proposition to customers and other market actors in the supply chain.

Activity 4: Technology Demonstration. This activity is ongoing as of publication of this interim report. In September 2020, four SCE residential customers had connected pool pumps installed to prepare for technology demonstration. SCE will soon grant access to a research team at the Electric Power Research Institute (EPRI) to remotely test various DR use cases.

Activity 5: Final Report will integrate all project tasks into a summary document and will recommend next steps for SCE to consider in its development of new residential DR programs that may include additional research or pilot programs for connected pool pumps. The final report will build on this interim report and will be available in Q4 2020.

2. Literature Review

This literature review has examined the publicly available pool pump DR emerging technology studies, active pool pump DR programs, and pilot programs using pool pumps as a flexible resource in California, the United States and internationally. The purpose is to analyze previous and current efforts in this field to help inform how new connected variable-speed pool pumps can create a significant year-round, flexible load resource for SCE. This activity has focused on lessons learned regarding tested communication protocols, connectivity issues, customer acceptance, and flexible load capacity.

Demand Response Pool Pump Emerging Technology Studies

Since 2008 SCE and San Diego Gas & Electric (SDG&E) have sponsored four emerging technology studies examining various aspects of DR related to pool pumps. These four studies are briefly summarized below. One key finding is that the efforts to date have not researched pool pumps to utilize excess supply on the grid, only to shed load. A fifth study completed in 2018 and conducted by the National Renewable Energy Laboratory tested pool pumps, among other products, in a laboratory setting and did explore the potential to employ pool pumps for excess supply.

Pool Pump Demand Response Potential, Demand and Run-Time Monitored Data

Sponsored by: Southern California Edison
Prepared by: SCE Design & Engineering Services, Customer Service Business Unit
Published: June 2008
Location: Across SCE Service Territory: Coastal, Inland Valley, and Desert

This study sponsored by SCE was published in 2008 and focused on the load shed potential of pool pumps in SCE territory (SCE 2008). To start, a random selection of 500 SCE territory single family residences (SFRs) with pools were called to participate in a phone survey. The 500 participants surveyed provided their feedback on the potential of a pool pump DR program with 362 reporting their pool operating hours. Of the original 500, 152 ultimately participated in a site survey where a survey representative visited the SFR to take measurements, resulting in pool pump load profiles among other information. Of those 152, 146 SFRs agreed to allow site monitoring of their pool pumps for at least one full week between January and March 2008.

To assess the load shed potential of pool pumps, the study focused on two primary aspects: 1) pump availability, or what hours pool pumps operate, and 2) the kW load available during those hours. Respondents estimated their pool pump operating hours over the phone and actual operating hours were measured for those SFRs that agreed to site monitoring. The results focused on the site-monitored data as this measured data was considered more reliable than phone survey results. The site-monitored data of the 146 homes found average pool pump operation of 5.2 hours per day with the majority of this operation occurring during the hours of 10 AM and 2 PM. Also, monitored inland sites (46 SFRs) showed a significant load during the hours of 8 PM to 10 PM. Figure 2 shows the average availability

across all SCE regions (coastal, inland valley, and desert) as well as the average pool pump power demand (kW) of the 146 monitored pool pumps. Pump availability was monitored for at least one week at each SFR between January and March 2008, and when operating, pumps averaged 1.4 kW.

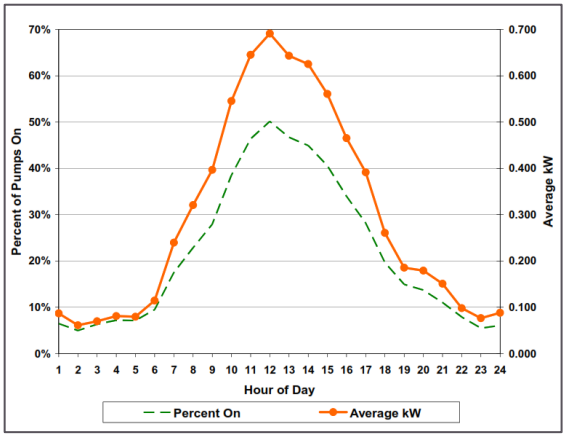


Figure 2: Each kW data point refers to the hour that precedes that hour, e.g. 5pm is the kW load between 4:00 PM and 4:59 PM.

Source: (SCE 2008)

This measured data was compared to baseline operation data collected by SCE for the Summer Initiative Pool Pump Program in 2001. On average, the pool pump load increased during the window of peak demand as shown in Table 1.

Table 1: Average kW across different operating windows.

Window	Window Description	2008 Average kW	2001 Average kW	% Change
12pm - 6pm	Report Discussed Peak	0.49	0.44	12%

Source: (SCE 2008)

To determine the overall DR potential for pool pumps in SCE territory four factors were multiplied: 1) the number of pool pumps in SCE's service territory, 2) the percentage of pool pumps operating during each hour, 3) the estimated operating pool pump demand and 4) the likelihood of DR program participation from survey data. The results of these inputs represented a likely DR load shed potential of 174 MWs.

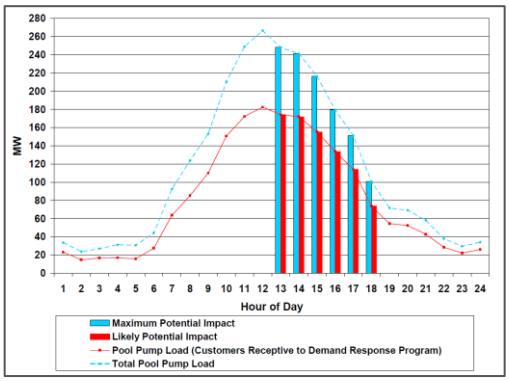


Figure 3: Potential impacts of pool pump DR program.

Source: (SCE 2008)

Demand Response Enabled Pool Pump Analysis

Sponsored by: San Diego Gas & Electric
Prepared by: NegaWatt Consulting
Published: November 2013
Location: SDG&E Service Territory

This report, Demand Response Enabled Pool Pump Analysis, sponsored by SDG&E, describes a study of ten SFRs and explores viability of pool pumps for DR (SDG&E, Negawatt, et al. 2013). The focus of this case study is on the technological viability itself, with some additional information on customer acceptance and energy monitoring.

This study replaced single speed pumps at ten SFRs in SDG&E territory with variable-speed pumps capable of responding to an Automated Demand Response (ADR) signal. At the time of this study, only one pool pump, the Pentair IntelliFlo variable-speed pump offered such capabilities. As a result, the Pentair Intelliflo pump was selected as the measure case pump for all ten SFRs. The baseline average pump capacity was 1.69 kW (2.25 HP), and ran for 5.7 hours per day. The replacement of the single speed pumps with the Pentair Intelliflo pump resulted in a significant energy reduction based on a more efficient motor and variable (lower) speed operation. By right-sizing and setting the pumps to run an average of 7.8 hours per day, including an average of 2.3 hours for high speed cleaning, an average energy savings of 52 percent was achieved as illustrated below.

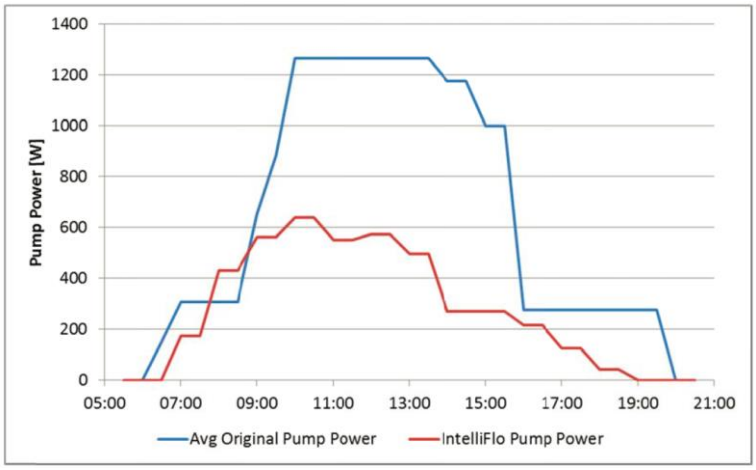


Figure 4: Single-speed and variable-speed retrofit average pump power for 10 SFR.
Source: (SDG&E, Negawatt, et al. 2013)

After accounting for the energy savings, a theoretical DR event was evaluated between the hours of 11am and 6pm. The DR potential was calculated by subtracting the expected usage from the pool pump schedules from the programmed DR measure, dropping to a very low speed during the event hours. The expected energy use and DR measure energy use was found from monitoring equipment directly connected to the pool pumps. Under this measure, for a 7-hour event lasting between the hours of 11am and 6pm, an average demand reduction of 273 watts would be expected as shown below. The expected load shed is based on scheduling and previously measured load, not an actual demand response event.

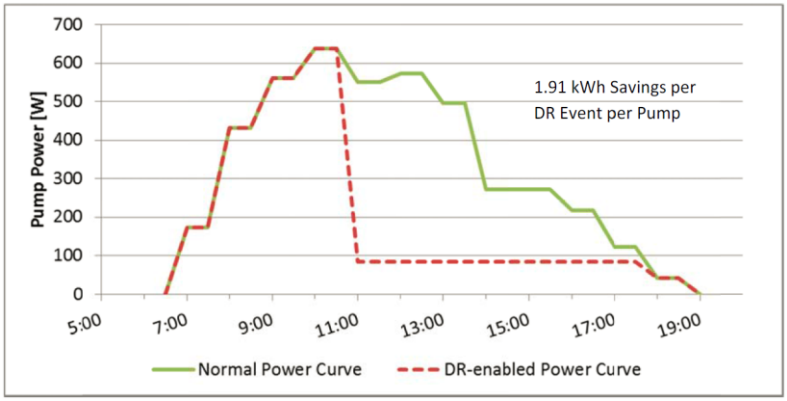


Figure 5: DR event load shed post-variable speed pump retrofits.

Source: (SDG&E, Negawatt, et al. 2013)

In this study, the measure case Pentair Intelliflo pool pump was estimated at a cost of $500 without installation. The entire installation, including the pool pump, replumbing to correctly size the piping as was needed in this study, DR controller, installation, and commissioning was $2,300. This cost represents situations where replumbing was necessary.

Overall, the participants who responded to a follow up survey (7 of 10) after the theoretical DR event were happy with the operation of their Pentair Intelliflo pool pump. Additionally, before the case study, most participants were not familiar with DR, but all responders indicated that they would be happy to participate in a DR program in return for an equipment incentive or a reduced utility rate. One participant who had historically been reluctant to participate in DR with their HVAC responded to the survey stating a pool pump DR measure was a great idea, as it would not impact their comfort and they would be happy to participate.

Demand Response Ready Pool Pumps for Residential Retrofit Using ZigBee/Wi-Fi

Sponsored by: Southern California Edison
Prepared by: SCE Emerging Products, CP&S, Customer Service Business Unit
Published: February 2015
Location: SCE Service Territory

This study, Demand Response Ready Pool Pumps for Residential Retrofit Using ZigBee/Wi-Fi, sponsored by SCE, evaluated the operation and capabilities of DR controllers applied to single speed residential pool pumps using ZigBee as the communication link between the SCE smart meter and the gateway (SCE 2015). Two different pool pump retrofit systems were used to enable ADR at four SFRs with single speed pool pumps from late 2013 through late 2015. The purpose of the study was to evaluate the retrofit controller's ability to respond to an ADR signal and the resulting pre-, event, and post-event pump electrical load.

The two controller retrofit systems used on the single speed pumps at the four SFRs are referred to as "system 1" and "system 2." Both consisted of a communication gateway to enable ADR signaling and a load controller to turn the pump on-and-off in response to the ADR event signal. Installation, commissioning, and testing were conducted using system 1 before replacing each with system 2 at each SFR. Two of the participating SFRs removed themselves from the study prior to the installation of

system 2 due to pump controller issues. These issues arose due to ZigBee communication problems, resulting in difficulties maintaining pump control and operation schedules.

For both system 1 and 2, the gateway, which receives the ADR signal and passes along the event information to the load controller, was connected directly to the router through an ethernet cable offering a stable connection. The load controller communicated with the gateway through ZigBee. For system 1, the gateway to load controller communication spawned numerous control issues, including uncontrolled on-and-off pump operation and the inability to return to normal operation after a mock DR test. Numerous troubleshooting measures were introduced: firmware updates, range extenders, and powerline carrier installations, but the communication issues were never fully resolved, and commissioning was abandoned in favor of a system 2 installation.

However, similar issues arose with system 2 for the two SFRs that remained in the study. Due to this communication issue, further commissioning efforts for system 2 were abandoned and the study was concluded.

Residential Pool Pump Real Time Demand Response Pilot using FM Radio

Sponsored by: San Diego Gas & Electric
Prepared by: MelRok
Published: February 2016
Location: SDG&E Territory

This study, sponsored by SDG&E, demonstrated the use of FM radio technology to signal DR events to pool pumps (SDG&E and Melrok 2016). The signaling and receiving technology were specific to the company MelRok, who also conducted the study. The capabilities of this technology and the magnitude of load shed was measured in real-time.

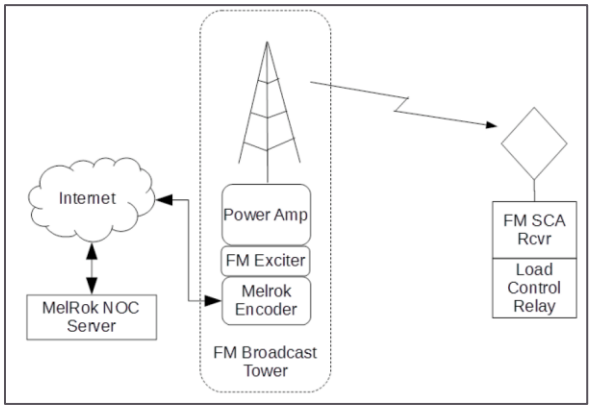


Figure 6: Melrok FM Load Control System.
Source: (SDG&E and Melrok 2016)

Twenty-two SFRs were chosen to participate in the study and had Melrok FM receivers and relay controlling equipment (a light version of the MelRok Touch) installed on their pool pumps. Energy monitoring was established through smart meter reading equipment that was transmitted to MelRok, as well as sub-metering at some SFRs. Of those SFRs surveyed, the site-specific pump details of 20 SFRs were provided in the report. These sites were chosen from homeowner associations approached by the

study implementors as well as homeowners with previous relationships with the study implementors. These SFRs represented a good mix of single and variable-speed pumps.

- Eight variable-speed pumps with an average nameplate size of 2.6 HP (ranging from 2.5-3 HP) operated for an average of 7.7 hours in houses with an average size of 3,571 ft^2 and an average pool size of 23,226 gallons.
- 12 single speed pumps with an average nameplate size of 1.5 HP (ranging from 1-2 HP) operated for an average of 6.4 hours in houses with an average size of 3,620 ft^2 and an average pool size of 22,489 gallons.

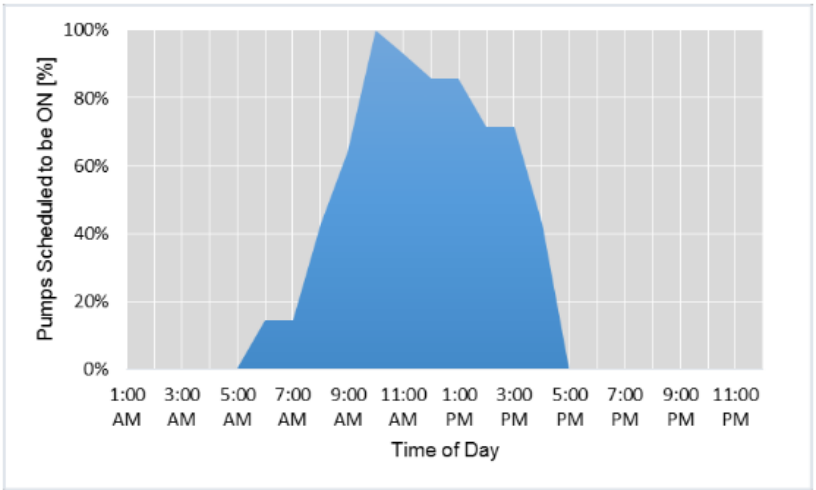


Figure 7: Pool pump availability of the 22 SFRs.

Source: (SDG&E and Melrok 2016)

To test for DR signal receipt and kW potential MelRock initiated a two-week testing period in which the pool pumps were automatically cycled off for 10-minute intervals at the start of every hour during regularly scheduled pumping as shown in Figure 8.

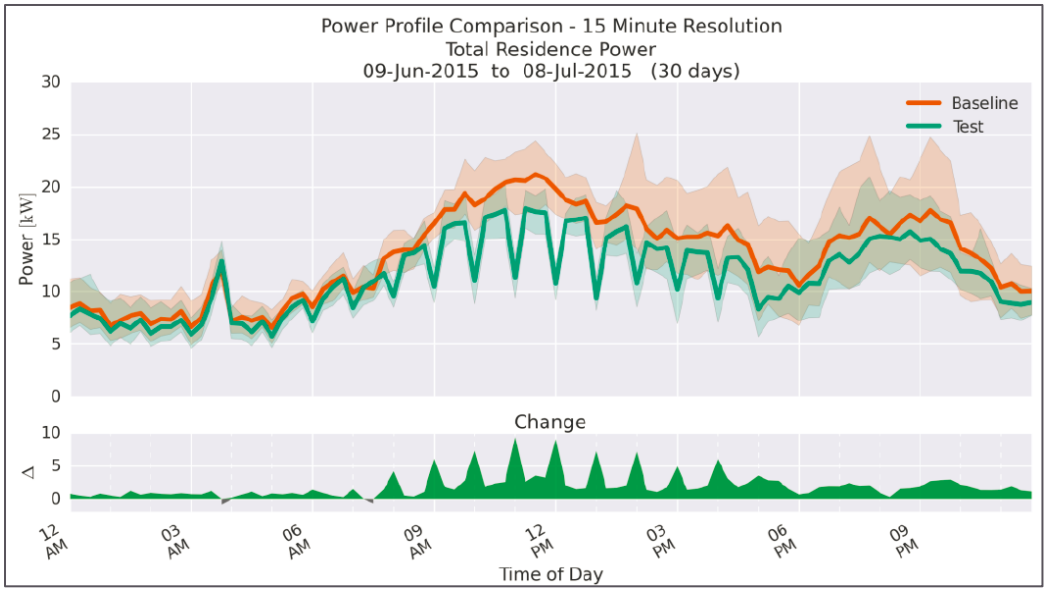


Figure 8: Utility smart meter data example during testing.

Source: (SDG&E and Melrok 2016)

Table 2: Nameplate ratings and measured loads for seven participants.

Source: (SDG&E and Melrok 2016)

Pump Speed Type	Nameplate (kW)	Average Operating Load (kW)	Operating vs Nameplate Load
Variable	2.25	0.75	33%
Variable	1.86	1.30	70%
Single	0.75	1.7	227%
Single	1.12	1.6	143%
Single	1.5	2.05	137%
Single	0.75	1	133%
Single	0.75	1.85	247%

Cohesive Application of Standards-Based Connected Devices to Enable Clean Energy Technologies

Sponsored by: National Renewable Energy Laboratory (NREL)
Prepared by: National Renewable Energy Laboratory/ Electric Power Research Institute
Published: February 2018
Location: Golden, CO

The Electric Power Research Institute (EPRI) and a team of partners were selected by NREL to carry out a project that developed and tested means by which smart, connected consumer devices could act to enable the use of higher penetration of clean energy in the electric power grid. This involved testing five different products integrated with CTA-2045 modular communication standards, including the Pentair pool pump with an Intelliconnect controller as shown below.

Figure 9: Pentair Intelliflo pool pump with CTA-2045 modular communication standard.

Source: (NREL 2018)

The testing focused on how connected devices could help mitigate relevant grid issues. The grid issues in question and associated connected product actions, specific to pool pumps, are listed in Table 3.

Table 3: Identified grid issues and pool pump actions.

Source: (NREL 2018)

Grid Issue	Summary of Pool Pump Actions
Residential Transformer Loading	• Scheduled operation • Increase consumption during periods of need • Monitoring real power level
Customer/Secondary Overvoltage	• Increase consumption by variably increasing the pump speed as needed
Bulk System Over Generation	• Reduce circulation rate prior to the period of excess generation • Heighten circulation during the period of excess generation • Scheduled operation to pump during the known/predictable over-generation period • Monitoring of the pool pumps' remaining ability to use/take energy (e.g. per the daily schedule)
Bulk System Generation Fast Ramping	• Scheduled operation to avoid or reduce operation in the 5-8 PM period as renewable generation is dropping • Dispatched operation to increase consumption (before mid-ramp) and reduce consumption (following mid-ramp).
Excess Renewable Generation	• Monitoring of present real power level. • Monitoring of present ability to use energy based on the scheduled daily circulation plan • Dispatched increase in energy consumption to heighten circulation during periods of excess renewables *Note*: Fixed scheduling not deemed useful due to non-predictability of events.

Additionally, laboratory testing was conducted on pool pumps, along with the other CTA-2045 compatible devices in this study. The intelligence of the Pentair pool pump system was highlighted as the logic is designed to ensure pool daily circulation requirements are met and not exceeded during various demand response events. Specifically, it was highlighted that the pool pump controller kept track of its activity so that:

- *"If requested to run earlier than scheduled, it would do so, but would finish earlier in the day so as not to perform unnecessary circulation*
- *If requested to curtail operation or delay, it would do so, but would run when it became necessary to ensure that it could complete its daily circulation*
- *If requested to run at a higher power level, it would speed up accordingly, but would complete its daily work earlier as a result*
- *If requested to run at a lower power level, it would slow accordingly, but would run longer in the day as needed to finish its daily circulation"*

The benefit of this type of smart response, in contrast to a conventional load-control switch, is that the utility or other entity managing the DR program can make full and aggressive use of the load resource without concern that their actions will result in unsafe or unsatisfactory behavior of the end device. The end result is then a significantly greater value and utilization of the load resource because they do not have to err on the side of caution." (NREL 2018)

Figure 10 and Figure 11 below show the smart responses graphically as presented in the report.

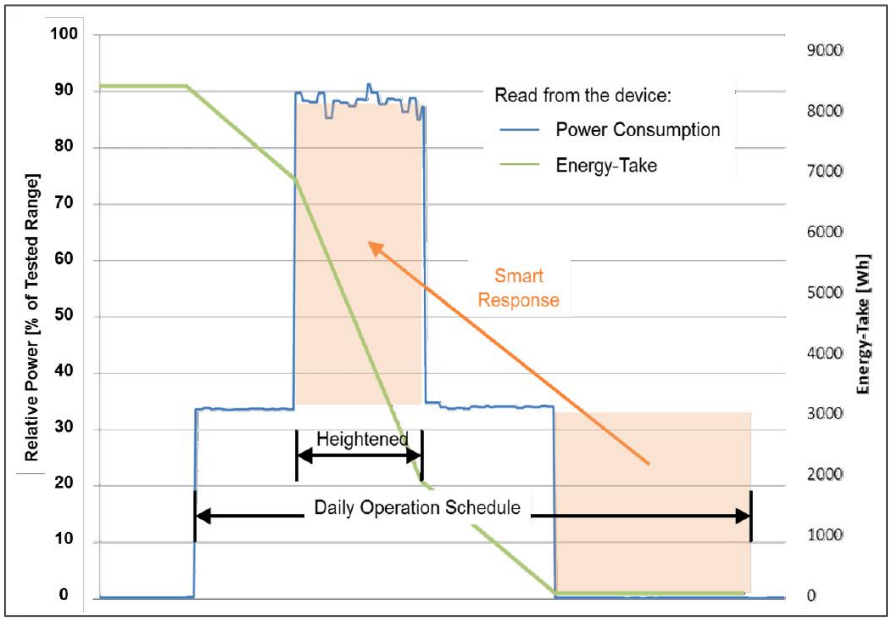


Figure 10: CTA-2045 smart "load up" response with Pentair pool pump.

Source: (NREL 2018)

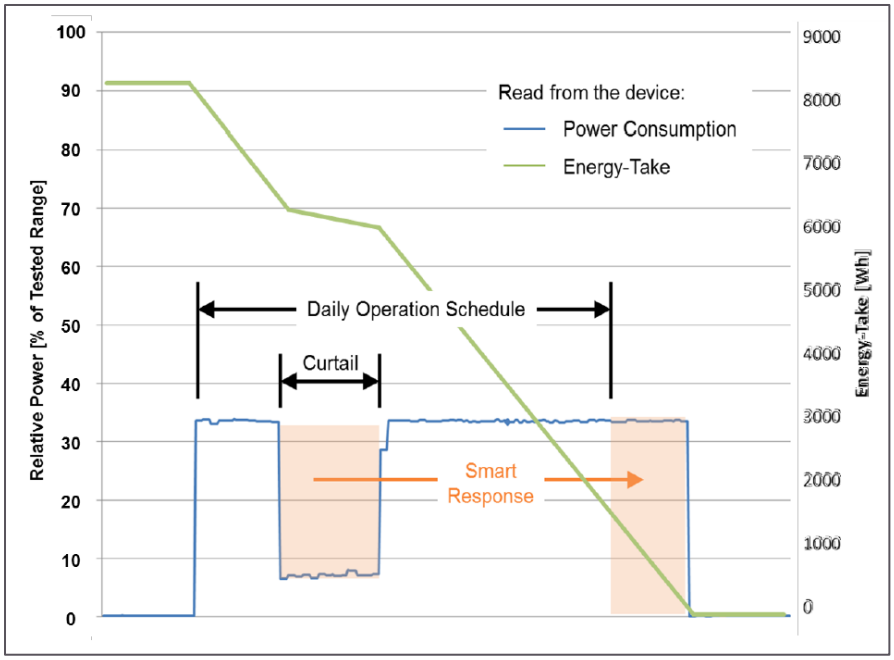


Figure 11: CTA-2045 smart "shed" response with Pentair pool pump.

Source: (NREL 2018)

Finally, the unique ability of pool pumps to "load up" was highlighted in the report as a unique attribute for pool pumps to absorb renewable energy.

> *"it was noted that the ability to increase consumption (speeding up) is particularly useful in relation to enabling the integration of renewables. The normal behavior of the pump controller is to optimize efficiency, which results in operation at a lower speed for longer periods of time, with normal power consumption of only a few hundred watts. But as indicated in the variable test results…the unit can be variably adjusted upward."* (NREL 2018)

Pool Pump Demand Management Programs

Pool pumps have been used in demand response and load management for many years, most prominently in Florida which, behind California, has the largest pool market in the country with 1.03 million in-ground pools as of 2015 (Pkdata 2015). In Florida, both Duke and Florida Power & Light (FPL) have ongoing direct load control incentives for pool owners.

Duke Energy (Florida) Direct Load Control: EnergyWise Home

Duke Energy offers monthly residential bill credits for allowing direct load control of up to four different household electric appliances: water heaters, heating, cooling and pool pumps. Allowing the EnergyWise Home program to install a direct load controller on a residential pool pump could lead to a bill credit up to $2.50 per month or $30 per year. Events can be called year-round and can last up to 5 hours. During events pool pumps are controlled to operate at least 5 minutes per hour. This ensures that during winter peak events, water in pipes is not subject to freezing. According to EnergyWise Home, pool pumps are the second resource called during events, after water heaters, but before electric heating and cooling.

Duke Energy launched their pool pump demand management program in 1982. Typically, events are called for system peak demand management purposes in the winter between 6 AM and 11 AM, and 6 PM and 11 PM. The peak hours in the summer are between 1 PM and 11 PM. Variable-speed, two-speed and single speed pumps are currently eligible for participation in the EnergyWise program, though most pumps are single-speed (Duke Florida 2018).

How long are the cycles?

Options*	Timing of cycles**		Potential for cycles
Water heater	Up to five hours during a period of peak energy demand		Year-round
Pool pump			Year-round
Heating***	Up to 16.5 minutes out of each 30-minute period	Between 6 and 11 a.m. and/or 6 and 11 p.m.	November-March
Cooling		Between 1 and 11 p.m.	April-October

*During an event, water heaters and pool pumps are cycled first. Central heating and cooling units are the last to be cycled off and are rarely affected by the event at all.

**Devices may be cycled off outside peak usage periods during an extremely rare system emergency.

***For heat pump customers: Cycles may affect heat pump backup heat strips continuously during peak usage periods, not to exceed 300 minutes, but the heat pump itself will not be affected.

Figure 12: Duke Florida's EnergyWise Home event cycle times.

Source: (Duke Florida 2018)

Year-round Program

Options	Monthly savings potential*	Annual savings potential*
Heating	$8	$40
Cooling	$5	$35
Pool pump**	$2.50	$30
Water heater**	$3.50	$42
TOTAL ANNUAL SAVINGS OPPORTUNITY		**$147**

*Credits prorated according to use over 600 kilowatt-hours (kWh) per month. Monthly credit may vary based on equipment compatibility and number of appliances enrolled.

** Optional for year-round participants.

Figure 13: Duke Florida bill credit for EnergyWise Home participation.

Source: (Duke Florida 2018)

Florida Power & Light Direct Load Control: Residential On Call

Residential in-ground pool owners in FPL service territory can receive up to $3/ month or $36 per year to participate in FPL's "Residential On Call" program. When events are called, pool pumps can be turned off by FPL for up to four hours from a direct load controller as shown below.

Figure 14: FPL On Call Controller.

Source: https://www.artplumbingandac.com/the-house-whisperer/ive-got-the-power/

APPLIANCE	SEASON	ANNUAL SAVINGS
Central air conditioner	April - October	$63
Central heater**	November - March	$20
Water heater	All Year	$18
Pool pump	All Year	$36

Figure 15: FPL total annual bill credits for participating in Residential On Call Program.

Source: (FPL 2018)

FPL launched their pool pump demand management program in 1990. Typically, events are called for frequency regulation and system peak demand management purposes. FPL uses load control transponders made by Aclara, which use power line carrier communication technology that places the communication signal directly on the power line. Only single speed pumps are eligible for participation in the Residential On Call program (FPL 2018).

Pilot Pool Pump Demand Management Programs

In addition to the traditional load management programs, focused on peak load events, there are numerous known pilot programs focusing on using pool pumps as a more flexible demand-side management resource (Pooled Energy 2018).

Marin Clean Energy Pilot Demand Response Pilot

On October 6, 2016, Marin Clean Energy (MCE), a community choice electricity provider servicing about 250,000 customers throughout the California Bay Area announced selection of the AutoGrid Flex™ flexibility management software application suite for its pilot DR program. The pilot program launched on May 31, 2016 with the goal of connecting smart thermostats and pool pumps.

According to the press release: "MCE is using the pilot program to determine if it can use its customers' smart thermostats, pool pumps, and – in the future – connected water heaters, electric vehicle chargers, energy storage systems and other distributed energy resources (DERs) to reduce energy procurement expenses during times of peak energy demand. MCE will also study whether the program can provide an additional revenue stream to MCE by bidding DR capacity from the customer-owned DERs into the CAISO market" (AutoGrid 2016). However, as of July 2018, outreach to MCE and AutoGrid indicated that the program was unsuccessful in enrolling any customers with pool pumps.

Australia "Pooled Energy" Intelligent Pool Control System Pilot

On February 21, 2018, the Australian Renewable Energy Agency announced $2.5 million in funding to a Sydney, Australia based company, Pooled Energy, for a pilot-scale demonstration of its technology that reduces energy consumption of household swimming pools and unlocks the potential for DR from pool equipment (Pooled Energy 2018). The total cost of the project is $5 million and will enable Pooled Energy, who is also an energy retailer, to expand the trial of their technology from 400 to 5,000 residential swimming pools.

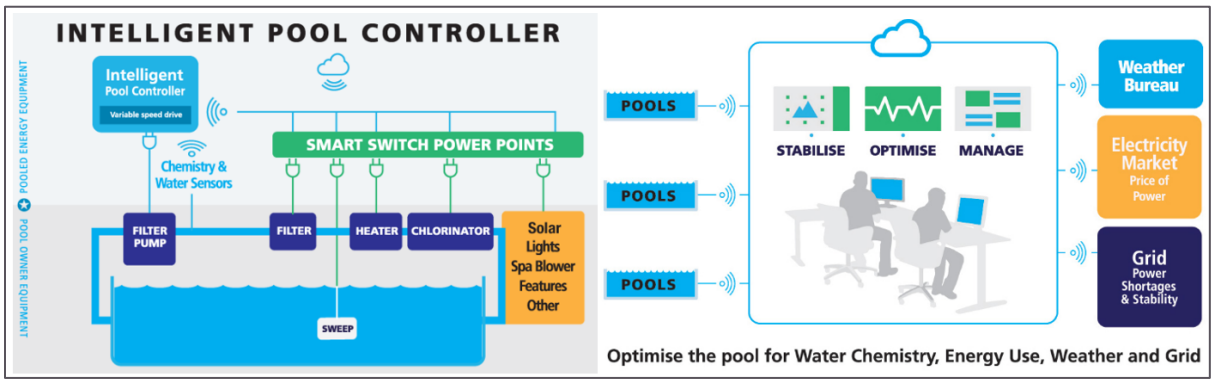


Figure 16: Pooled Energy's Intelligent Pool Controller system.

Source: (Pooled Energy 2018)

Pooled Energy replaces traditional time clocks with cloud-based controls that allow pool equipment operation to be a function of the various inputs including: time-of-day, time-of-year, swimming activity, water quality, the costs and prices of electricity and the technical state of the electricity grid. As an energy retailer in Australia, Pooled Energy can offer a bundle of electricity for homes and automated swimming pool services.

3. Technology Assessment

Energy efficiency efforts throughout the country have moved the pool pump market from single-speed to variable-speed through incentive programs, state level efficiency standards, and a national pool pump efficiency standard set to take effect in 2021. This new national standard will effectively require all pool pumps over roughly 1 horsepower to be variable-speed, significantly expanding the number of variable-speed pool pumps nationally. While California has had Title 20 appliance standards and incentive programs that have helped move the market towards variable-speed products for many years, the standard will create another wave of adoption of variable-speed pool pumps. This creates a significant opportunity to connect these new pumps and turn them into a grid resource as variable-speed pumps have inherently more operational flexibility than single-speed pumps.

Between 2016 and 2018, many pool pump and pool pump motor manufacturers began offering affordable connected capabilities for their variable-speed pool pumps. These technologies allowing homeowners, service technicians and/or manufacturers to change motor speed, flow, turn on/off, modify schedules, and control auxiliary loads instantaneously through a Wi-Fi or other remote connection. This section will explore the commercialization status of connected pool pumps and the communication standards, protocols, and languages currently being employed by different manufacturers or those which may be appropriate for pool pumps.

Pool Pump Technology Drivers

In the early 2000s, in response to the energy crisis, California utilities and the California Energy Commission (Energy Commission) began exploring residential pool pump energy efficiency opportunities. This led to the development of rebate programs focused on newly available residential 2-speed and variable-speed pool pumps, a Title 20 efficiency standard in 2008, and a national pool pump efficiency standard set to take effect in 2021. This new national standard will require all pool pumps to meet a Weighted Energy Factor (WEF) requirement which, for most self-priming pool pumps (i.e. backyard inground filtration) will effectively require variable-speed capabilities. The 2017 ENERGY STAR Unit Shipment and Market Penetration Report showed the variable-speed pool pump saturation at 43 percent of sales in 2017 which is largely the result of state standards (California, Arizona, Oregon and Connecticut) and various utility incentive programs across the country (ENERGY STAR 2018).

Dozens of utilities across the country continue to offer financial rebates for customers to adopt variable-speed pool pumps. However, many of these are likely to be discontinued as the July 2021 federal standard approaches and variable-speed pool pumps become the new baseline.

Existing Manufacturing Connected Options

As of 2018, at least four major manufacturers offered connected pool pump systems that are designed for a typical residential in-ground pool: Hayward, Pentair, Jandy, and Century Motors (replacement motors only). Pentair, Jandy, and Hayward represent three of the largest pool pump manufacturers. Century motors is also a leader in aftermarket replacement pool pump motors, in addition to selling some original equipment manufacturer (OEM) motors to numerous manufacturers. While advanced automation and control systems have existed for many years for higher-end pools, only starting around 2016 have these manufacturers offered connected capabilities for the typical backyard in-ground pool, with Pentair and Hayward debuting their systems in 2018. These systems were investigated, and manufacturer interviews

conducted, to understand their commercialization status, current capabilities and demand response potential. Below is a brief overview of each system, followed by Table 4 comparing various attributes.

Hayward - VS Omni

Hayward, a major manufacturer of pool equipment, including pool pumps and controls, launched a new simplified control system called "VS Omni" in 2018. VS Omni is designed for the typical backyard pool and gives pool owners remote control over their variable-speed pump and a pool light, heater, and booster pump as applicable. The VS Omni system lays on top of the existing mechanical time clocks and only requires low-voltage wiring for the controls. Using Wi-Fi, the pool owner can modify pool pump operating schedules and speed using the interior control pad, a smart phone, Nest unit, or Amazon's Alexa device. Of note, the VS Omni control system is only compatible with their new line of VS Omni pool pumps. The VS Omni control system is not able to be added to an existing Hayward pump.

Figure 17: Hayward VS Omni control system.
Source: (Hayward 2018)

Pentair - Intelliconnect

Pentair, a major manufacturer of pool equipment, including pool pumps and controls, launched a new simplified control system called "Intelliconnect" in 2018. Intelliconnect is designed to replace traditional mechanical time clocks found on most backyard pools and gives pool owners web-based control over a Pentair variable-speed pump and a pool light, heater, and booster pump if present. The Intelliconnect is designed to connect via an RS-485 cable to most of Pentair's existing variable-speed pool pumps, so that a new pool pump is not required. For a price of roughly $300 (excluding labor), a Pentair variable-speed pool pump can be connected via Wi-Fi where flow and/or RPM, pump schedule, and auxiliary functions can be controlled by homeowners through a mobile app.

Figure 18: Pentair Intelliconnect controller.
Source: (Pentair 2018)

Jandy - iQPUMP01

Jandy pool pumps, a brand of Zodiac Pool Systems, is another of the major pump and control manufacturers who recently launched a simplified control system. The Jandy option, iQPUMP01, launched in 2017. iQPUMP01 is a very simple control system that connects with all market available Jandy variable-speed pumps and retails for roughly $80. A unique feature of the iQPUMP01 system includes the ability for pool owners and pool service professionals to control the pump speed, schedule, and more through the iAquaLink app. If service is warranted, the pool professional can remotely troubleshoot the pump and make any adjustments as needed before scheduling a field repair. The iQPUMP01 can also connect and control an auxiliary load such as a booster pump.

Figure 19: Zodiac iQPUMP01 control system.

Source: (Jandy 2018)

Century Motors - vLink

Century Motors, part of Regal Beloit motors, is a major pool pump motor manufacturer who sells motors to OEM pump manufacturers, and replacement aftermarket motors for mounting on nearly all pump heads in the pool market. In 2016, Century debuted their vLink control system, which can be connected via Wi-Fi to their vGreen 165 and vGreen 270 variable-speed replacement motors and enable remote control of motor speed, schedule, and more. The vLink also provides the opportunity to connect a single auxiliary load to be remotely controlled. The vLink controller retails for around $280.

Figure 20: Century vLink control system

Source: (Century Motors 2018)

See Table 4 for a summary of the different capabilities of each of the four manufacturers connected product capabilities and other information.

Table 4: Connected pool pump product comparison

Connected Capabilities	Century Motors vLink	Pentair Intelliconnect	Jandy iQPUMP01	Hayward VS Omni
Product Type	Replacement motor	Pump & Motor	Pump & Motor	Pump & Motor
Controller can be added to manufacturers existing deployed pumps?	Yes	Yes	Yes	
Product Capabilities				
Displays power draw (watts)		Yes	Yes	Yes
Change RPM	Yes	Yes	Yes	Yes
Change flow (GPM)		Yes		
Turn on/off	Yes	Yes	Yes	Yes
Create/ modify schedules	Yes	Yes	Yes	Yes
Number of auxiliary loads controlled	1	3	1	3
Works with Nest				Yes
Works with Alexa		Yes		Yes
Connection Protocol	Wi-Fi	Wi-Fi	Wi-Fi	Wi-Fi or Wired Ethernet

Pool Pump Communication Specifications/Standards

There are two established communication specifications/standards currently being used or considered for use in this market: The first is the ENERGY STAR Connected Product Criteria optional standard. Version 1 of this standard was published in 2014 and Version 2.0 was finalized in 2018 with minor updates. Concurrently, the Electric Power Research Institute (EPRI) finalized the CTA-2045 modular communication protocol for pool pumps. The specifications are similar in several ways and there are ongoing efforts to align these standards.

Finally, the OpenADR standard is briefly described as it is a potential connected standard for pool pumps. This would be one method for pool pumps to participate in ADR with the California IOUs.

ENERGY STAR Connected Product Criteria

ENERGY STAR established a pool pump test procedure for validating compliance with DR functionality as set forth in the ENERGY STAR residential pool pumps connected functionality criteria. This test procedure and subsequent optional standards define two primary connected products:

1. **Connected Pool Pump System (CPPS)** that is comprised of the pool pump, integrated or separate communications hardware, and additional hardware and software required to enabled connected functionality.

2. **Communication Link** that is the mechanism for bi-directional data transfer between the CPPS and external applications, devices, or systems.

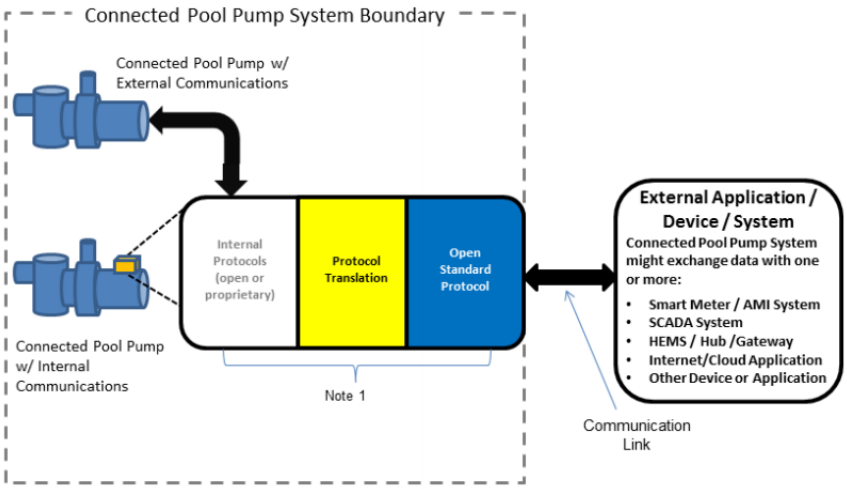


Figure 21: ENERGY STAR v2.0 Connected Pool Pump System.

Source: (ENERGY STAR 2018)

As required by the pool pump ENERGY STAR Qualified Product List (QPL), the manufacturer of a pool pump intended to be certified as having connected functionality must submit and list the Open Standard CPPS communication link that will be used. This includes, but is not limited to, Smart Energy Profile (SEP) 1.x or 2.x, OpenADR, Z-Wave, CTA-2045, Zigbee, Wired Ethernet, and Wi-Fi.

These two product types comprise the entire connected system to be tested in the ENERGY STAR Test Method to Validate Demand Response. The test itself requires a stable connection between the CPPS and Utility Equivalent Communication Devices (UECD), such as a Demand Response Automation Server (DRAS), and conducts three separate signal tests, denoted as response types 1, 2, and 3. Each test is required to respond to the incoming signal within five minutes and the CPPS is not required to respond if doing so would compromise hardware safety or result in unexpected damage as determined by the manufacturer.

For variable-speed pumps:

1. Type 1 is intended to curtail demand while minimizing customer impact. The CPPS shall ship with default settings that enable a response for at least four hours and can provide at least one response in a rolling 12-hour period. For variable-speed pumps the pump response is to reduce speed to 1/3 of maximum RPM or, if pre-signal operation was less than 1/3 of maximum RPM, remain at operating speed.

2. Type 2 is intended to immediately shut down pumping operations and is intended to manage more extreme peak load and grid emergency conditions. The CPPS shall ship with default settings that enable a response of at least 20 minutes and can provide at least three responses in a rolling 24-hour period.

3. Type 3 is intended to increase demand temporarily to utilize excess load. If idle, the CPPS shall initiate pumping at a rate appropriate for regular filtration. If active, the CPPS shall increase motor speed but not exceed the recommended operating speed. For CPPSs that manage daily pumping volume or duration, the response shall terminate when such limits are reached.

With respect to demand response applications, the Type 1 signal represents a traditional demand response event, curtailing load for a significant period of time once over a 12-hour period. A Type 2 signal is intended to elicit a more aggressive load shed that is typical of customers seeking to reduce their demand further or grid emergency conditions. A Type 3 signal is most closely aligned with a shimmy service type of demand response, represented by quick responding devices with flexible loads, eliciting an increase in load to manage a surplus of generation.

Additionally, the ENERGY STAR specification requires an Interface Control Document (ICD), Application Programming Interface (API), or other documentation be made available to interested parties to allow easy transmittal of energy consumption reporting, operational status, user settings, messages, and demand response information/statuses.

As of September 2020 only one pool pump on the ENERGY STAR Qualified Products List was certified to standards put forth in the Connected Product Criteria.[1] Version 2.0 of the pool pump ENERGY STAR Specification has been released and manufacturers could begin testing their products to this standard after April 30, 2018, with the standard going into effect on January 2, 2019. With respect to connected features, version 2.0 is similar in operation to version 1.1 but with these deviations:

1. Real-time power is a required reporting field for the ICD and API documentation, replacing energy consumption. Energy consumption data is optional in v2.0.

2. The response time for Type 1, 2, and 3 responses are reduced from five minutes to 10 seconds.

3. Version 2.0 specifies that the Type 3 response will increase pumping speed by at least 10 percent of maximum RPM from its current speed while v1.1 did not define the rate of increase.

Version 3.0 of the ENERGY STAR specification for pool pumps was released simultaneously as Version 2.0 and are available for product certification starting October 19, 2020. However, no changes were made between versions 2.0 and 3.0 with respect to the connected criteria.

CTA-2045 Modular Communication Standard

To advance grid connectivity among various appliances, EPRI has co-developed and demonstrated an interface, or port, based on a 2013 Consumer Technology Association (CTA) standard known as CTA-2045 (formerly CEA-2045). The port enables customer appliances to connect to any communication network and receive and execute commands using a common language and mechanical interface. The port makes it possible for thermostats, water heaters, electric vehicle chargers, pool pumps, and other devices to participate collectively in automated demand response programs or other grid flexibility services.

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[1] Pentair - IntelliFlo VSF with IntelliConnect WiFi Controller, Model #011056

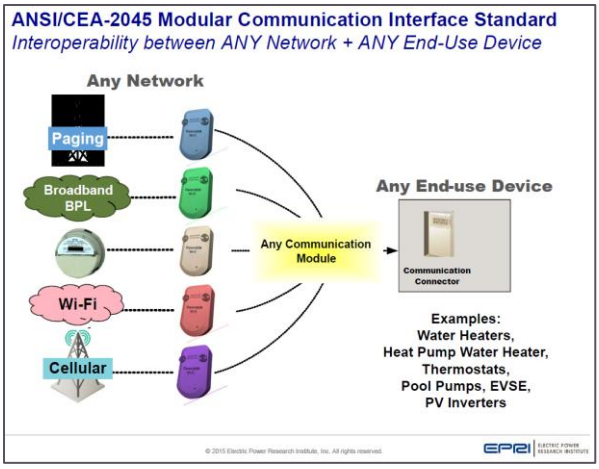

Figure 22: CTA-2045 Modular Communication Interface Standard.

Source: (Thomas and Seal 2015)

In 2015, EPRI launched a three-year project with 23 electric utilities (including SCE) and 14 manufacturers to develop and demonstrate CTA-2045-compliant devices. Pentair, a large pool pump manufacturer, was one of the manufacturers to participate with the EPRI project. According to an EPRI Journal article:

> *"EPRI's project is helping to address the chicken-and-egg dilemma with market adoption and product availability," said Jeff Farlow, program manager of energy initiatives at Pentair Water Quality Systems. "The module allows us to proceed with product development without having to worry about which communication protocol wins the race to mass market adoption."* (EPRI 2016)

Duke Energy has, as a part of the EPRI CTA-2045 initiative, been testing pool pump equipment with CTA-2045 communication modules since 2016 in their Florida service territory. So far, Duke has mostly focused on testing various communication pathways such as Wi-Fi and FM spectrum. The pilot project has been successful communicating with the CTA-2045 modules from multiple suppliers (Duke 2018).

CTA-2045 DEMAND RESPONSE-READY VARIABLE-SPEED POOL PUMP SPECIFICATION

In May 2016, EPRI published the "Demand Response-Ready Variable-Speed Pool Pump Specification, Preliminary Requirements for CEA-2045 Field Demonstration" which outlines the various requirements for pool pump manufacturers to follow to certify their products to the CTA-2045 standard (EPRI 2016). This includes the CTA-2045 port mechanical and electrical characteristics and user interface requirements. It also details the CTA-2045 communication requirements for a pool pump manufacturer. These include:

- Link-Layer Requirements
- Control Requirements
- Monitoring Requirements

Most of these requirements are similar to the ENERGY STAR control requirements, including traditional load shed, controls to manage grid emergencies, and ramping to absorb load. However, one unique feature in the CTA-2045 pool pump specification includes a "Present Relative Price" command

where a consumer could set a "Low Price Threshold" and "High Price Threshold" to allow the pump to respond to pricing signals.

The specification provides examples of how a pool pump could respond to this signal:

- *"If Present Relative Price is below "Low Price Threshold": pool pump immediately acts to maximize the rate of circulation and continues until the Low Price ends or the required daily circulation is accomplished.*
- *If Present Relative Price is between "Low Price threshold" and "High Price Threshold": pool pump behaves normally, the same as when a "Run Normal" message has been received.*
- *If Present Relative Price is above "High Price Threshold": pool pump will defer circulation altogether or circulate at the minimum rate possible"* (EPRI 2016)

The CTA-2045 standard also offers, for informational purpose only, various sample utility control strategies for variable-speed pool pumps including:

- *Direct Load Control:* Traditional load shed/ turn-off a pool pump
- *Time of Use:* To aid pool pumps to operate given predictable time of use rates
- *Critical Peak Pricing:* To inform pool pumps of infrequent critical peak events
- *Grid Emergencies:* Signal to devices to cease operation during emergency situations
- *Cycling-Based Managed-Load Operation:* Control strategies in which the pool pump may be requested to operate at times (to absorb energy) in addition to avoiding operation at other times

MARKET READINESS OF CTA-2045

While the NREL field test provided useful results, there remain barriers to commercializing this connected pool pump arrangement. These barriers are described below.

Water safety with CTA-2045

Pool pumps operate in areas where water regularly presents itself on all equipment. In fact, to earn the UL-1081 pool pump safety standard, a "splash test" is required to ensure safety of equipment. The CTA-2045 module is, by design, made to be "plugged-in" to a device by a consumer and therefore does not create a water-tight seal. To manage this issue during the EPRI testing, the CTA-2045 module was placed inside the Intelliconnect box. This adds some cost and additional complexity to the CTA-2045 module for pool pumps. Ideally it would be mounted directly on the pool pump, as is common with other devices designed for CTA-2045 modules.

Interactions with auxiliary equipment

In California it is common to have auxiliary equipment, such as a booster pump or jet pump, to run an inground pool cleaner or spa jets (respectively). If a filter pump turns off due to a DR event, the auxiliary pump likely needs to turn off as well, as it is served by flow from the filtration pump. Otherwise, the booster pump or jet pump could run without water and eventually overheat and breakdown. This issue has been considered to an extent as many smart controls described above can control auxiliary loads. However, it does not appear the interactions between connected filtration pumps and auxiliary pumps have been tested in the field. Existing CTA-2045 testing has taken place in the

Florida market, where booster pump cleaning is rare. It is likely a manageable issue, but one that should be explored further or considered for testing to ensure customer satisfaction and equipment longevity.

OpenADR Certification

The OpenADR Alliance oversees and supports the development, testing, and deployment of the OpenADR communication protocol. It is included briefly in this report as a potential specification option to test and certify for pool pumps. The certification process is outlined below in Figure 23.

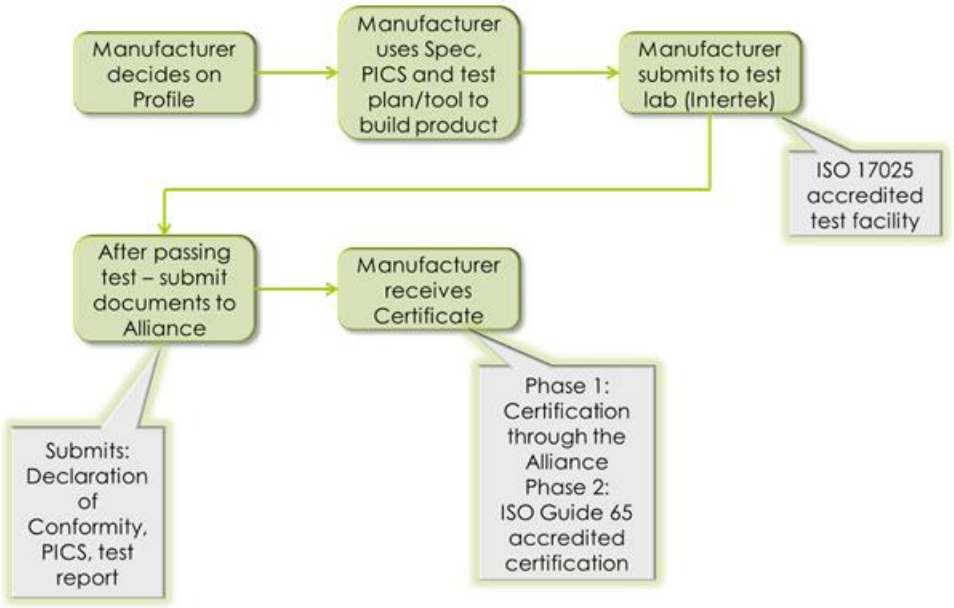

Figure 23: OpenADR certification process.

Source: (OpenADR 2018)

As described on the OpenADR website, in addition to the steps outlined in Figure 23, manufacturers must at least be a Contributor member of the OpenADR Alliance, which can cost up to $7,500. While a sample test plan is available to download for free for Contributor members, a more thorough testing tool is available for purchase at a price of $5,500. After in-house testing and commissioning has been completed, the product in question must be submitted to an Intertek testing facility at a cost up to $10,000 for final testing. Upon certification, individual client certificates must be issued with annual maintenance fees with significantly lower bulk pricing available. For more about how pool pumps may interact with OpenADR in SCE territory see the section "Pool Pumps in SCE's Demand Response Ecosystem" below.

Pool Pump Communication Pathways

The ENERGY STAR Connected Criteria is a very broad connected standard which does not limit the communication standard and pathways that may be employed. It cites Smart Energy Profiles, CTA-2045, OpenADR, Z-Wave, Zigbee, Wired Ethernet, and Wi-Fi among eligible communication standards and pathways. However, to-date the pool pump market has focused on enabling communicating with three communication pathways:

- Radio Frequency (RF) to Internet
- Wired Ethernet
- Wi-Fi

The connectivity that each of these communications pathways provide is to enable pool pump, and associated pool equipment, control over the internet. Customer demand has been cited by all manufacturers as being the primary driver for internet connectivity.

RF to internet consists of an RF antenna installed on the pool control hub and a separate antenna wired directly into a home modem or router. Compared to the other communication configurations, this offers the benefit of a stable and long-range internet connection that does not depend on the pool control hub being installed within close proximity of a home's modem or router. This stable connection comes at a premium as this connection configuration is only deployed on the more expensive full-pool system control packages, such as the Pentair ScreenLogic2 and Hayward AquaConnect.

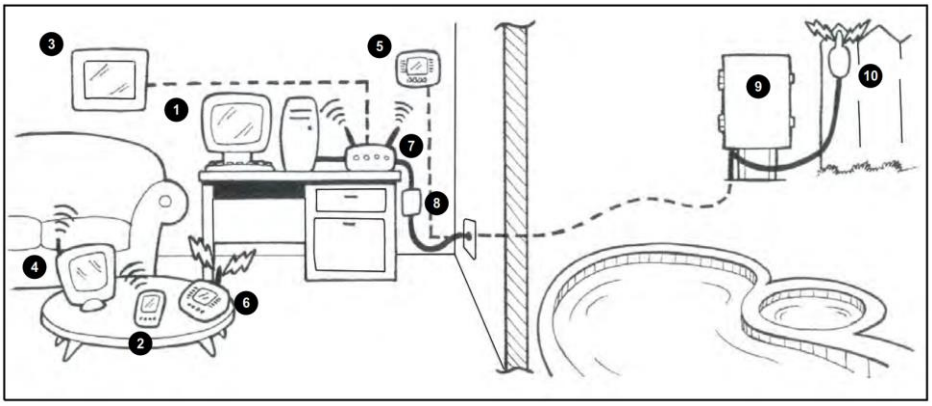

Figure 24: Pentair ScreenLogic2 Installation Diagram.
(Item 7 is the home modem or router. Item 8 & 10 are the RF antennas. Item 9 is the control box.)
Source: (Pentair 2018)

A wired ethernet connection offers a cheap and stable internet connection but requires long outdoor rated cables that can take significant effort to safely install around a pool. A standard Wi-Fi connection is the most common connection medium currently deployed by major pool pump manufacturers to achieve a cheap, easily accessible, and installable product. Connected products such as the Pentair IntelliConnect, Hayward VS Omni, Jandy iQPUMP01, and Century Motors VLink are marketed as entry level products to enable easy remote control over a pool pump. While easily accessible, to offer stable conditions an internet connection via Wi-Fi depends heavily upon the homeowner's equipment and proximity of the home and pool.

An additional limiting factor are the proprietary languages used to directly control the pool pump load. Entry level automation systems are limited to variable-speed pool pumps of the same manufacturer, as outlined in the existing manufacturer connection options. For some manufacturers, an entry level automation system must be paired with a relatively new pool pump of the same manufacturer (e.g. Hayward), whereas others have designed their products to work with a larger number of legacy of models (e.g. Pentair and Jandy). The proprietary nature of technology and control is common and has benefits and drawbacks. There is an advantage to offering a relatively straightforward and easy to operate systems for customers who operate within a single manufacturer ecosystem. However, this may

limit options for customers retrofitting existing pool pumps who want an automation system of a different manufacturer's based on available features or cost. This hurdle can be removed by using a universal controller interface such as CTA-2045.

Pool Pumps in SCE's Demand Response Ecosystem

Given the market realities of DR in California, it can be assumed that pool pumps will ultimately need to use OpenADR at the device or aggregator level to communicate with a utility. However, direct market participation would not require OpenADR communication.

OpenADR Overview

OpenADR was first developed in 2002 with the OpenADR 1.0 specification released in 2009 as an open and secure standard that standardized the message format used for ADR and DER management. This allows dynamic price and reliability signals to be exchanged in a uniform and interoperable fashion between utilities, independent service operations, and energy management and control systems. OpenADR describes all aspects of the OpenADR interfaces, including virtual top nodes (VTNs) and virtual end nodes (VENs) or clients. VTN and VEN devices can be separate or a single device, but historically the VTN refers to a manufacturer cloud, program aggregator, or utility while the VEN refers to the controlled load (e.g., the pool pump controller).

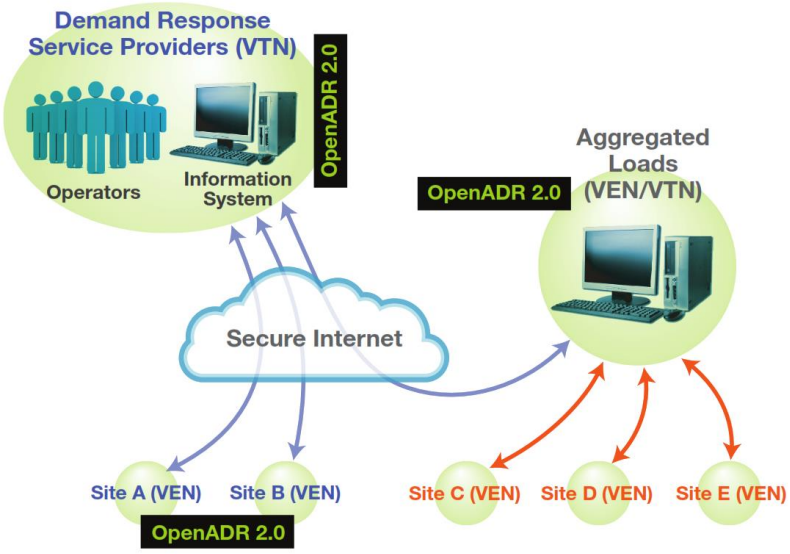

Figure 25: Possible relationships of VTN and VEN of OpenADR.

Source: (OpenADR 2018)

In 2012 and 2013 OpenADR 2.0a and b specifications were released, respectively.

- OpenADR 2.0a: Is designed for resource-constrained, low-end embedded devices that can support basic DR services and markets.
- OpenADR 2.0b: Builds upon the 2.0a profile specification, adding enhanced DR event and price scheduling and robust reporting services enabling system operators, utilities, and aggregators better insight into curtailment levels.

The event payload that can be issued through OpenADR is limited to a predetermined set of signals and does not include specific commands of the end use device. This standard requires the end-user to program the appropriate response to OpenADR signals such as shedding load when a load shed event is issued, ramping up when a load increase event is issued, or adjusting operating schedules when dynamic price signals are issued. The reporting features associated with OpenADR 2.0b are limited to the capabilities of the specific VEN but can include historical usage information along with current usage and status information.

Skycentrics is a manufacturer or CTA-2045 modules for applications in pool pumps and other devices and serves as an aggregator of these devices through their enterprise, DREAM (Demand Response Energy & Asset Management) platform (shown below). Skycentrics has been actively involved in the continued development of intelligent controls and CTA-2045 specifications and testing.

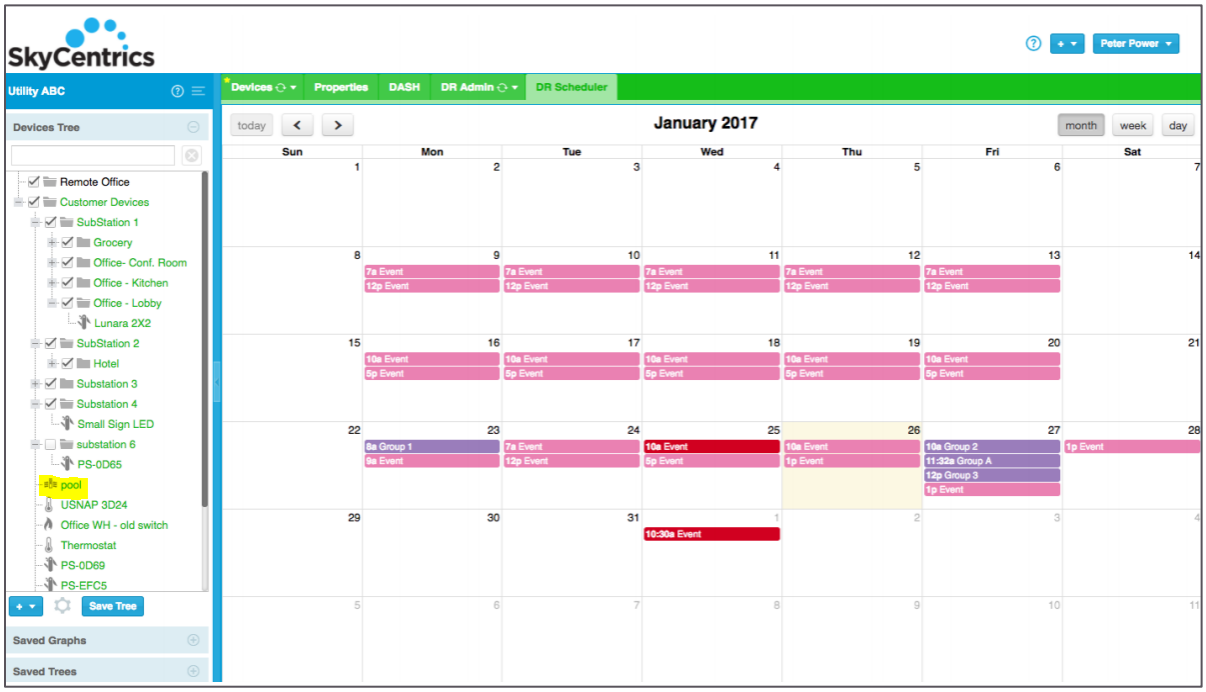

Figure 26: Skycentrics DREAM platform

Source: (Skycentrics 2018)

4. Supply Chain and Market Assessment

The supply chain and market assessment research activity is focused on the connected pool pump DR market potential in SCE territory. It explores and quantifies pool pump equipment stock and shipments, distribution channels, and other market factors unique to the Southern California pool market. Additionally, based on upcoming DOE national standards and other available data, this review discusses the technical connected-DR potential, use cases, business models for deployment and utility intervention strategies. The technical flexible demand potential for common backyard in-ground pool pumps is large, at nearly 750 MW in SCE territory. However, realizing this potential is a function of appropriate market interventions and consumer protections to create a strong value proposition for customers and other market actors in the supply chain.

SCE Residential Pool Pump Equipment Types

There are many different types of pool pumps with potential for demand response, but the self-priming residential filtration pool pump that circulates and filters water in permanent in-ground pools is most commonly referred to and studied. However, there are other types of pool pumps (such as non-self-priming pumps, pressure cleaner booster pumps and waterfall pumps) that serve different applications in residential pools. It is important to understand these pumps to appreciate the broader pool pump market, interactive system effects and the potential for additional flexible load.

In some pools, pump flow may be interdependent with other pumps or filtration systems, and steps must be taken to ensure both pump safety and water quality when recommending or implementing a DR strategy. For example, a pressure cleaner booster pump (used to power an in-ground pool floor robotic cleaner) relies on the flow from the filtration pump to operate. If the filtration pump turns completely off due to a DR event without a proper signal to the pressure cleaner booster pump, it could cause the pressure cleaner booster pump to run dry which may eventually lead to failure. These different residential pool pumps, their applications, and connected potential and limitations are described below using the equipment types as defined, and to be regulated, by DOE in 2021 (DOE 2017).

Self-Priming Pool Pumps (In-ground Filtration Pumps)

Self-priming pool pumps are also commonly referred to as "in-ground pool pumps" and are the largest category of pool pumps. They are the main filtration and circulation pump found in every in-ground residential backyard pool.[2] Filtration pumps serve to pull dirt and debris from the pool's surface via a skimmer and from the pool's main drain and push it through a filter medium (such as a paper cartridge, sand, or diatomaceous earth) before returning to the pool. This also circulates the water to ensure proper chemical disinfectant distribution (e.g. chlorine).

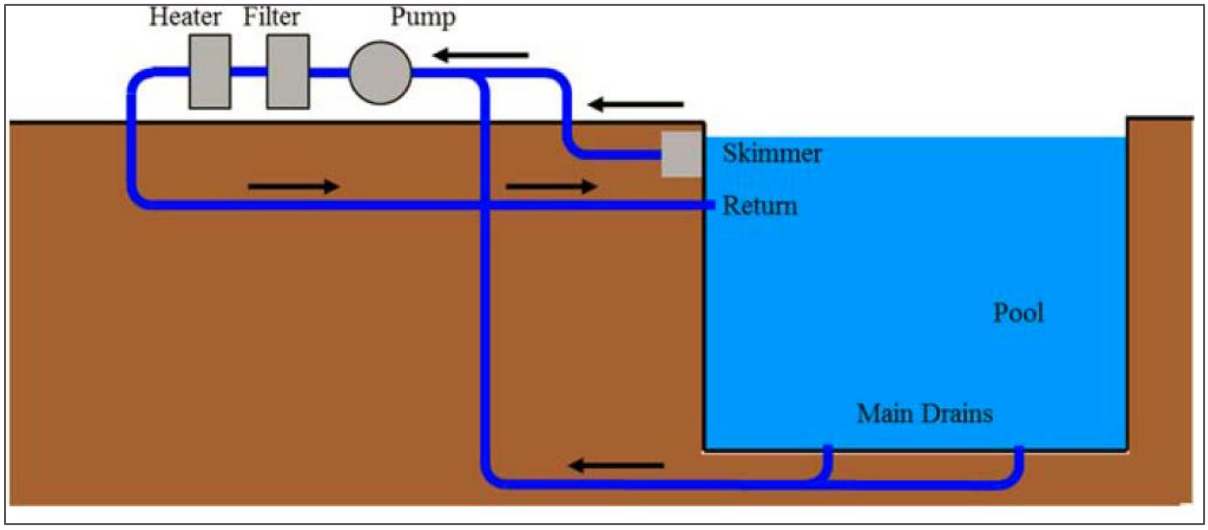

Figure 27: Basic in-ground pool plumbing schematic

Source: (CEC 2018)

[2] These same pumps are also used in small in-ground small commercial pool (e.g. hotel/ motel pools), but due to health codes, these pumps in this commercial sector are not a good candidate for DR.

"Self-priming" refers to the unique pump head design with an internal recirculation passage which enables the pump to prime itself (each day for example) after an initial manual filling of the pump casing. While this slightly decreases pump head efficiency, it is necessary because in-ground pool equipment is typically located higher than the pool water level, typically by a few feet, and needs to "prime" itself upon each start-up. This category of pool pumps typically ranges between ¾ total horsepower (THP) and 5 THP. Existing CA Title 20 appliance energy standards and the 2021 DOE pool pump standard essentially require all self-priming pool pumps to be variable-speed over 1 THP. Pool pumps used in commercial applications are not currently covered by Title 20, but will be covered by the 2021 DOE standard (DOE 2017). Self-priming pumps below 1 THP can be single-speed but have a smaller market share as they have limited utility in many backyard pools as they are often too small to achieve higher flow demands.

While pool pumps may be operated on different schedules, a commonly recommended energy efficient operation schedule will include at least 2 hours at high flow (~ 50 to 60 gallons per minute (GPM)) for surface skimming/mixing setting, followed by an additional 6-10 hours per day at a lower flow (~30 GPM) filtration setting depending on the size of the pool. Before variable-speed pool pumps, single-speed pumps would operate at one high speed, consuming significant amounts of energy pushing high flows of water against significant system head. Due to the pump affinity law[3], variable-speed pool pumps can perform much of the needed filtration pumping at a significantly lower speed and thus lower power draw. During the high-speed setting, power draw on average should be ~1.3 kW whereas low speed should draw ~ 0.2 kW if set up properly. This power draw roughly represents the shipment-weighted average demand for a variable-speed pool pump tested to the DOE test procedure, in a "Energy Commission Curve C" pool. This standardized representative hydraulic system curve is meant to represent the total dynamic head present in a new swimming pool built to CA's Title 24 standards with 2.5-inch plumbing and a cartridge filter system. The Energy Commission requires manufacturers to report flow and power demand data on three separate hydraulic system curves including two additional system curves: B & A. Energy Commission Curve B is more restrictive and meant to represent a pool with a sand filter and 1.5-inch copper plumbing and Energy Commission Curve A is meant to represent an average older pool with 2 inch plumbing and a cartridge filter (Gutai 2015).

Figure 28: Self-priming pool pump for in-ground pools

Source: (Pentair 2018)

[3] The pump affinity law quantifies that power consumption drops at a nonlinear rate as pump speed and water flow is reduced. When the motor speed is reduced by half, the flow rate is also reduced by half, but the power consumption of the pump is reduced to 1/8th of the original draw.

Non-Self-Priming Pool Pumps

Non-self-priming pool pumps are also commonly referred to as "above-ground pool pumps" and are the second largest category of pool pumps as they are the main filtration pump found in residential backyard above-ground pools. "Non-self-priming" refers to a pump head design and its *inability* to prime itself, which is unnecessary as this equipment is typically on the ground next to the pool, below the water level, and therefore the pump head is flooded by gravity.

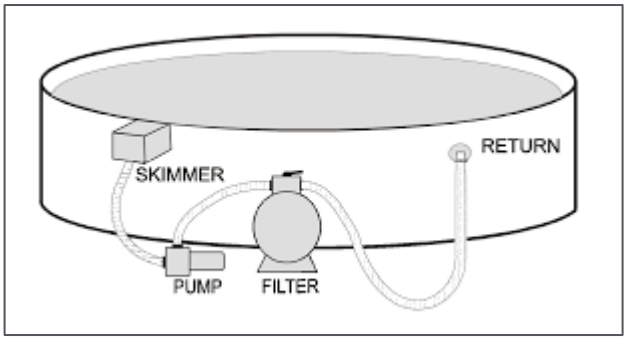

Figure 29: Above-ground Pool Schematic

Source: (Canada 2019)

These pumps are typically of single-speed design though there are some two-speed and variable-speed designs. Furthermore, per DOE standards starting in 2021, these pumps will be required to be more energy efficient but will likely remain primarily single-speed. Non-self-priming pumps typically range from ½ THP to 2 THP, with many common models drawing around 1.1 kW of demand. Typical operating schedules are dependent on whether the pool is set-up to run seasonally or year-round. If seasonal, it is not uncommon for these pumps to run continuously (24/7) throughout the summer swimming season as controls may not exist and the pump is often plugged into a standard 115-volt wall outlet.

Figure 30: Non-self-priming pool pump (for above-ground pools)

Source: (The Pool Supplies Superstore 2019)

Pressure Cleaner Booster Pumps

Pressure cleaner booster pumps are auxiliary pumps typically used in in-ground residential pools to provide high pressure with low flow to an in-ground pool cleaner. These are generally considered the

best options where there is regularly significant debris load such as leaves, and are standard in size at 1.25 THP. DOE energy standards taking effect in 2021 will require these pumps to be more energy efficient but they will likely remain mostly of single-speed design. However, at least one model of variable-speed design on the market allows for considerable energy savings (Waterway Plastics, Inc. 2019).

Notably, booster pumps must be paired with a self-priming filtration pump and require its operation to function. This is important in the context of a connected pool pump operation because if the main filtration pump is turned off, but the appropriate signal is not sent to the booster pump to turn off, the booster pump will continue running when dry, which can lead to overheating and failure.

As described in the Technology Assessment, most new connected pool pump offerings from major manufacturers have built-in controls for auxiliary features such as booster pumps, so that they only operate when the filtration pump is operating. In theory, the booster pump provides an additional flexible load for connected pools that is unique in that it can operate its ~1.4 kW load any time when the filtration pump is running, which, presuming a variable-speed filtration pump, is typically between 6-10 hours per day.

Figure 31: Pressure Cleaner Booster Pump

Source: (Leslie's Pool Supplies, Service & Repair 2019) and (Pool Supply World 2019)

Waterfall Pumps

Waterfall pumps are auxiliary pumps uniquely designed for low head, high flow applications such as a waterfall or other decorative water features. These pumps are self-priming and served by single-speed 4-pole motors, meaning they operate at only 1,800 revolutions per minute (RPMs). Shipments of these pumps are low as they are typically only used on in-ground pools with specialty additions such as rocks, statues, bubblers, and fountains. Many of these pumps are not operated daily, but only when a homeowner desires the visual effects of the waterfall or water features.

Figure 32: Waterfall Pump

Source: (Pentair 2018)

SCE Pool Pump Stock and Shipment Summary

Table 5 shows the estimated stock and annual shipments in SCE service territory for the different pool pump types typically found in residential pools. Shipments for these equipment types are broken down by sizes of the representative units DOE used to analyze impacts of national efficiency standards, in terms of hydraulic horsepower pump capacity (HHP) and total horsepower (THP), or motor capacity at an assumed 58% hydraulic efficiency.

Table 5: SCE Stock and Shipment Summary[4]

Source: (DOE 2017), (KEMA 2010), (Pkdata 2015), (CEC 2018)

	SCE Territory 2021 Stock	Equipment Life Estimate	SCE Territory Annual Shipments
In-Ground Pool Pumps			
Small Self-Priming Pool Pumps (0.44 HHP/ 0.75 THP)	77,000	7.3	11,000
Medium Self-Priming Pool Pumps (0.95 HHP/ 1.65 THP)	289,000	7.3	40,000
Large Self-Priming Pool Pumps (1.88 HHP/ 3.25 THP)	302,000	7.3	41,000
Booster Pumps (0.31 HHP/ 1.15 THP)	53,000	5.3	10,000
Waterfall Pump (0.40 HHP/ 0.72 THP)	11,000	7.3	2,000
Above-Ground Pool Pumps			
Non-Self-Priming pumps (0.09 HHP/ 0.16 THP)	21,000	5.3	4,000
Non-Self-Priming pumps (0.52 HHP/ 0.9 THP)	179,000	5.3	34,000
Total			
All Residential Pool Pumps	932,000	-	142,000

Many sources were used to derive estimates for stock and shipments in SCE territory, which according to RASS accounts for 41 percent of the in-ground residential pools in California. In 2021, there will be an estimated 932,000 residential swimming pool pumps operating in SCE territory (KEMA 2010).

[4] Stock data was derived from industry data, (Pkdata 2015), the 2009 RASS report, DOE dedicated-purpose pool pump rulemaking documents (DOE 2016), California Energy Commission 2018 Staff Report (CEC 2018) and a 2011 KEMA evaluation study of PG&E's pool incentive program. (KEMA 2009) Equipment life averages were sourced from the DOE rulemaking and annual shipments were derived by divided stock by equipment life. Shipments for self-priming pool pumps were reduced by 10% to estimate how many are used for main filtration pump purpose as compared to auxiliary purposes such as spa jets).

Pool Pump Supply Chain

When pools are first constructed the pool builder typically installs all electrical equipment including the pool pump. However, after the pool is built the owner (often with the support of a pool and spa maintenance contractor) is generally responsible for ensuring ongoing operations and repairs. For replacement equipment, there is a significant aftermarket where replacement pool pumps are typically sold to customers through a few distinct distribution channels. Within these distribution channels there are multiple influencers who impact the selection of replacement pool pumps and motors.

Pool Builders

Since 2008, all new pools in California are required to be built to CA Title 24 Part 6 energy efficiency building codes which include a variety of requirements such as hydraulically efficient plumbing, a pool cover (if heated by electricity or natural gas) and a Title 20 compliant pool pump (Energy Code Ace 2016).

Nationally, new pool construction is highly sensitive to economic factors (as shown in Figure 33) as pools are generally considered a discretionary luxury amenity in a home. For California, the Energy Commission estimates a 1 percent annual growth in shipments of self-priming pool pumps, which roughly correlates with in-ground pool construction as most pools have one self-priming filtration pool pump (CEC 2018).[5]

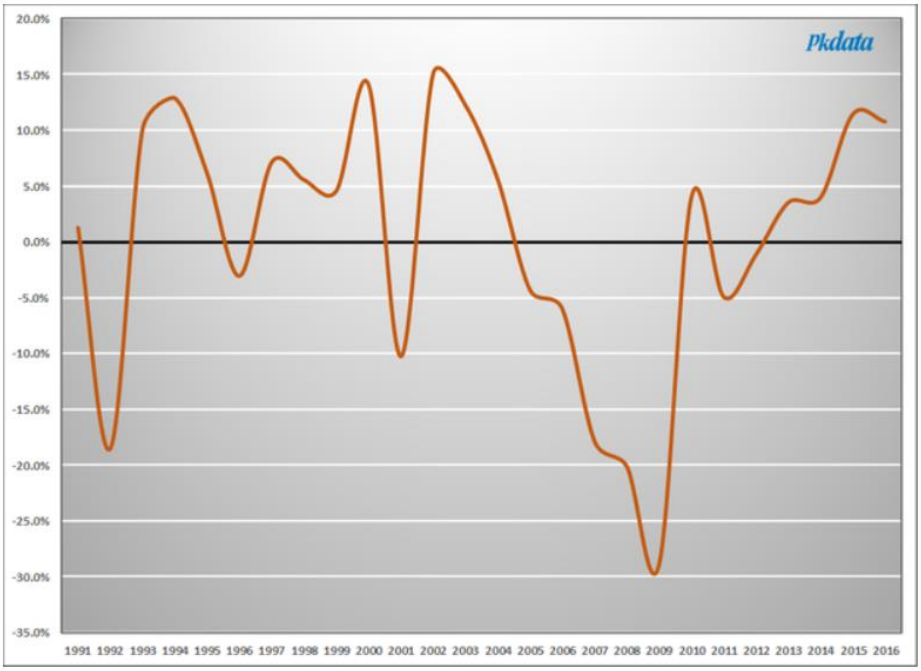

Figure 33: U.S. Annual changes for in-ground pool new construction

Source: (Pkdata 2019)

[5] While most pools have only one filtration pump, higher end pools with multiple bodies of water or attached spas may often have 2 or more. Data on these types of pools is not available, but for this analysis, it was assumed that 10% of self-priming pool pump shipments are NOT used in a typical filtration application.

Pool builders design the initial plumbing and select the initial pool pump and other equipment such as controls. Pool builders hold a C-53 contractor's license in California (California Department of Consumer Affairs 2015). Building a pool system with energy efficiency in mind is important as much of the lifetime energy consumption of the pool pump is fixed by the initial design. Using sweep elbows, larger plumbing (e.g. 2.5 inches), larger filters, and other techniques will reduce the pressure and power demand the pool pump must overcome to achieve the needed flow rates (Energy Code Ace 2016).

While the number of new in-ground pools built in SCE territory each year is very small relative to the installed base, pool builders are influential as they design, select and install the original equipment as a system. The pool builder market is largely regional with many different companies operating to serve different market segments from high-end to traditional backyard pools.

When the pool pump eventually needs replacing, after 7 years on average, it is very common for pool owners to seek a "like for like" replacement pump. Beyond having influence on the original selection, pool builders also have significant influence on the overall energy demand of the pool pump through the hydraulic efficiency of the plumbing system design. Much as it is difficult to retrofit a building with thicker, more insulated walls after it is built, digging up pipe many feet below the ground after a pool is built is unrealistic.

Pool Supply Store

A very common method of purchasing replacement pool equipment is to visit a neighborhood pool supply store, where pool pumps are displayed on a showroom floor and can be purchased directly by pool owners. Often these retail institutions offer in-house installation services, or pool owners will purchase and arrange to install the pool pump themselves or via their contractor. Pool supply store employees can have significant influence on purchasing decisions.

The pool supply store industry is fairly widely distributed with many independently owned stores and small chains around the country. However, there is one very large national chain retailer, Leslie Swimming Pool Supply, having significant market share with 910 stores nationwide (as of 2015) including 180 in California alone (Leslie's Pool Supplies, Service & Repair 2019).

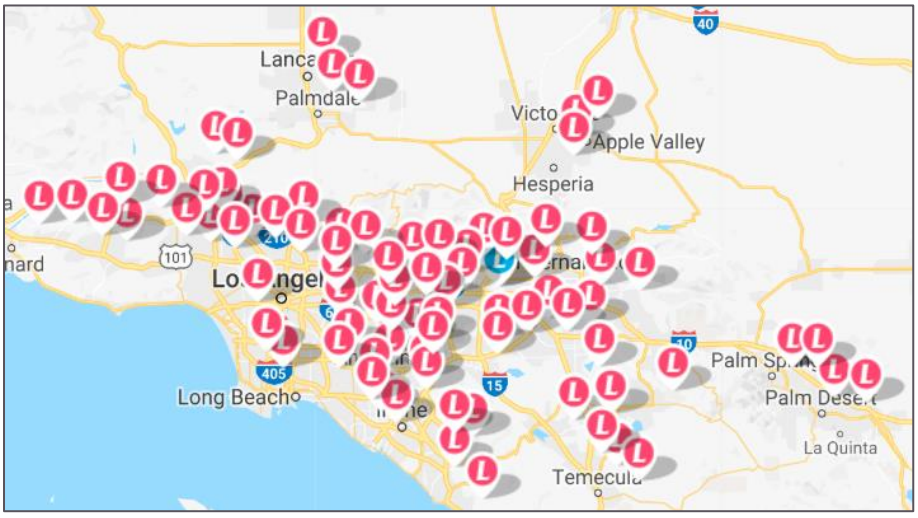

Figure 34: Leslie Swimming Pool Supply store locations in Southern California

Source: (Leslie's Pool Supplies, Service & Repair 2019)

Online Retailer

Online retailers are a large and growing distribution channel for replacement pool pumps. In addition to sites such as Amazon.com and Homedepot.com, a few specialty online retailers are dedicated to pool pump equipment. These sites often have significant educational materials including how-to guides, videos, and reviews of equipment.

Major online retailers of pool equipment include, but are not limited to:

- Pool Supply World (https://www.poolsupplyworld.com/)
- InyoPools (http://www.inyopools.com/)
- The Pool Supplies Superstore (https://www.poolsuppliessuperstore.com/)
- In The Swim (http://www.intheswim.com)

The prevalence and growth of online purchases of pool pumps has prompted some pushback from neighborhood pool supply stores and pool and spa maintenance contractors, who believe manufacturers are undercutting their business by selling the same equipment at lower prices online. In recent years, this has prompted most major pump manufacturers to start offering premium "trade only" lines of equipment that can only be purchased and installed through neighborhood pool supply stores and pool and spa maintenance contractors. Going a step further, on January 1, 2019 Zodiac will stop selling its pool equipment (including pumps) on the internet entirely (Pool and Spa News 2018). Typically "trade only" lines have been premium equipment, often with additional features such as connectivity.

Pool Maintenance Contractor

Replacement pool pumps are often purchased and installed exclusively through a licensed pool and spa maintenance contractor. In California, pool and spa maintenance contractors hold a D-35 license and are permitted to broadly install and repair all pool equipment from diving boards, to circuit breakers, to pool pumps. In some cases, pool and spa maintenance contractors, or their firms, may also perform weekly pool service to balance chemicals and clean pools. According to Pkdata, roughly 27 percent of in-ground pool owners nationally have regular pool service, with most being serviced weekly (Aqua Magazine 2017). This number may be higher in Southern California and other similar year-round swimming markets, though regional data is not available. When a repair or upgrade is needed, the pool and spa maintenance contractor will often make the recommendation and perform the pump repair/installation.

Figure 35: National saturation of pool service for in-ground pools

Source: (Aqua Magazine 2017)

In other cases, regular pool service is provided by separate pool service companies who only perform chemical balancing, cleaning, and simple repairs. Pool service companies are not required to have a contractor's license in California. When pump replacements or more technical work is needed, they will often recommend a licensed (D-35) pool and spa maintenance contractor to their customers. Licensed pool and spa maintenance contractors typically purchase their products wholesale through a pool equipment distributor.

Flexible Load Potential from Connected Pool Pumps

The use cases and quantification of flexible load potential from connected pool pumps is described in the following sections.

Current Non-Connected Pool Pump Operation

A "clean" pool is a priority for customers and is a function of filtration for water clarity and disinfection for water sanitation. Pool pumps operate daily to remove large debris and also serve to circulate the water to ensure even chemical distribution.

It is generally recommended that pool pumps achieve one "turnover" of water each day, filtering the entire volume of the pool. For an 18,000-gallon pool, it would take 10 hours to turnover the water if the pump operated 30 GPM.[6] One turnover is also the assumption of the California IOU energy efficiency workpapers for calculating the energy savings for variable-speed pool pump incentive programs. In a 2016 impact evaluation of SDG&E's pool pump rebate program, estimated turnover rates in the field varied, but skewed towards over-pumping, showing pools achieved an average of 1.5 turnovers (DNV-GL 2016). This tendency to "over-pump" is likely a function of conservative operations (i.e. "it doesn't

[6] 18,000 gallons divided by 30 GPM = 600 minute or 10 hours.

hurt to pump more"), or lack of instrumentation to accurately measure pool volume or flow. This insight could lead to capturing energy efficiency savings in addition to DR benefits with connected pool pumps as manufacturers can provide feedback and energy savings recommendations to customers based on their current operating schemes.

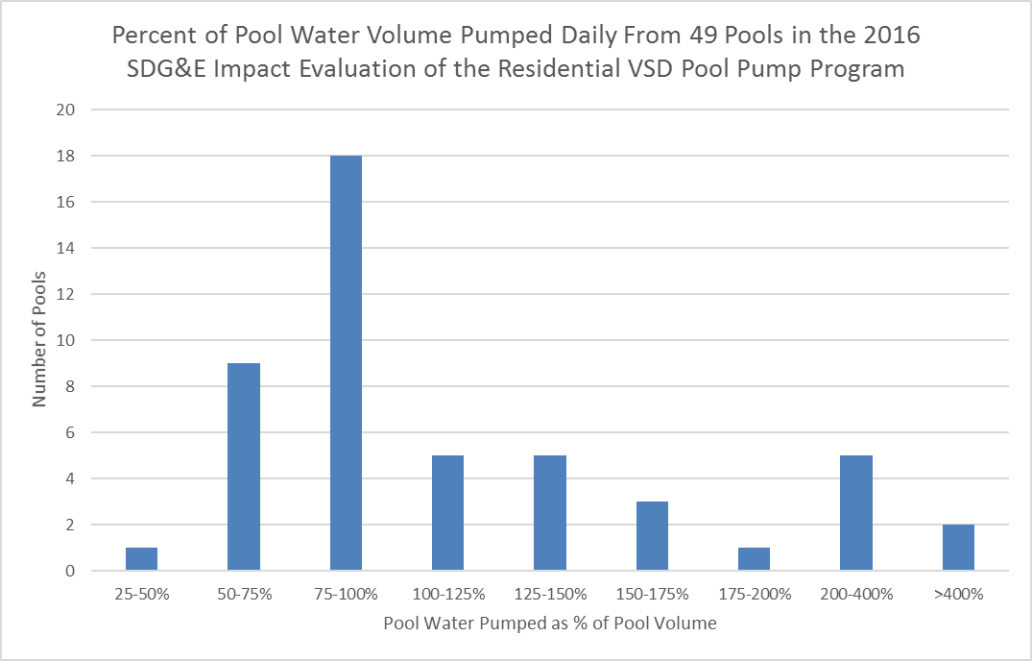

Figure 36: Observed turnover rates in SDG&E territory in 2016

Source: (DNV-GL 2016)

It is generally recommended that some of this filtration occur at a higher speed to enhance skimming functions and/or operate in-ground pool cleaners that don't require a pressure cleaner booster pump. As described above, the commonly recommended operations scheme for a self-priming pool pump includes roughly 2 hours at a high-speed setting (~1.3 kW) for cleaning and an additional 6-10 hours at low speed setting (~0.2 kW) for filtration depending on the pool size.

Because there are very few diurnal constraints, pool pumps can generally operate their cleaning or filtration modes any time during the day. Some recommendations, especially for very hot climates, indicate that pool pumps should at least continue to circulate water during part of the daytime hours to ensure proper chlorine generation and/or distribution.

The existing, but limited, data as described in the Literature Review, shows that pools generally operate during the daytime hours. Additionally, for the 2016 Impact Evaluation Report of SDG&E's pool pump rebate program, data were logged for 49 variable-speed pool pumps finding the peak operation around 1 PM - 2 PM year-round (DNV-GL 2016).

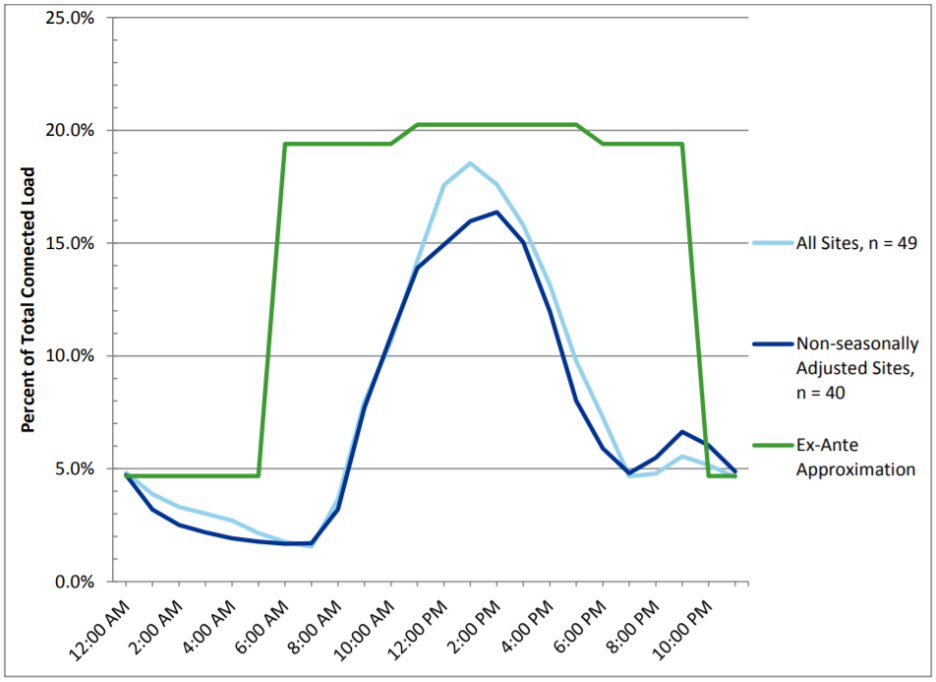

Figure 37: Variable-speed pool pump load profiles in SDG&E territory in 2016

Source: (DNV-GL 2016)

With the mandatory shift towards time-of-use (TOU) rates for all existing residential customers in SCE territory, there will be increased economic incentive to operate pool pumps during off-peak hours. There are likely many pool owners currently on volumetric rate schedules, who will be transitioned to time-of-use rates in 2020 and will likely reconsider their pool pump operating schedules to avoid higher TOU energy prices.

Connected Pool Pump Demand Response Use-Cases

With few technical or operational constraints, connected pool pumps have the potential to be a valuable flexible DR resource. Based on the definitions created by Lawrence Berkeley National Lab in the 2015 California Demand Response Potential Study, connected pool pumps have the potential to provide three of the four types of DR (LBNL 2015). There are a variety of ways pool pump flexibility can be harnessed and this section provides discussion on a few use case options:

- **Shape** captures DR that reshapes customer load profiles through price response or on behavioral campaigns or "load-modifying DR" with advance notice of months to days.
- **Shift** represents DR that encourages the movement of energy consumption from times of high demand to times of day when there is a surplus of renewable generation. Shift could smooth net load ramps associated with daily patterns of solar energy generation.
- **Shed** describes loads that can be curtailed to provide peak capacity and support the system in emergency or contingency events at the statewide level, in local areas of high load, and on the distribution system, with a range in dispatch advance notice times.

Connected pool pumps can effectively implement the three DR types above. This contrasts with other DR measures such as lighting which are not able to shift load to other times of the day. These three demand response types in the context of pool pumps are described further below.

SHAPE

Pool pumps in California (especially in warmer climates) generally operate 365 days per year, therefore there is significant opportunity to shape the operation of the pool during the day on a medium to long-term basis using economic signals such as TOU rates. Pool pumps are generally a "set-it and forget" type home appliance. However, connectivity offers the ability to shape the demand each day, week, month or season to best optimize the customer's energy usage, reduce their bills, and meet the needs of the grid. From a utility perspective, knowing when a pool pump is operating and being able to contrast that with the customer's rate schedule provides an opportunity to inform customers to shape the load and save money.

The first pool pump rebate program in California was in PG&E territory in 2000, which incentivized customers to change their time clocks for their pool pumps to operate during the "off peak" hours (avoiding the noon to 6 PM time frame). Fast forward to 2018, when Arizona Public Service began coordinating with smart variable-speed pool pump product owners to encourage off-peak operation. There is significant precedent to encourage pool owners to pump off-peak if they are not already doing so, with little-to-no likely customer resistance.

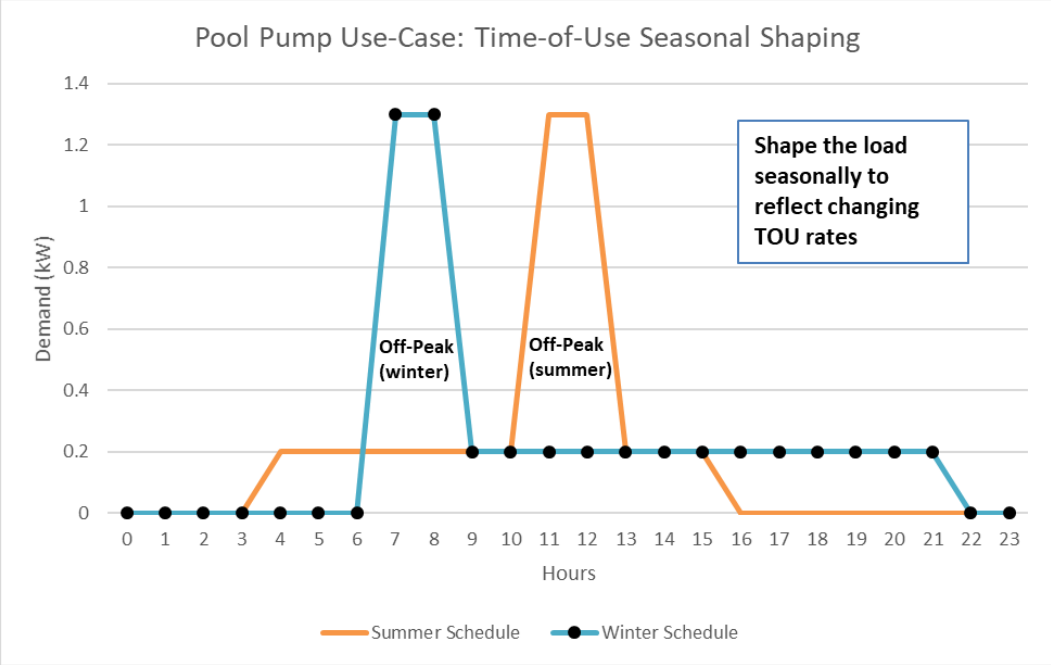

Figure 38: Shape Load Use Case

Key Considerations:

- Data has shown that most pool pumps operate in the middle of the day. With the changing TOU rates moving to the middle of the day to reflect off-peak due to reduced wholesale cost of energy from excess solar generation, many pool pumps may (subject to verification) already be planned operate off-peak, diminishing this opportunity for load shaping.

SHIFT: INCREASE LOAD

Increasing load is likely the most unique attribute of pool pumps relative to other residential loads. Simply put, a pool cannot technically be "over-pumped" or "over-filtered." Customer bill impacts aside, pool pumps can easily be called upon to absorb load, and with this operation pools will only become cleaner with little to no impact to chemical levels. For pools with salt-generators used to make chlorine, there may be some effect such as increased chlorine generation, but it is expected to be limited. However, the load a pool pump can absorb is a function of the pool pump and the pool plumbing system. Often, variable-speed pool pumps are oversized for what is required. This is a function of the limited sizes of products in the market and the practicality of a variable-speed pool pump being a one-size-fits-all solution.

For example, a pool service contractor may keep a 3 THP variable-speed pool pump on the truck or in their shop knowing it could meet the needs of any pool. However, simple because a pool pump *can* ramp to 3450 RPMs and draw (absorb) ~2.5 kW does not mean that any pool system's plumbing should be subject to these higher flows. While less of a concern on newer pools built with larger 2.5-inch plumbing, to minimize the (already low) risk of plumbing damage a reasonable upper power limit should be implemented that will likely be less than the pool pump's full capacity. From a utility's perspective, a good and conservative rule of thumb would be to not to operate the pump higher than the current highest speed setting set by the customer, pool and spa maintenance contractor or pool service company.

Key Considerations:

- Bill impact may be a concern if more energy is being consumed overall, even during off-peak.
- Not all pool pumps should be ramped to maximum capacity even if they can do so, to avoid potential plumbing and/or equipment damage. A rule of thumb would be to not operate the pump higher than the current highest speed setting set by the customer, pool and spa maintenance contractor or pool service company.

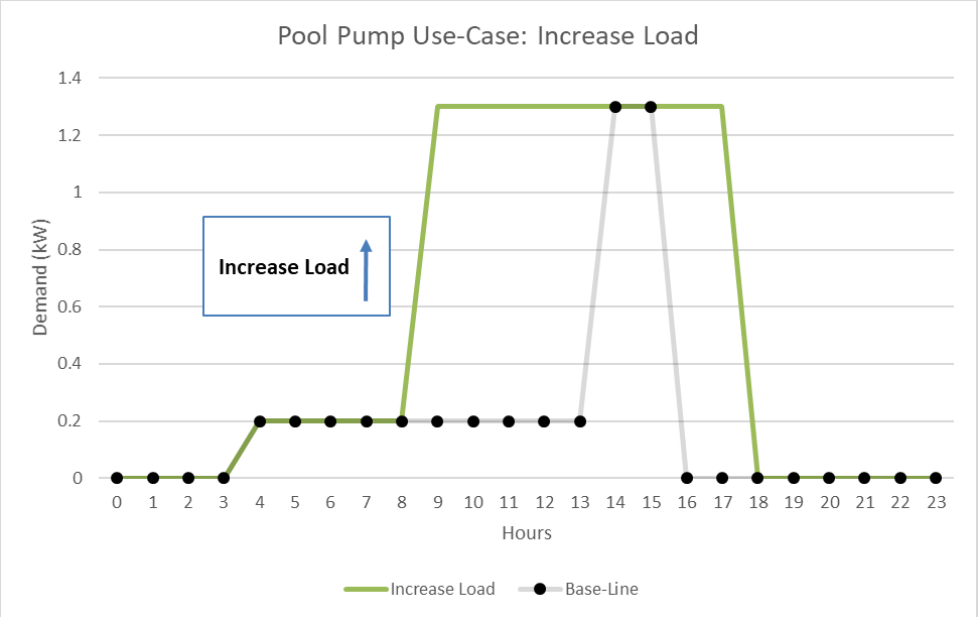

Figure 39: Increase Load Only Use Case

SHIFT

Load-shifting as defined by the LBNL study cited above is likely the easiest and lowest-risk use case for connected pool pumps. A pool's operation schedule and settings are usually tailored to the demands or needs of the pool system, or based on pool owner, pool service, or pool contractor preference. However, there is generally less preference as to exactly when the pool pump operates, especially in regard to a higher-speed cleaning mode, with two exceptions:

- If there are audible concerns, for example, operating the high-speed cleaning mode at night if the operation causes a disturbance.
- When the pool owners' electric cost changes bill if the high-speed cleaning cycle moves from off-peak to on-peak.

However, the benefit of this use case is that it ensures the same utility (i.e. cleaning and filtration to achieve a single turnover) from the pool pump is provided each day. In theory there would be no sacrifice of filtration or cleaning as the operation schedule is moved around, because the pool pump will run the same number of hours at the pre-determined speeds. This has the added benefit of working with the current pool owner's pumping set-up but adjusting the times of operation each day. The utility avoids telling a pool owner "how" to operate their pool pump, only "when," which may be an important program attribute for pool owners.

Key Considerations:

- Ensure any auxiliary equipment is connected and can operate at different times.
- If load shifting is used frequently, impacts to customer bills should be studied with consideration of whether load is being shifted away from off-peak periods.
- In some cases pool pumps may be located near the bedrooms of the pool owner (or the pool owner's neighbors), so audible high-speed operation may not be tolerable during certain hours.

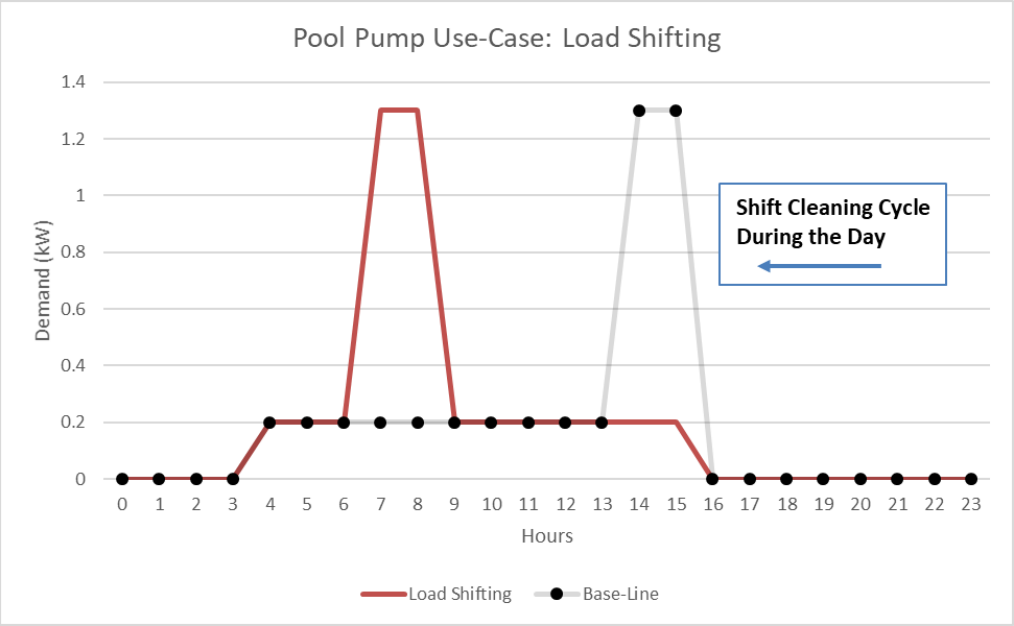

Figure 40: Load Shifting Use Case

SHED

In traditional DR, pool pumps are used to reduce or shed load. This is the only DR action pool pumps have performed at scale, as evidenced by the historic DR programs run in Florida, as described in the Literature Review. Because pool pumps are not a critical load, this can be done in numerous ways, the most obvious being to turn off the pump completely during an event. However, as the pool pump market continues to transform due to variable-speed equipment, the magnitude (kW) of the opportunity generally decreases. Pool pumps *should* be mostly operating at a low-speed filtration mode with a load around 0.2 kW during most hours of operation. This load itself is not significant enough to shed alone. However, it is recommended that variable-speed pool pumps operate for at least two hours at a higher speed for cleaning or to operate a pool cleaner, presenting a larger load to shed, upwards of 1.3 kW. This load also can be reduced with little to no interactive effects with other equipment, other than a slightly reduced cleaning performance on occasion. This would not become a significant issue, however, unless the cleaning mode were to be reduced on a regular basis, causing pool cleanliness to be impacted and customer acceptance eroded.

Key Considerations:

- Ensure any auxiliary equipment is connected and turned off during the event.
- To ensure water clarity, load shed DR events can likely only be called infrequently. Multiple 4-hour events back-to-back may result in insufficient filtration, especially in the heat of the summer when chorine distribution is important.

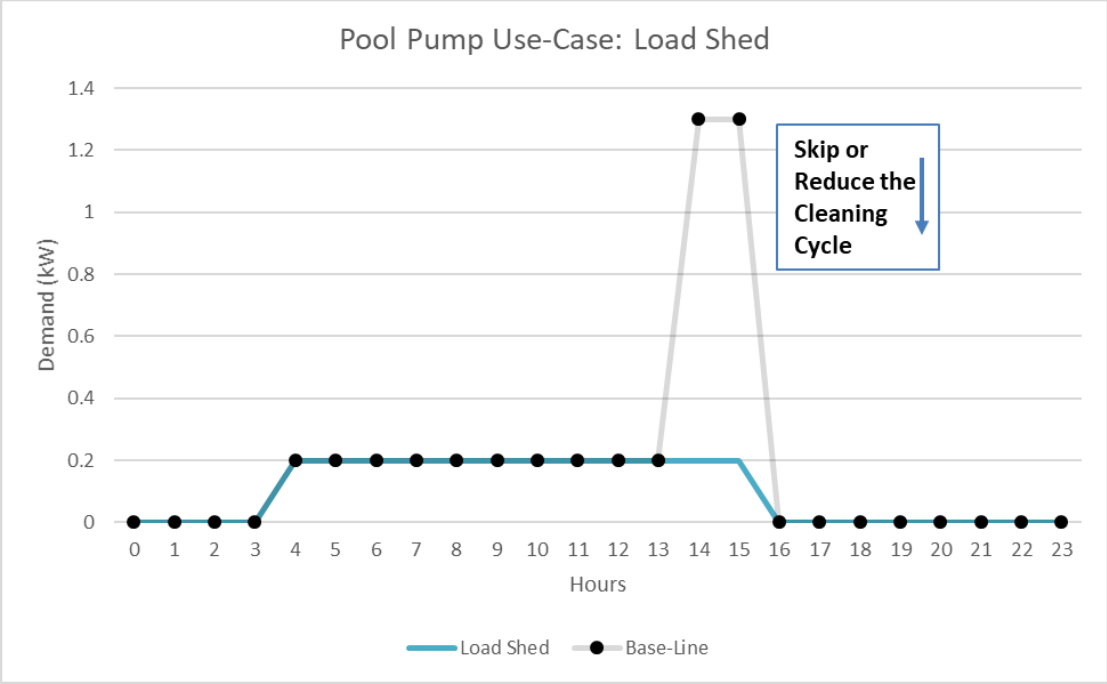

Figure 41: Shed DR Use Case

These are only four potential use cases, though at this time they are likely the use cases best suited for connected residential pool filtration pumps. An additional use case, not shown would be a real-time price-following use case where motor speed increases or decreases slightly due to real-time pricing signals. This use case is promising and may be demonstrated in *Task 4: Technology Demonstration* but

requires further research to better understand the potential impacts on pool cleanliness and interactive effects on auxiliary loads.

Connected Pool Pump Flexible Capacity in SCE Territory

The gross demand potential for pool pumps, at roughly 1,100 MW in SCE territory, is large. If all the residential in-ground pool pumps, including auxiliary pumps and above-ground pool pumps as described above were turned on at once, assuming high-speed settings where applicable, there would be nearly 1,100 MW of pool pumping demand. This assumes every pump meets DOE standards in 2021, which will not be the case until full stock turnover is achieved. However, given nearly a decade of incentive programs and a Title 20 standard since 2010 requiring at least two-speed pool pumps, the market is already relatively mature in terms of DOE-compliant equipment.

Of all the pool pumps previously described, the self-priming (in-ground) filtration pool pumps residential applications are market-ready for DR and represent a majority of the technical-connected load potential, at roughly 750 MW. These pool pumps are market-ready in the sense that they have been studied and tested as described in the Literature Review and connected capabilities are currently available from major manufacturers as described in the Technology Assessment. Market, economic and technology barriers remain to be overcome to achieve this potential, but manufacturers are offering connected products for this market segment. The gross demand and market-ready technical potential shown in Table 6 assumes coincidence of high-speed operation where each self-priming variable-speed pool pump operates on a generally recommended schedule of 6-10 hours at low-speed (0.2 kW) and 2 hours at high-speed (1.3 kW). Similarly, coincident low-speed operation would yield roughly 100 MWs of demand.

Table 6: Connected Pool Pump "Market-Ready" Technical Potential (MW)

	SCE Territory 2021 Stock	Gross Demand at High Speed (MW)	Market Ready Technical Potential (MW)
In-Ground Pool Pumps			
Small Self-Priming Pool Pumps (0.44 HHP/ 0.75 THP)	77,000	74	Not ready
Medium Self-Priming Pool Pumps (0.95 HHP/ 1.65 THP)	289,000	272	272
Large Self-Priming Pool Pumps (1.88 HHP/ 3.25 THP)	302,000	486	486
Booster Pumps (0.31 HHP/ 1.15 THP)	53,000	76	Not ready
Waterfall Pump (0.40 HHP/ 0.72 THP)	11,000	8	Not ready
Above-Ground Pool Pumps			
Non-Self-Priming pumps (0.09 HHP/ 0.16 THP)	21,000	9	Not ready
Non-Self-Priming pumps (0.52 HHP/ 0.9 THP)	179,000	195	Not ready
Total			
All Residential Pool Pumps	932,000	1,120	757

These gross and technical potential estimates are a function of the values found in the Table 7 which display power demand assuming the four equipment types described in this assessment comply with DOE standards. It is very important to note that pool pumps come in a variety of sizes for a variety of pools with different system pressures and features, and actual power draw varies widely based on settings. This estimate uses the representative units provided in the DOE rulemaking to give the best

shipment-weighted portrayal of DR potential in SCE territory. In general, the medium (1.65 THP) and large size (3.25 THP) self-priming pool pumps, as analyzed by DOE, are the common size variable-speed pool pumps found in residential in-ground pools. Shipment weighted, these self-priming variable-speed pool pumps that are market-ready for DR programs draw on average 1.3 kW at high-speed and around 0.2 kW at low speed.

Table 7: Summary of Connected Pool Pumps Resources

	Technology Summary (Assuming DOE Compliance)	High-Speed Demand (Watts)	Low-Speed Demand (Watts)
In-Ground Pool Pumps			
Small Self-Priming Pool Pumps (0.44 HHP/ 0.75 THP)	Efficient Single-speed	963	-
Medium Self-Priming Pool Pumps (0.95 HHP/ 1.65 THP)	Variable-speed	940	170
Large Self-Priming Pool Pumps (1.88 HHP/ 3.25 THP)	Variable-speed	1608	178
Booster Pumps (0.31 HHP/ 1.15 THP)	Efficient Single-speed	1429	-
Waterfall Pump (0.40 HHP/ 0.72 THP)	Single-speed (No code)	745	-
Above-Ground Pool Pumps			
Non-Self-Priming pumps (0.09 HHP/ 0.16 THP)	Efficient Single-speed	428	-
Non-Self-Priming pumps (0.52 HHP/ 0.9 THP)	Efficient Single-speed	1091	-

As shown above, other pool pumps are often found alongside self-priming filtration pumps in residential pools, including pressure-cleaner booster pumps and waterfall pumps that can account for additional connected load. However, both of these auxiliary pumps are estimated to be found at less than 10 percent of pools in SCE territory[7] (KEMA 2009) (DOE 2016). As described in the Technology Assessment, most manufacturers have accounted for controlling these auxiliary pumps within their connected product offerings but due to low market saturation and the additional complexity of trying to control and value this load in a DR program, auxiliary pool pumps should not be considered market-ready flexible load at this time. These auxiliary pumps are low in saturation and have not been studied and tested in recent years as self-priming filtration pumps have been. Though pools with auxiliary equipment are not the easiest and "lowest-hanging fruit" the mere presence of this equipment should not exclude pools from connecting the self-priming filtration pump as flexible load. Manufacturers have developed adequate controls to ensure equipment safety and proper operation of auxiliary pool pumps.

Finally, non-self-priming pool pumps which are used in the above-ground pool market are a significant resource in terms of load and significant shipments. These pool pump systems are generally very simple and do not typically have any auxiliary pumps, heaters, chlorinators, or other equipment, which can be attractive for a DR program. However, due to the lack of connected capabilities, seasonal operation considerations and cost sensitivities in this market segment, these pool pumps are not currently an ideal or market-ready flexible load.

[7] Northern CA (PG&E territory) is known to have a higher concentration of pressure cleaner booster pumps than the national average. Based on discussions with manufacturers and pool and spa maintenance contractors they are less common in Southern California therefore a national saturation, derived from DOE shipment data, was used.

Connected Pool Pump Market Commercialization

There are different business models and different market interventions strategies for SCE to consider incentivizing to realize the connected pool pump opportunity.

Business Models

The following business and deployment models have been or are currently being explored by various industry actors including manufacturers, utilities, and aggregators.

Utility → Aggregator → Manufacturer → Device: Aggregators may consider working with a manufacturer to leverage the manufacturer's cloud to collectively manage pool pump load. This may be achieved through an aggregator having the ability to receive an OpenADR 2.0A or B signal from utilities, then sending signals directly to the manufacturer's cloud to make changes to pump operations.

Utility→ Manufacturer → Device: Pool pump manufacturers may pursue a business model where they, as the manufacturer, would maintain the customer relationship and be able receive OpenADR 2.0 A or B signals and payments directly from a utility to make changes to pump operations.

Utility → Aggregator → Device: Utilities may consider engaging directly with an aggregator to recruit and control pool pumps. The CTA-2045 module was designed to be universal and adopted by many manufacturers, such that an aggregator could receive a signal from a utility and then send a signal directly to different pool pumps made by different manufacturers equipped with the same CTA-2045 module.

Utility → Device: Utilities may consider sending or installing CTA-2045 modules to identified pool owners and directly communicating with devices for load control. For decades, single-speed pool pumps have been managed via direct load control switches from Florida Power and Light and Duke Energy for peak demand response events.

Market Interventions Opportunities

There are several market intervention strategies which could create the incentive for residential connected pool pumps, including economic signals and technology incentives.

Economic Signals

Load Increase Program: A market incentive or a program to utilize excess supply would send a signal to connected pool pumps. The pump can run as long and as fast (in RPMs) as is technically feasible based on the limitations of the pool pumping system, customer bill impacts aside.

TOU Rates: Many pool customers may already be on TOU rates as there are significant economic benefits to pumping off-peak. As mandatory residential TOU rates are implemented in SCE territory, the off-peak period will be towards the middle of the day. Pool pumps not already on TOU rates will be encouraged to take advantage of the peak hour shift although existing data already shows many pool pumps already operate during the middle of the day. Daytime operation is also recommended by some manufacturers and pool professionals for chemical distribution during sunny and hot days.

Critical Peak Pricing (CPP): CPP programs are similar to TOU rates, but with 9-15 critical event days per year, and are well suited for connected pool pumps as reducing or shifting pool pumping will have very little impact on pool cleanliness or operations over the limited number of events of a DR season.

Flexible Ramp Products: The CAISO has a flexible ramping product which may be well suited for connected pool pumps. This includes 15- and 5-minute markets as well as ramp up and ramp down awards to account for grid uncertainty due to demand and renewable forecasting errors. The award prices are market based and historically have offered a higher incentive rate for the ramp up than ramp down product.

Proxy Demand Resource: Customers can bid DR services directly into the CAISO wholesale day-ahead and real-time markets by way of the proxy demand resource product. This participation is treated as a supply side resource. While this product has a minimum curtailment of 100 kW, smaller loads can be aggregated together to reach this threshold and need to work with a scheduling coordinator to participate in the energy market.

Technology Incentives

In addition to market incentives, there are a variety of ways residential connected pool pumps or connected controller retrofits on existing variable-speed pool pumps, could be incentivized and included in existing CA IOU ADR technology incentive programs.

Downstream: Incentives could be offered directly to pool owners to have connected equipment installed and then enrolled in a program, similar to Florida DR programs.

Midstream: Incentives could be offered to one of four different midstream actors: pool supply store retailers, pool service contractors, wholesale pool distributors or pool builders. Providing an incentive to any of these market actors would leverage scale to increase deployment.

- *Pool Supply Store:* Providing incentives to large retailers to offer or sell connected pool pumps could enable widespread adoption in a relatively streamlined manner, through a market actor that is a primary source of information for pool owners.
- *Pool and Spa Maintenance Contractor:* Incentives could be provided directly to, or split with, pool and spa maintenance contractors, as has been done for many years with the current variable-speed pool pump energy efficiency rebate in SCE territory. In the case of a pool and spa maintenance contractors, there may be added non-energy benefits that motivate participation. For example, connecting with Zodiac's platform would not only earn the contractor an incentive, but would also give the contractor visibility into their customers pool operations with alerts and other capabilities not typically remotely accessible to a pool service contractor. Additionally, a midstream incentive to the pool and spa maintenance contractors could encourage them to keep a connected offering "on the truck" such that when repairs occur, they have an incentive to up-sell connectivity with a variable-speed pool pump.
- *Wholesale Distributor:* Providing incentives at the wholesale level will impact equipment stocking and prices of equipment typically purchased by pool service contractors. Additionally, distributors serve as a significant technical resource to many pool and spa maintenance contractors.
- *Pool Builders:* The best and easiest time to install pool connectivity is when building the pool when all equipment can be thoughtfully designed ahead of time. Offering incentives to

licensed pool builders to install connected capabilities on new pools would align with other home new construction efforts to embed connectivity such as smart thermostats.

Upstream: Manufacturers with connected pool pump offerings have access to and the technical ability to control their fleet of customer-owned connected pool pumps. Providing incentives at the manufacturer level may result in manufacturers passing the savings down to pool owners to incent purchase of connected equipment. Additionally, because pool manufacturers control the data, they may be prepared to receive OpenADR signals themselves and be interested in receiving any incentives in exchange for DR program participation. There is also significant benefit in the manufacturer "owning" the relationship and offering an ongoing incentive to ensure long-term connectivity.

5. Conclusion

This Connected Pool Pump Market Assessment Interim Report documents Activity 1, 2 and 3 of the Market Assessment. The full SOW includes a field-testing component that will be completed in the fall of 2020 where connected pool pump equipment will be purchased, installed and tested at four residential pools in SCE territory. The final deliverable (to be published in the fourth quarter of 2020) will be the full market assessment report including descriptions of field installations, research conclusions and next steps to realize the opportunity from connected pool pumps.

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