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DRAFT STAFF REPORT

ANALYSIS OF EFFICIENCY STANDARDS FOR POOL PUMPS AND MOTORS, AND SPAS

2015 Appliance Efficiency Pre-Rulemaking

Docket Number 15-AAER-02

California Energy Commission

Edmund G. Brown Jr., Governor

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California Energy Commission

Ben Fischel
Sean Steffensen
Primary Authors

Elliot Bogart
Jessica Lopez
Bogdan Pishtoy
Research and Technical Support

Sean Steffensen
Project Manager

Kristen Driskell
Supervisor
Appliance Efficiency Program

Dave Ashuckian, P.E.
Deputy Director
EFFICIENCY DIVISION

Robert P. Oglesby
Executive Director

PREFACE

On March 14, 2012, the California Energy Commission issued an Order Instituting Rulemaking to begin considering standards, test procedures, labeling requirements, and other efficiency measures to amend the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through Section 1609). In this Order, the Energy Commission identified appliances with the potential to save energy and/or water. The goal of the rulemaking is to develop proposed appliance efficiency standards and measures to realize these savings opportunities.

On March 25, 2013, the Energy Commission released an "Invitation to Participate" to provide interested parties the opportunity to inform the Commission about the product, market, and industry characteristics of the appliances identified. The Commission reviewed the information and data received, and hosted workshops on May 28 through 31, 2013, to publicly vet this information.

On June 13, 2013, the Energy Commission released an "Invitation to Submit Proposals" to seek proposals for standards, test procedures, labeling requirements, and other measures to improve the efficiency and reduce the energy or water consumption of the identified appliances.

On May 28, 2014, the Energy Commission released a notice to request additional information from interested parties to develop standards for network equipment, commercial clothes dryers, portable electric spas, and pool pumps and motors.

The Energy Commission reviewed all of the information received to determine which appliances were candidates for efficiency standards and measures. This report contains the proposed regulations for portable electric spas, and pool pumps and motors.

ABSTRACT

This report discusses proposed updates to the pool pumps and motors, and portable electric spas standards in the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 to 1609). These proposed updates are part of the 2012 Appliance Efficiency Rulemaking, Phase I (Docket #15-AAER-02). California Energy Commission staff analyzed the cost-effectiveness and technical feasibility of proposed efficiency standards for pool pumps and motors, and portable electric spas. Statewide energy use and savings, and related environmental impacts and benefits are also included.

Staff proposes two tiers of standards for single-speed, dual-speed, multi-speed, and variable-speed motors sold in combination with pool pumps or sold separately as replacements. The proposed Tier 1 standard would take effect on January 1, 2018, and Tier 2 would take effect on January 1, 2021, for all pool pump motors 5 hp or less. The proposed standby power standard and label requirement for portable electric spas would take effect on January 1, 2018. In addition, staff proposes to amend and add definitions, and update test procedures so that the standards can be enforced effectively.

The proposed updates would save about 129 GWh the first year the standard is in effect. By the year that stock turns over (2026), the proposed standards would have a combined annual savings of about 1,320 GWh. This equates to roughly $211 million in annual savings to California businesses and individuals. In addition, GHG would be reduced by 455 thousand tons of carbon dioxide equivalents annually.

Staff analyzed available market data and concluded that the updates to standards for pool pumps and motors, and portable spas would significantly reduce energy consumption and are technically feasible and cost-effective.

Keywords: Appliance Efficiency Regulations, appliance regulations, energy efficiency, pool pumps and motors, portable electric spas.

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EXECUTIVE SUMMARY

The California Energy Commission proposes to create significant energy efficiency opportunities for pool pump motors and portable electric spas through Title 20 standards. The following Appliance Efficiency Program analysis provides support for the proposed standards. Staff analysis demonstrates that the proposed pool pump motor and portable electric spa standards are technically feasible for the industry and cost-effective for consumers. After full stock turnover, the proposed standards combine for an estimated 1,320 GWh of statewide energy savings per year.

Staff is proposing to expand the existing scope of pool pump and motor combinations (pump and motor packaged together), and replacement pool pump motors (standalone motors) that are used for filtration and circulation, water features and waterfalls, and as booster pumps. The proposal includes modifications and additions to the pool pump and motor definitions to meet the new scope expansion and ensure that the standards can be enforced effectively. Test procedures are proposed for all pool motors from CSA 747-09 and for all pool pumps from ANSI/HI-14.6 2011.

Two tiers of standards are proposed for single-speed, dual-speed, multi-speed, and variable-speed motors sold in a combination with pool pumps or sold separately as replacements. During Tier 1, the proposed minimum efficiency requirement for single-speed motors at full speed shall be 70 percent; and for variable-speed, multi-speed, and dual-speed motors at full speed and at half speed, shall be 70 percent and 50 percent, respectively. When Tier 2 begins, the proposed minimum efficiency requirement for single-speed motors at full speed shall be 80 percent; and for variable-speed, multi-speed, and dual-speed motors at full speed and at half speed, shall be 80 percent and 65 percent, respectively. The proposed Tier 1 standard would take effect on January 1, 2018, and the Tier 2 standard would take effect on January 1, 2021, for all pool pump motors that are 5 hp or less. The proposed standards would result in an estimated 117 GWh of first-year energy savings and an estimated 1,778 GWh of energy savings after full stock turnover.

New standards for portable electric spas are also proposed. The scope includes all types of portable electric spas, such as exercise spas, combination spas, swim spas, and inflatable spas. Staff proposes to adopt the ANSI/APSP/ICC-14 2014 standby power standard, new test requirements, and label requirements. The standby power standard will tighten power consumption on larger spas while providing modest relief on smaller spas. The test method provides elaboration on test setup and measurements. The label standard requires manufacturers to display the standby power and list the spa cover that was used during testing to achieve the reported standby power. The label requirement will help consumers make informed choices based on energy, boosting energy savings. The proposed standards would take effect on January 1, 2018. The estimated standby power savings after complete stock turnover is 61 GWh with $10 million in cost savings. The label requirement will have an additional estimated 80 GWh of energy savings with $13 million of cost savings after complete stock turnover.

CHAPTER 1: Legislative Criteria

Section 25402(c)(1) of the California Public Resources Code mandates that the California Energy Commission reduce the inefficient consumption of energy and water by prescribing efficiency standards and other cost-effective measures[1] for appliances that require a significant amount of energy and water to operate on a statewide basis. Such standards must be technologically feasible and attainable, and must not result in any added total cost to the consumer over the designed life of the appliance.

In determining cost-effectiveness, the Energy Commission considers the value of the water or energy saved, the effect on product efficacy for the consumer, and the life-cycle cost to the consumer of complying with the standard. The Commission also considers other relevant factors including, but not limited to, the effect on housing costs, the total statewide costs and benefits of the standard over the lifetime of the standard, the economic impact on California businesses, and alternative approaches and the associated costs.

1 These include energy and water consumption labeling, fleet averaging, incentive programs, and consumer education programs.

CHAPTER 2: Efficiency Policy

The Warren-Alquist Act[2] establishes the Energy Commission as California's primary energy policy and planning agency and mandates that the Commission reduce the wasteful and inefficient consumption of energy and water in the state by prescribing standards for minimum levels of operating efficiency for appliances that consume a significant amount of energy or water statewide.

For nearly four decades, appliance standards have shifted the marketplace toward more efficient products and practices, reaping large benefits for California's consumers. The state's appliance efficiency regulations saved an estimated 22,923 GWh of electricity and 1,626 million therms of natural gas in 2012[3] alone, resulting in about $5.24 billion in savings to California consumers in 2012 from these regulations[4]. Since the mid-1970s, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed in the state. In the 1990s, the CPUC de-coupled the utilities' financial results from their direct energy sales, facilitating utility support for efficiency programs. These efforts have reduced peak load needs by more than 12,000 MW and continue to save about 45,519 GWh per year of electricity[5]. Still, there remains huge potential for additional savings by increasing the energy efficiency and improving the use of appliances.

Reducing Electrical Energy Consumption to Address Climate Change

Appliance energy efficiency is identified as a key to achieving the GHG emission reduction goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006)[6] (AB 32), as well as the recommendations contained in the ARB's *Climate Change Scoping Plan*[7]. Energy efficiency regulations are also identified as key components in reducing electrical energy consumption in the Energy Commission's *2013 Integrated Energy Policy Report* (*IEPR*)[8] and the 2011 update to the CPUC's *Energy Efficiency Strategic Plan*[9]. Finally, Governor Brown identified reduced energy

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2 The Warren-Alquist State Energy Resources Conservation and Development Act, Division 15 of the Public Resources Code, § 25000 et seq, available at http://www.energy.ca.gov/2015publications/CEC-140-2015-002/CEC-140-2015-002.pdf.
3 California Energy Commission. *California Energy Demand 2014-2024 Revised Forecast*, September 2013, available at http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC-200-2013-004-V2-CMF.pdf.
4 Using current average electric power and natural gas rates of: residential electric rate of $0.164 per kilowatt-hour, commercial electric rate of $0.147 per kilowatt-hour, residential gas rate of $0.98 per therm, and commercial gas rate of $0.75 per therm. This estimate does not incorporate any costs associated with developing or complying with appliance standards.
5 *California Energy Demand 2014-2024 Final Forecast* available at http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC-200-2013-004-V2-CMF.pdf, p. 86.
6 AB 32, California Global Warming Solutions Act of 2006, available at http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.html.
7 *Climate Change Scoping Plan* available at http://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf.
8 California Energy Commission, *2013 Integrated Energy Policy Report*, January 2014, available at http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-CMF.
9 CPUC, *Energy Efficiency Strategic Plan,* updated January 2011, available at

consumption through efficiency standards as a key strategy for achieving his 2030 GHG reduction goals[10].

Loading Order for Meeting the State's Energy Needs

California's loading order places energy efficiency as the top priority for meeting the state's energy needs. *Energy Action Plan II* continues the strong support for the loading order, which describes the priority sequence for actions to address increasing energy needs. The loading order identifies energy efficiency and demand response as the preferred means of meeting growing energy needs[11].

For the past 30 years, while per capita electricity consumption in the United States has increased by nearly 50 percent, California electricity use per capita has been nearly flat. Continued progress in cost-effective building and appliance standards and ongoing enhancements to efficiency programs implemented by investor-owned utilities (IOUs), publicly owned utilities, and other entities have significantly contributed to this achievement[12].

Zero-Net-Energy Goals

The *California Long-Term Energy Efficiency Strategic Plan*[13], adopted in 2008 by the CPUC, and developed with the Energy Commission, the ARB, the state's utilities, and other key stakeholders, is California's roadmap to achieving maximum energy savings in the state between 2009 and 2020, and beyond. It includes four "big bold strategies" as cornerstones for significant energy savings with widespread benefit for all Californians[14]:

- All new residential construction in California will be zero-net-energy (ZNE) by 2020.
- All new commercial construction in California will be ZNE by 2030.
- HVAC will be transformed to ensure that energy performance is optimal for California's climate.
- All eligible low-income customers will have the opportunity to participate in the low-income energy efficiency program by 2020.

These strategies were selected based on their ability to achieve significant energy efficiency savings and bring energy-efficient technologies and products into the market.

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http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.
10 Gov. Edmund G. Brown Jr., 2015 Inaugural Address, available at http://gov.ca.gov/news.php?id=18828
11 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF , p. 2.
12 *Energy Action Plan II,* available at http://www.energy.ca.gov/energy_action_plan/2005-09-21_EAP2_FINAL.PDF, p. 3.
13 California Energy Commission and CPUC, *Long-Term Energy Efficiency Strategic Plan,* updated January 2011, available at http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.
14 California Energy Commission and CPUC, *Long-Term Energy Efficiency Strategic Plan*, available at http://www.cpuc.ca.gov/NR/rdonlyres/14D34133-4741-4EBC-85EA-8AE8CF69D36F/0/EESP_onepager.pdf , p. 1.

On April 25, 2012, Governor Brown further targeted ZNE consumption for state-owned buildings. Executive Order B-18-12[15] requires ZNE consumption for 50 percent of the square footage of existing state-owned buildings by 2025 and ZNE consumption from all new or renovated state buildings beginning design after 2025.

To achieve these goals, the Energy Commission has committed to adopting and implementing building and appliance regulations that reduce wasteful energy and water consumption. The *Long-Term Energy Efficiency Strategic Plan* directs the Commission to develop a phased and accelerated "top-down" approach to more stringent codes and standards[16]. It also calls for expanding the scope of appliance standards to plug loads, process loads, and water use. The Commission adopted its detailed plan for fulfilling these objectives in the *2013 IEPR*[17].

Governor's Clean Energy Jobs Plan

On June 15, 2010, as a part of his election campaign, Governor Brown proposed the *Clean Energy Jobs Plan*[18], which directed the Energy Commission to strengthen appliance efficiency standards for lighting, consumer electronics, and other products. The Governor noted that energy efficiency is the cheapest, fastest, and most reliable way to create jobs, save consumers money, and cut pollution from the power sector. He stated that California's efficiency standards and programs have triggered innovation and creativity in the market. Today's appliances are not only more efficient, but they are cheaper and more versatile than ever due, in part, to California's leadership in the area.

15 Office of Edmund G. Brown Jr., Executive Order B-18-12, April 25, 2012, available at http://www.gov.ca.gov/news.php?id=17506http://gov.ca.gov/news.php?id=17506.
16 California Energy Commission and CPUC, *Long-Term Energy Efficiency Strategic Plan*, p. 64.
17 California Energy Commission, *2013 IEPR*, pp. 21-26.
18 Office of Edmund G. Brown Jr., *Clean Energy Jobs Plan,* available at http://gov.ca.gov/docs/Clean_Energy_Plan.pdf.

PART A: POOL PUMPS AND MOTORS

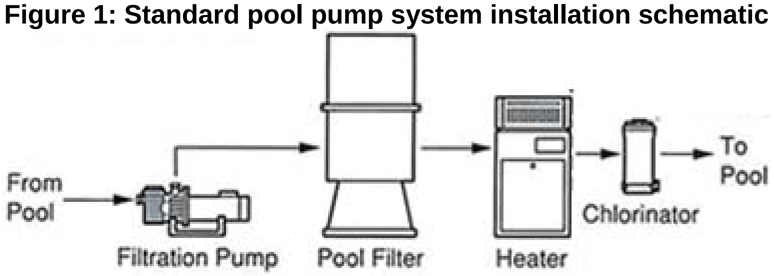
CHAPTER 3: Product Description

Overview of Pool Water Circulation System

The pool water circulation system incorporates the technological advances in filtering and chlorination first introduced to reduce frequent outbreaks in waterborne illness in the drinking supply system. Pool users demand that pool water be clean and clear, and that the water be free of disease-causing pathogens such as typhoid, dysentery, and cholera. The pool circulation system provides the essential functions to meet both aesthetic and safety requirements[19].

A pool pump and motor combination circulates pool water through a filter and ensures adequate chlorination to maintain clarity and sanitation. The filter removes dirt, leaves, hair, insects, and other debris. The heater maintains the water temperature, and the chlorinator adds sanitizing disinfectants, oxidizers, and algaecides. A search of online pool pump and motor vendors shows many recommend that residential pool systems be designed to circulate the entire pool water volume in 8 to 12 hours[20,21,22]. Commercial pool systems are designed to complete circulation or turnover in 6 hours due to their higher level of use[23]. A common pool system configuration including these components can be seen in **Figure 1.**

Figure 1: Standard pool pump system installation schematic



Source: epoolshop.com

Pool maintenance programs are typically broken up into filtering, heating, and cleaning applications. An in-ground spa will require an additional application to provide high speed jets for spa massage. These maintenance applications as well as the pool equipment types, pool plumbing design, and pool volume influence the pool pump and motor sizing.

19 *The History of Drinking Water Treatment*, U.S. EPA Feb, 2000, available at http://www.epa.gov/safewater/consumer/pdf/hist.pdf.
20 *Hayward Hydraulics and Pump Sizing for Existing Pools*, Hayward Industries, 2011, p. 7, available at http://www.nuccibros.com/sec_0934drRb_dl/data_sheets/Hydraulics%20%20and%20Pump%20Sizing%20for%20Existing%20Pools%20Guide.pdf.
21 *How to Size a Pool Pump for Your In-Ground Pool*, INYO Pools, 2015, available at http://www.inyopools.com/HowToPage/how_to_size_a_pool_pump_for_your_in_ground_pool_.aspx.
22 *Pool Pump Sizing*, poolplaza.com, 2015, available at https://www.poolplaza.com/pool-pump-sizing.
23 California Health and Safety Code Sections 116064.2 (b) (2) (E).

Filtering is the primary maintenance task for pools. A filtering time should be selected that will ensure adequate water turnover (the entire pool water volume will be filtered once per day). Significant energy and cost savings can be achieved if the pump is set to the lowest possible speed that will result in complete water filtration. In addition, at lower speeds, the filtration system will more completely clean the water as less water will bypass the filter at lower flow rates.

The heater task requires a minimum flow rate to ensure efficient heat transfer within the heating system and to protect against overheating. A moderate to high flow rate should be selected according to the heater guidelines.

The cleaning and in-ground spa tasks require the highest flow. The cleaning task provides a high flow rate into the pool to stir up settled debris so that it is captured by the filter. The jet task in in-ground spa applications also requires a high flow to provide the user with a therapeutic massage. The cleaning and jet tasks are typically shorter in duration than the pool filtering task.

Figure 2: Pool Plumbing System Complete with Filter, Heater, Skimmer, and Pump and Motor Combination

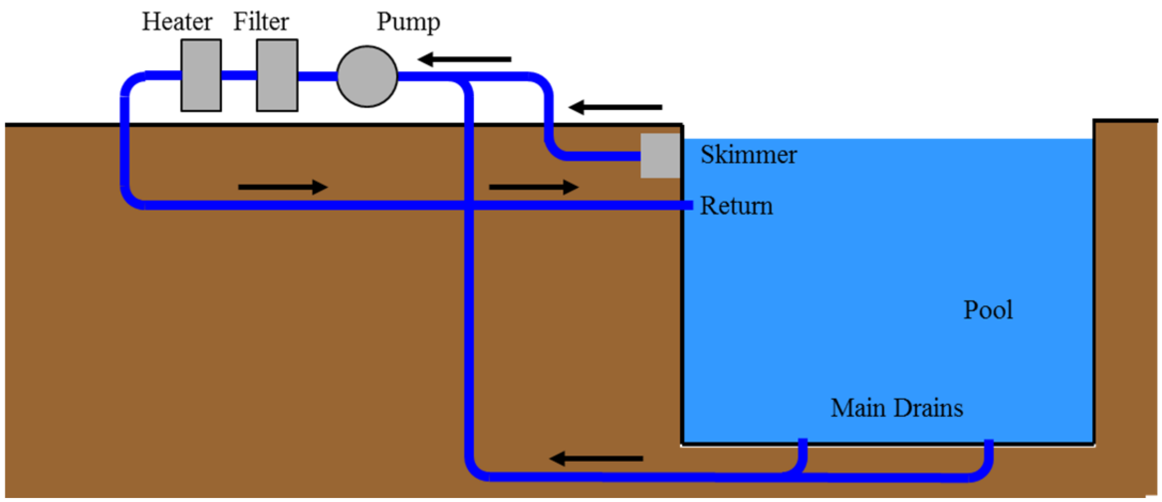


Illustration Credit: Staff Illustration

The pool pump motor combination may also be called upon to provide water flow to the pool sweeper and vacuum, and to run water features such as a waterfall or fountain. Motors used in these applications are run at full speed for longer durations, resulting in substantial energy consumption[24].

24 U.S. DOE, *Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings*, pp. 2-3, available at http://www.nrel.gov/docs/fy12osti/54242.pdf.

A pool owner can achieve significant energy savings by running the pool pump and motor combination at the lowest available motor speed that meets the task's minimum water flow requirements[25]. Different motor technologies exist to allow the consumer to select the speed adequate to the pool maintenance task to achieve energy savings. Variable-speed pool pump and motor combinations provide the most flexibility and provide the greatest savings. Dual-speed motors provide a low-speed choice to enable savings for the pool filtering task. Single-speed pool pump and motors require all pool maintenance tasks to be run at full speed and do not provide a choice in motor speeds.

Pump and Motor Equipment Description

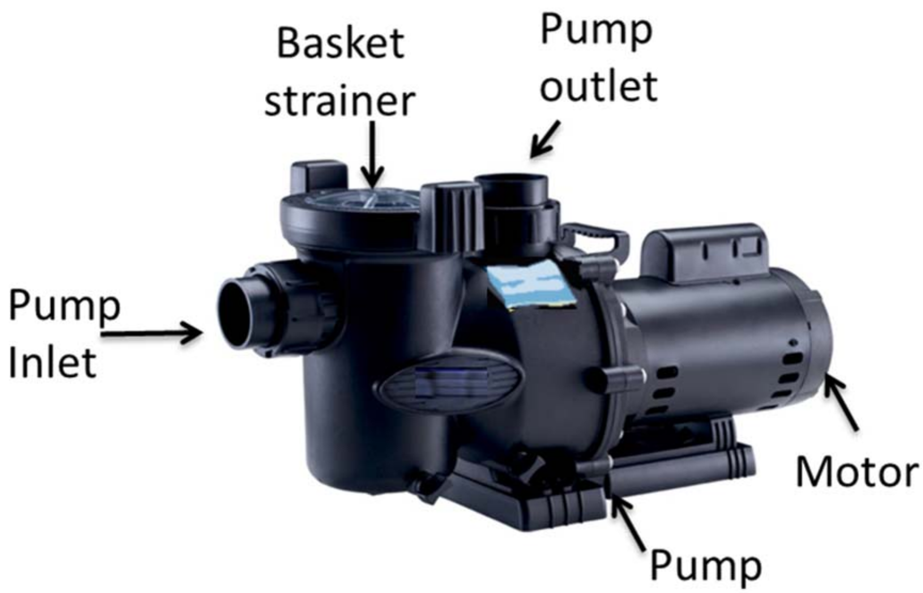
The pool pump relies on an end suction centrifugal rotor design to move the water through the system. The pump draws water through the center of the pump's impellor and generates a pressure force sufficient to overcome flow resistance in the pool's plumbing system. The pressure head forces the water through the pool's plumbing, filtering equipment, and heater. Pool pumps use end suction centrifugal pump designs exclusively due to their low initial cost, low complexity, and moderate energy efficiency when compared to double suction centrifugal pumps or positive displacement pumps[26].

An electric motor powers the pump by converting electrical energy to rotational energy. The electric motor is typically sized between 0.1 and 5.0 nameplate hp. The motor may provide single-speed, dual-speed, multiple-speed, or variable-speed operation depending upon the electric motor design.

Pool pump and motor combinations are typically sold when a consumer installs a pool or upgrades an existing pool pump and motor combination from a single-speed to a dual-speed or variable-speed system. Pool pump and motor combinations are also sold with above ground storable pools. As a low cost alternative, electric motor manufacturers sell replacement pool pump motors since the motor typically fails before the pump. Electric motors used in pool pump applications have a lifetime expectancy of about 10 years. Replacement pool pump motors are included within the scope of this report. **Figure 3** shows a typical pool pump and motor combination. **Figure 4** shows a typical replacement pool pump motor.

25 *Variable Speed Pumping, A Guide to Successful Applications*, Executive Summary, pp. 4-5 available at http://www.energy.gov/sites/prod/files/2014/05/f16/variable_speed_pumping.pdf.
26 *Improving Pumping System Performance, A Sourcebook for Industry*, U.S. DOE Second Edition, pp. 13-14, available at http://energy.gov/sites/prod/files/2014/05/f16/pump.pdf.

Figure 3: Pool Pump and Motor Combination



Source: Hayward Pools

Figure 4: Replacement Pool Pump Motor

Source: Century A.O. Smith

Pool Circulation System Energy Consumption

The pool circulation energy consumption consists of the energy dissipated by the circulation process since the pool water begins and ends in the same location. The pool water is drawn from the pool, pushed through the plumbing system and returned to the pool. The energy is dissipated by energy losses in the electrical motor and frictional losses within the plumbing system.

The total energy consumption of a pool circulation system depends on the motor efficiency, the pump efficiency, pool plumbing configuration, and the options available to the user to select pump motor speed and run time.

In-ground public swimming pool and plumbing configurations are regulated by California Health and Safety Code (Sections 116025 through 116068) and California Building Code, Title 24, Part 2 (Sections 3101B through 3162). Residential in-ground and above-ground swimming pools and spas are regulated by California Building Code, Title 24, Part 6 (Sections 110.4 and 150.0 (p)). The requirements control the design of new pools and the significant retrofit of existing in-ground public swimming pools and residential in-ground swimming pools and spas to ensure safe and energy efficient pools, and pool maintenance. The regulations control the placement of pool inlets and outlets, skimmers and drains, pipe sizing, and the use of pipe elbows. The pool system configuration requirements are outside the scope of the Title 20 Appliance Efficiency Standards, but understanding them is relevant to determining the representative energy performance of the pool pump and motor.

The energy dissipated in the plumbing system is proportional to the speed or flow rate that the water is pushed through plumbing system[27]. The energy loss phenomenon is similar to the energy losses encountered by a car from wind resistance. Just as a car will achieve better fuel economy at lower speeds by reducing the wind resistance, a pool system will achieve greater efficiency by reducing the resistance in the plumbing system at lower flow rates. The phenomenon is described by the three pump affinity laws shown below that are applicable to a wide field of systems utilizing pumps and fans, and including pool circulation systems. The laws describe how varying the pump rotational speed affects the flow rate, pressure, and power performance of a pump system.

Pump Affinity Law 1 Flow Rate (gallon per minute)

$q_1/q_2 = (n_1/n_2)$

where q = volume flow rate (gpm,) and n = Motor Speed - revolution per minute (rpm)

Pump Affinity Law 2 Head or Pressure (psi)

$h_1/h_2 = (n_1/n_2)^2$

where h = head or pressure (psi)

Pump Affinity Law 3 Power (kW or hp)

$P_1/P_2 = (n_1/n_2)^3$

where P = power (kW, hp)

27 U.S. DOE, *Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings*, pp. 3-4, available at http://www.nrel.gov/docs/fy12osti/54242.pdf.

Energy Consumption (kWh)

Energy = Power × time

According to the pump affinity laws, there is a cubic relationship between the power requirement of the motor and the rotational speed of the attached pump. Therefore, if a pump rotor speed were reduced to one half of its maximum, the electrical power demanded by the motor would be reduced to one eighth of its maximum. The pump affinity laws also state that the volumetric flow rate is directly proportional to the speed of the motor. For example, the volumetric flow rate through a pump would be reduced by half if the rotational speed of the attached pump is reduced by half[28]. To achieve the same volume of flow the pump must be run twice as long at half speed. The total energy consumed then, as defined by power multiplied by time, is 25 percent of the energy to move the same quantity of water at the pump's full speed. Substantial energy savings can be realized by running the motor at the lowest speed adequate to meet the needs of the pool maintenance application.

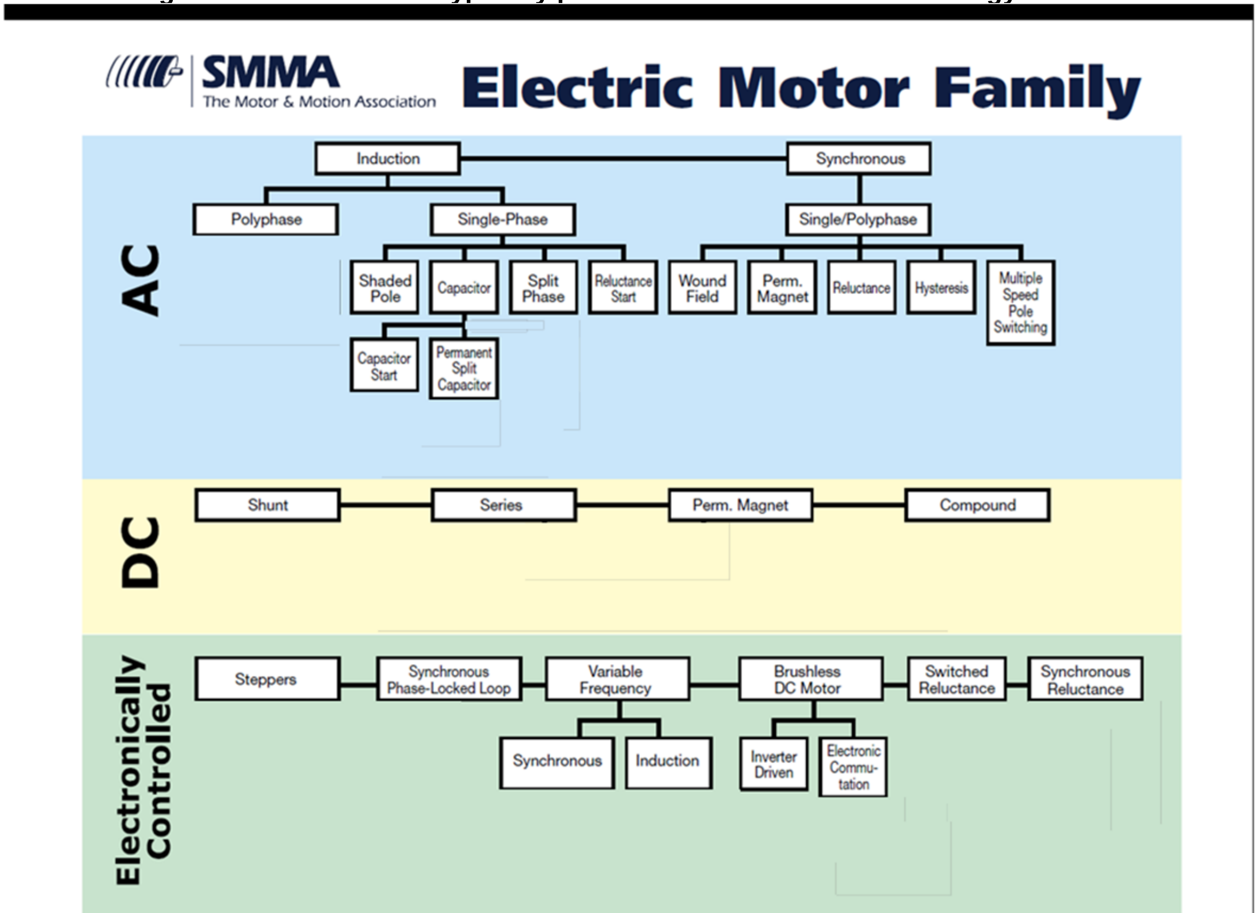
Motor Energy Consumption and Efficiency

The electric motor's type, design, and size determine the motor's efficiency. Motor types for pool circulation applications include single-phase alternating current (AC) induction, three-phase AC induction, and electrically-commutated brushless motors. Smaller above-ground pools utilize permanent magnet synchronous pool pump motors. Single-phase AC induction motors can achieve full speed efficiencies between 64 and 83 percent, and three-phase induction AC and electronically commutated motors can achieve full speed efficiencies between 77 and 92 percent[29]. Three-phase AC induction motors are more energy efficient than single-phase induction motors although their application is limited to sites that have three-phase electrical service. Different motor types are summarized by power type and motor technologies as seen in **Figure 5**. The ranges of efficiency and differences between motor types are discussed in Chapter 8.

28 *Pump Affinity Laws*, The Engineering Toolbox, available at http://www.engineeringtoolbox.com/affinity-laws-d_408.html.

29 Average motor efficiency of models found in the Appliance Efficiency Database of Title 20 compliant pool pump motors.

Figure 5: Electric motor types by power source and motor technology.



Source: Small Motors and Motion Association

Pool Pump and Motor Categories

Single-Speed Pumps

Single-speed pool pumps are powered by single-phase or three-phase AC induction motors. The motor design requires full-speed operation at the pump's highest flow and pressure capacity. Single-speed pumps cost significantly less and are simpler to install and control than dual-, multiple-, or variable-speed pumps. Due to the simplicity of installation and low cost, the majority of pool pump motors in California are single-speed motors[30]. Single-speed pumps are the least energy efficient pool pump type because the pump and motor must be run at full speed for all pool operations. Single-speed pump and motors dominate the pool pump market even as more energy efficient designs are mandated by regulation[31]. Single-speed pump and

30 Eaton, Eileen, *CEE High Efficiency Residential Swimming Pool Initiative*, December 2012, pp. 18-19.
31 CASE Report, *Analysis of Standards Proposal for Residential Swimming Pool & Portable Spa Equipment*, pp. 20-22, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-

motors persist in the market due to a lack of awareness among consumers and contractors regarding the regulation and energy savings of more efficient pump designs. An additional barrier is a need to educate pool contractors on how to select, install, and configure non single-speed pump systems to achieve energy savings while maintaining pool cleanliness[32].

Dual-/Multiple-Speed Pumps

Dual-speed pump motors are powered by single-phase AC induction motors. The motor design allows for dual-speed operation at the pump and motor's full and half speeds. At full speed, equivalent to a single-speed pump operation, the pump generates its highest flow and pressure, but this is the least energy efficient operational speed due to higher frictional losses within the pools' plumbing system. The pool's cleaning and vacuuming tasks require full-speed pump and motor operation to agitate and remove debris as effectively as possible. The pool's circulation for filtration tasks requires less flow and pressure, making the half-speed operation suitable for these tasks[33]. The lower operating speed results in more energy efficient operation because losses within the pool plumbing system are minimized. While the pump will need to operate twice as long to move the same quantity of water, the power consumption during this time will be 1/8, resulting in roughly 75 percent energy savings over full speed operation. Multiple-speed pump motors are similar in construction to dual-speed pump motors, but allow the user to select from three or more set speeds, rather than just half speed and full speed. The multiple speed pump may allow a user to select a more suitable and lower power pump speed for the task and thereby provide more savings.

Variable-Speed Pumps

Variable-speed pump motors are powered by electronically commutated motors (ECM) that allow a user to select a speed most appropriate for the pool maintenance task. Electronics on board the motor modify the incoming AC current and commutate the current to a three-phase waveform to set the motor speed and minimize electrical losses within the motor. A variable-speed motor may provide speeds between a minimum of 1/8 of full speed to full speed[34].

A variable-speed pool pump motor accrues energy savings exceeding dual- and multiple-speed motors in two ways. First, the user may select a speed slower than half speed or the lowest set speed on a multiple-speed motor to accomplish the pool's circulation and filtering tasks, resulting in energy savings. In addition, the slower speeds achieved by variable-speed motors

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2F_Residential_Pool_Pumps_and_Replacement_Motors/California_IOUs_Response_to_the_Invitation_to_Submit_Proposals_for_Pool_and_Spas_2013-07-29_TN-71756.pdf.

32 Eaton, Eileen, *CEE High Efficiency Residential Swimming Pool Initiative*, Consortium for Energy Efficiency, Inc., Dec. 2012, pp. 18-20.

33 Davis Energy Group, *Analysis of Standards Options for Residential Pool Pumps, Motors, and Controls*, pp. 11-12, available at http://consensus.fsu.edu/FBC/Pool-Efficiency/CASE_Pool_Pump.pdf.

34 CASE Report, *Analysis of Standards Proposal for Residential Swimming Pool & Portable Spa Equipment*, pp. 5-6, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2F_Residential_Pool_Pumps_and_Replacement_Motors/California_IOUs_Response_to_the_Invitation_to_Submit_Proposals_for_Pool_and_Spas_2013-07-29_TN-71756.pdf.

offer quieter operation and longer service life than can be achieved at half speed with a dual-speed motor.

Second, variable-speed motors utilize a permanent magnet rotor design that replaces the electro-magnetic rotor design in AC induction motors. The variable-speed motor achieves greater efficiency than the AC induction motor while running at the same speed because no current is required to power the rotor magnet, as is required by the AC induction motor[35].

35 *Machine Design, The difference between AC induction, permanent magnet, and servomotor technologies*, available at http://machinedesign.com/motorsdrives/difference-between-ac-induction-permanent-magnet-and-servomotor-technologies.

CHAPTER 4: Regulatory Approaches

Historical Approach

The California Energy Commission did not regulate pool pumps and motors before 2004. Most pool pump and motor systems used single-speed motors with some systems utilizing fairly inefficient electric motor types. In 2004, the Energy Commission adopted standards for residential pool pumps and motors, which included a prohibition on inefficient split-phase or capacitor-start induction electric motors, and a requirement that all pumps and motors that have a total of 1 hp or greater provide at least two-speed operation and controllers. The 2004 standards prohibition on split-phase or capacitor-start induction motors took effect in January 2006 and the two-speed requirements for pool pump motors 1 hp or greater took effect in January 2008.

In 2008, the Energy Commission adopted revisions to the 2004 standards, which included a requirement that motors 1 hp or greater, manufactured after January 2010, shall be capable of at least two speeds or be of variable-speed design. The scope of the regulation was expanded to include replacement residential pool pump motors[36].

The regulation has required that manufacturers test and certify all pool pump and motor combinations and replacement pool pump motors sold or offered for sale in California. The testing included motor efficiency and pump performance along three hydraulic system curves, A, B, and C, intended to simulate the types of pools found in California.

Federal Regulations

At the current time, there are no federal standards for pool pumps and motors.

The U.S. DOE released a Request for Information for dedicated-purpose pool pumps on May 8, 2015, (80 Fed. Reg. 26475), resulting from negotiations during its commercial and industrial pumps rulemaking. Among other things, the Request seeks to define dedicated-purpose pool pumps and asks whether a negotiated rulemaking is feasible.

California Regulations

The 2013 California Building Code set standards to regulate the construction and operation of public swimming pools. Both regulations require that the pool circulation system must achieve

36 Chrisman, Betty, Harinder Singh, Gary Flamm, and William Staak, *Proposed Amendments to the Appliance Efficiency Regulations*, Dec. 2008, p. 2, available at http://energy.ca.gov/2008publications/CEC-400-2008-021/CEC-400-2008-021-15DAY.pdf.

a six-hour turnover time, and that the circulation volume during in-use periods not fall below 65 percent of the six-hour turnover time[37].

The Energy Standards (Title 24, Part 6) incorporate the Title 20 requirements for pool pumps and motor combinations and provide further requirements for sizing the pumping equipment based upon pool size. The standard requires pool pump and motor combinations over 1 hp to be multiple-speed. The Building Efficiency Standards place requirements on system piping, filters, and valves to ensure energy efficient operation[38].

Regulations in Other States

Arizona enacted Title 44, Section 1375.02 (B) (2), Pool and Spa Energy Requirements, that require all pool pumps and pool pump motors to be certified in the Association of Pool and Spa Professionals' database or the Energy Commission database. The regulation carries the same prohibition on motor types as well as the requirement for two speeds for motors above 1 total hp as California regulation. The law became effective January 1, 2012.

Florida enacted Florida Building Code, Section 403.9.4, that carries the same prohibition on motor types as well as the requirement for two speeds for motors above 1 total hp. The law provides an exception for the default low speed operation during periods of high solar heat gain. The law also requires compliance with national energy standards ANSI/APSP 15 for residential pools and in-ground spas for new construction. The law became effective December 31, 2011.

Washington enacted Washington Building Code, Section 403.9.4, that carries the same prohibition on motor types as well as the requirement for a minimum of two speeds for motors above 1 total hp. The law became effective January 1, 2010.

Connecticut and New York have adopted residential pool pump standard similar to the California Title 20 regulations[39].

The states of Texas, Nevada, Michigan, Oregon, and New Jersey have considered legislative bills to adopt standards similar to the California Title 20 regulations for pools and spas[40].

ENERGY STAR®

ENERGY STAR, a partnership program of the U.S. EPA, collaborates with stakeholders to establish voluntary specifications for efficient appliances; among them are pool pumps and motors.

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37 California Building Code. Title 24, Chapter 31B, Sections 3101B – 3162, available at http://www.ecodes.biz/ecodes_support/free_resources/2013California/13Building/PDFs/Chapter%2031B%20-%20Public%20Swimming%20Pools.pdf.
38 Energy Commission Building Standard Section 150.0 (N) Pool Systems and Equipment Installation, available at http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf.
39 http://library.cee1.org/sites/default/files/library/9986/cee_res_swimmingpoolinitiative_07dec2012_pdf_10557.pdf.
40 http://www.poolspanews.com/legislation/states-introduce-out-of-date-energy-laws.aspx.

ENERGY STAR rates pool pump and motor combinations on an energy factor basis. The U.S. EPA defines energy factor as the volume of water pumped in gallons per watt hour of electric energy used. The U.S. EPA uses test procedures and hydraulic system curves to measure the pump and motor combination's performance identical to the California Title 20 regulation. Testing is required along system curves A, B, and C. Manufacturers must meet the energy factor criteria for performance measured on system curve A. Single-speed pump and motor combinations are tested at full speed while multi-speed, dual-speed, and variable-speed pump and motor combinations are measured at the most efficient speed[41]. Products must achieve an energy factor of at least 3.8 at low speed to meet the ENERGY STAR product specification. An energy factor of 3.8 was chosen to encourage the sale of dual-speed or variable-speed pool pump and motor combinations[42].

The CASE Report

In July 2013, the California IOUs submitted a Codes and Standards Enhancement (CASE) report to the Energy Commission in response to the Commission's invitation to submit proposals[43]. In September 2014, the IOUs submitted a revised proposal for pool pump standards[44]. In general, the proposal recommends that the current prescriptive standards be replaced with performance standards for all pool pump and motor combinations and replacement motors that are less than 5 hp by adding minimum efficiency requirements, measured at full speed and half speed. The proposal recommends the use of the Canadian Standards Association (CSA) test procedure C747-09 to verify compliance for motor efficiency.

The CASE team estimates the proposed standard would result in 63 GWh of energy savings in the first year and 630 GWh of energy savings each year after full stock turnover[45].

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41 https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Pool%20Pumps%20-%20Program%20Requirements%20Version%201.1.pdf.
42 ENERGY STAR Certified Pool Pumps, available at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.
43 CASE Report, *Pools & Spas* (July 29, 2013), available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2F_Residential_Pool_Pumps_and_Replacement_Motors/California_IOUs_Response_to_the_Invitation_to_Submit_Proposals_for_Pool_and_Spas_2013-07-29_TN-71756.pdf.
44 CASE Report, *Analysis of Standards Proposal for Residential Swimming Pool & Portable Spa Equipment*, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2F_Residential_Pool_Pumps_and_Replacement_Motors/California_IOUs_Response_to_the_Invitation_to_Submit_Proposals_for_Pool_and_Spas_2013-07-29_TN-71756.pdf.
45 Stock turnover occurs when all pumps in California meet proposed standards.

CHAPTER 5: Alternative Consideration

Staff analyzed the proposal in the CASE report to determine whether it meets the legislative criteria for the Energy Commission's prescription of appliance efficiency standards. Staff also reviewed and analyzed state standards for (1) maintaining current Title 20 standards, (2) incorporating the CASE report suggestions, (3) incorporating the CASE team proposal with tiered motor efficiency, and (4) incorporating the CASE team proposal with uniform full speed efficiency for all motor types.

Alternative 1: Maintaining Current Title 20 Appliance Standards

Staff believes the Title 20 standards need to be updated to adequately reflect the current market. The standards rely on prescriptive definitions for pool pump and motor combinations and replacement pool pump motors that result in low compliance rates. The standards should set minimum motor efficiencies. Based on the increased market penetration of higher efficiency products, it is reasonable to raise the minimum efficiency requirements to better reflect the cost-effective savings these products offer.

Alternative 2: Incorporate CASE Team Proposal

The CASE team proposal would establish minimum motor efficiency requirements (full and half speed) for all pump and motor combinations and replacement motors for residential and commercial pools that are less than 5 hp. The recommended efficiency standards for single-speed, dual-speed, and variable-/multiple-speed pump and motor combinations and replacement pump motors are shown in **Table 1**, and would go into effect one year from adoption. Most dual-speed motors in the Appliance Efficiency Database of certified pool pump motors qualify with the proposed full-speed motor efficiencies while only some pass the half-speed efficiency requirement. **Figure 6** plots pump and motor combinations certified in the database for both full- and half-speed motor efficiency.

The proposal recommends a half-speed requirement based on the half-speed horsepower of the motor. Dual-speed half-speed motor minimum efficiencies would vary between 48 percent at 1 hp and 57 percent at 5 hp. Variable-speed half-speed motor minimum efficiencies would vary between 63 percent at 1 hp and 72 percent at 5 hp. The proposal recommends a new CSA test method C747-09 to verify motor efficiency. Implementation of these standards would result in approximately 630 GWh of electricity savings once stock turnover is achieved in 2026

While the CASE team proposal offers significant energy savings, staff analysis suggests that there are additional savings that can be achieved with a more stringent standard.

Table 1: IOU Proposed Standards for Pool Pump Motors - Effective July 1, 2017

Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full Speed (3450 RPM)**	**Half Speed (1725 RPM)**
Single Speed (upto 1 HP)	$(0.06 * \ln(HP_{3450}) + 0.7) * 100\%$	N/A
Dual Speed	70%	$(0.06 * \ln(HP_{1725}) + 0.6) * 100\%$
Variable Speed/Multi-Speed	80%	$(0.06 * \ln(HP_{1725}) + 0.75) * 100\%$

Figure 6: CASE Report Single-Speed Efficiency Standard

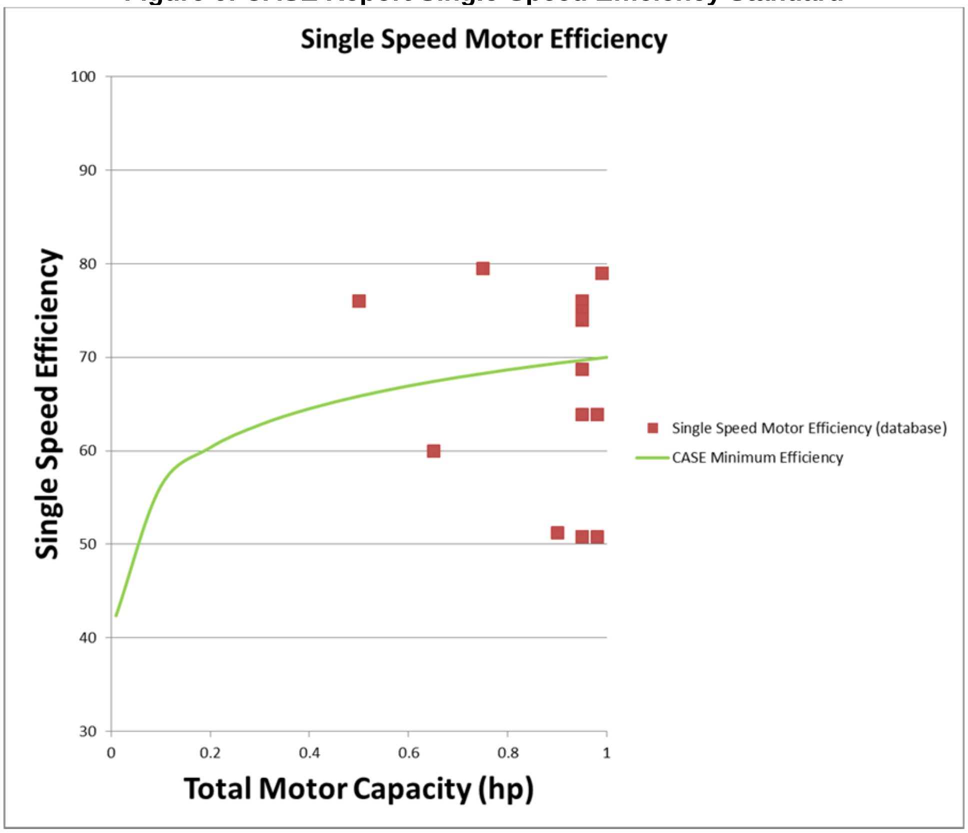
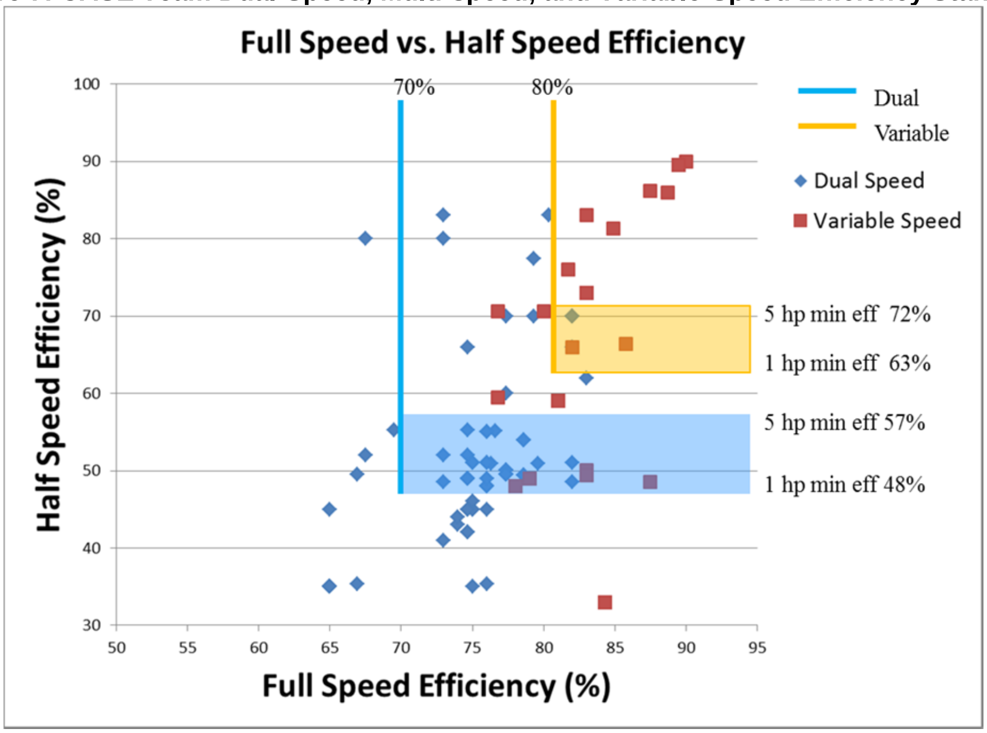


Figure 7: CASE Team Dual-Speed, Multi-speed, and Variable-Speed Efficiency Standard



Alternative 3: Incorporate CASE Team Proposal with Tiered Motor Efficiency

In this alternative, proposed standards incorporate and expand upon the CASE team proposal by establishing a two-tiered motor efficiency approach (see **Table 2** and **3)**. The Tier 1 single-speed motor efficiency is identical to the CASE Team proposal between 0.5 and 1 hp. Dual-speed, multi-speed, and variable-speed motor efficiency will be set to a unified minimum motor efficiency standard (see **Table 2)**, effective one year from adoption. Tier 2 will be implemented for dual-speed, multi-speed, and variable-speed four years after the adoption date and will raise the unified minimum motor efficiency standard (see **Table 2**). Tier 1 will achieve 634 GWh of electricity savings while Tier 2 will achieve an additional 78 GWh of electricity savings for a combined 716 GWh savings between Tier 1 and Tier 2.

While Alternative 3 provides significant savings, Alternative 4 proposes more stringent requirements for substantially more savings.

Table 2: Alternative 3, Tier I - Effective January 1, 2018

Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full Speed (3450 RPM)**	**Half Speed (1725 RPM)**
Single-Speed (up to 1 hp)	$(0.08*hp_{3450}+0.62)*100\%$	N/A
Variable-Speed/Multiple-Speed/Dual-Speed (1 to 5 hp)	70%	50%

Table 3: Alternative 3, Tier II - Effective January 1, 2021

Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full Speed (3450 RPM)**	**Half Speed (1725 RPM)**
Single-Speed (up to 1 hp)	$(0.08*hp_{3450}+0.62)*100\%$	N/A
Variable-Speed/Multiple-Speed/Dual-Speed (1 to 5 hp)	80%	65%

Alternative 4: Incorporate CASE Team Proposal with Uniform Full Speed Efficiency for All Motor Types

In this alternative, staff proposed standards incorporate and expand upon the CASE team proposal by establishing a two-tiered motor efficiency approach (see **Table 4** and **5**). While the dual-speed and variable-speed efficiencies would remain the same as shown in Alternative 3, the Tier 1 and Tier 2 single-speed motor efficiency would be set equal to the dual-speed, multi-speed, and variable-speed motor efficiency at full speed. The Tier 1 and Tier 2 effective dates would be the same as proposed in Alternative 3. Tier 1 will achieve 609 GWh of electricity savings while Tier 2 will achieve an additional 569 GWh of electricity savings for a combined 1178 GWh savings. Staff believes the single-speed Tier 1 standard is technically feasible and would request additional information on motors below 1 hp that can achieve a motor efficiency of 80 percent or greater.

As discussed in the following section, staff believes that Alternative 4 is cost-effective, technically feasible, and provides significant electrical energy savings.

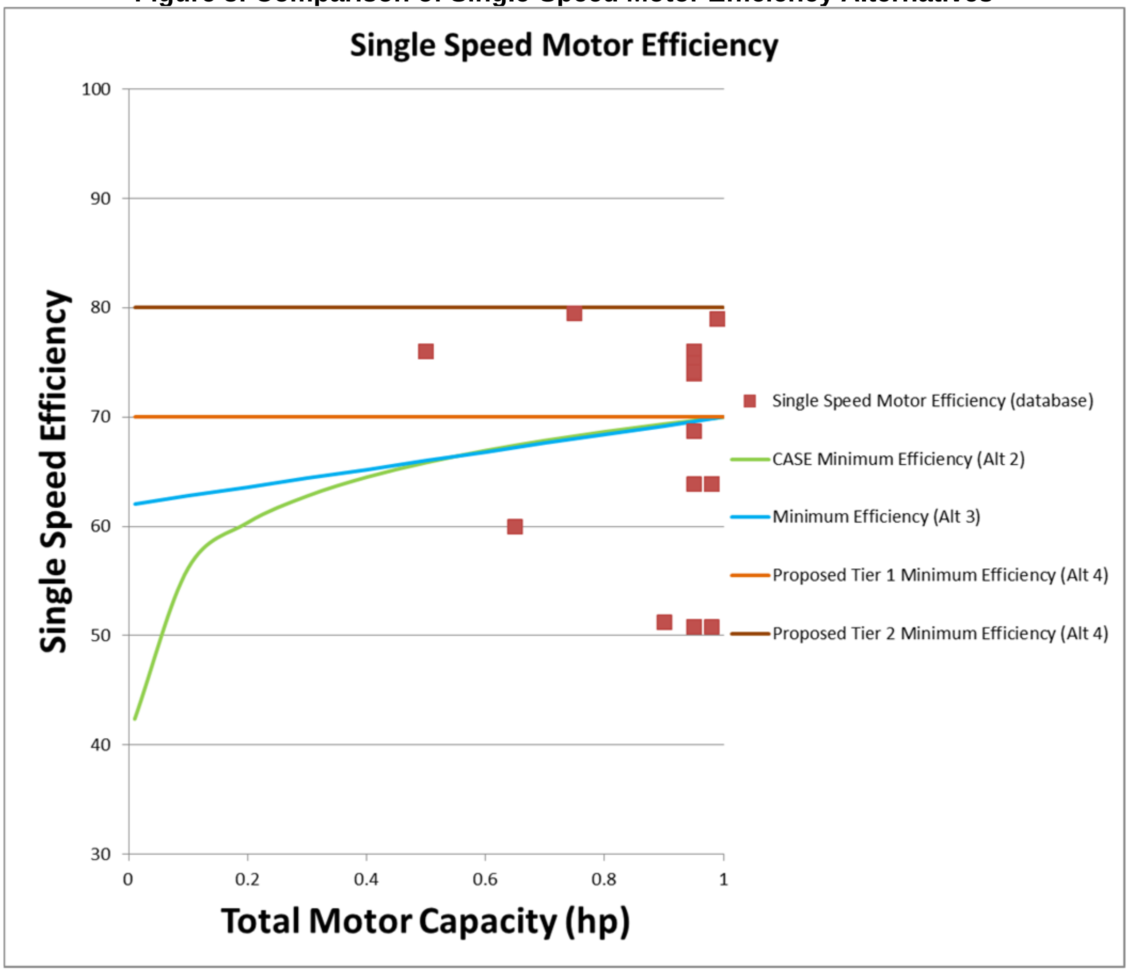
Table 4: Staff Proposed Alternative 4, Tier I - Effective January 1, 2018

Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full-Speed (3450 RPM)**	**Half-Speed (1725 RPM)**
Single-Speed (up to 1 hp)	70%	N/A
Variable-Speed/Multiple-Speed/Dual-Speed (1 to 5 hp)	70%	50%

Table 5: Staff Proposed Alternative 4 Tier II Effective January 1, 2021.

Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full Speed (3450 RPM)**	**Half Speed (1725 RPM)**
Single-Speed (up to 1 hp)	80%	N/A
Variable-Speed/Multiple-Speed/Dual-Speed (1 to 5 hp)	80%	65%

Figure 8: Comparison of Single-Speed Motor Efficiency Alternatives



CHAPTER 6: Staff Proposed Standards for Pool Pumps and Motor Combinations and Replacement Pool Pump Motors

Energy Commission staff analyzed the cost-effectiveness and technical feasibility of standards proposed in the CASE report, considered public comments, and surveyed the pool pump and motor combination and replacement motor market. Based on the information available, staff has determined that the savings resulting from reduced energy consumption under the proposed standards are significant and cost-effective to consumers. In addition, staff determined that the proposed standards are attainable through products available in the market.

Scope

Staff proposes to expand the existing scope of pool pump and motor combinations and replacement pool pump motors and to ensure that the standards can be enforced effectively. Staff proposes to cover pool pump and motor combinations (pump and motor sold together) and replacement pool pump motors (pumps sold alone) that are used for filtration and circulation, to run water features and waterfalls, and as booster pumps. In addition, the proposed scope will no longer distinguish between pool pumps used in residential pools and small commercial pools. The regulation will continue to apply to pumps and motors serving both in-ground and above-ground pools.

Staff amended the pool pump and motor definitions to expand the scope by removing references to residential and filtration uses. New motor type definitions were added to represent the current diversity of design solutions in the pool pump marketplace.

Motor Efficiency

Two tiers of standards are proposed for single-speed, dual-speed, multi-speed, and variable-speed motors sold in combination with pool pumps or sold separately as replacements. These proposed standards will take effect one and four years from adoption by the Energy Commission, respectively.

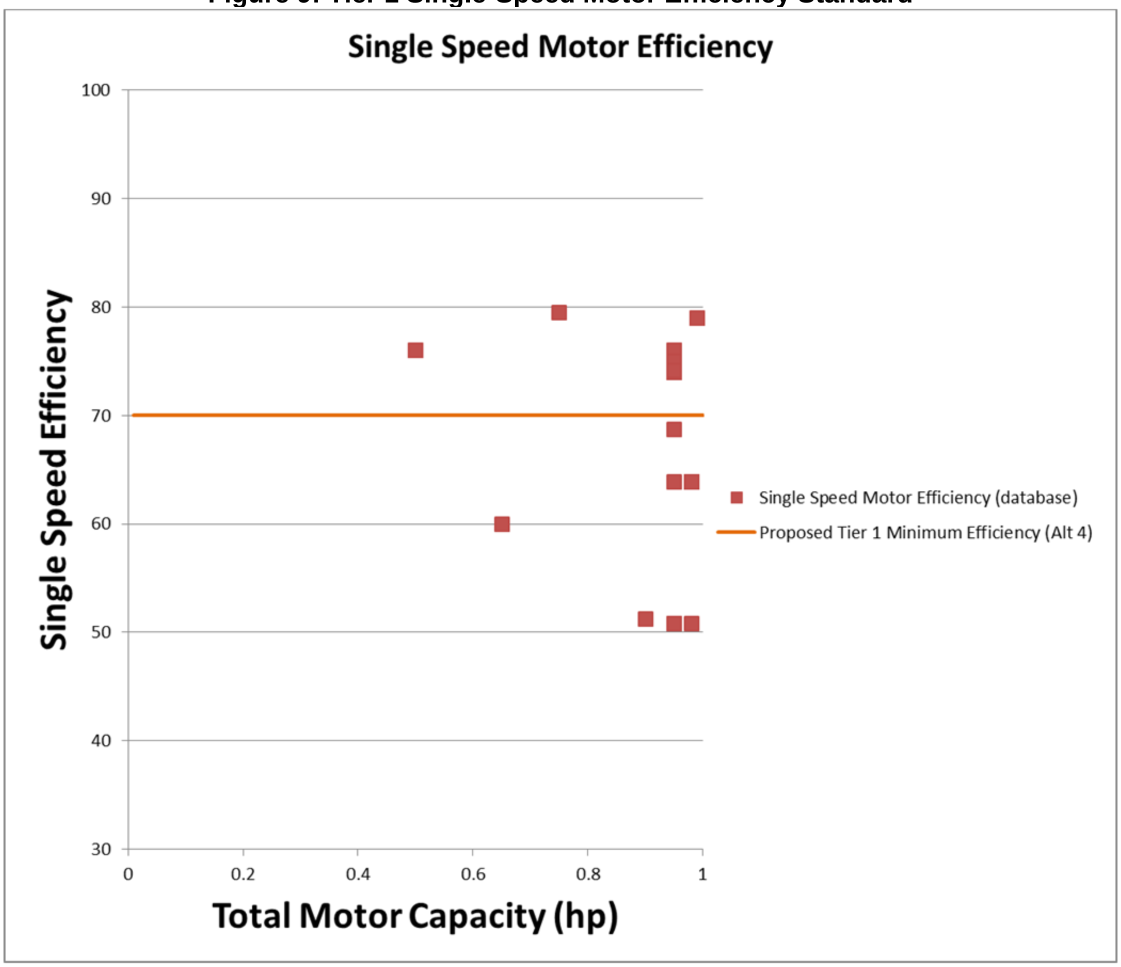
Tier 1

All pool pump motors that are 5 hp or less, manufactured on or after January 1, 2018, shall meet the efficiency standards outlined in **Table 6**.

Table 6: Tier I Proposed Standards for Pool Pump Motors

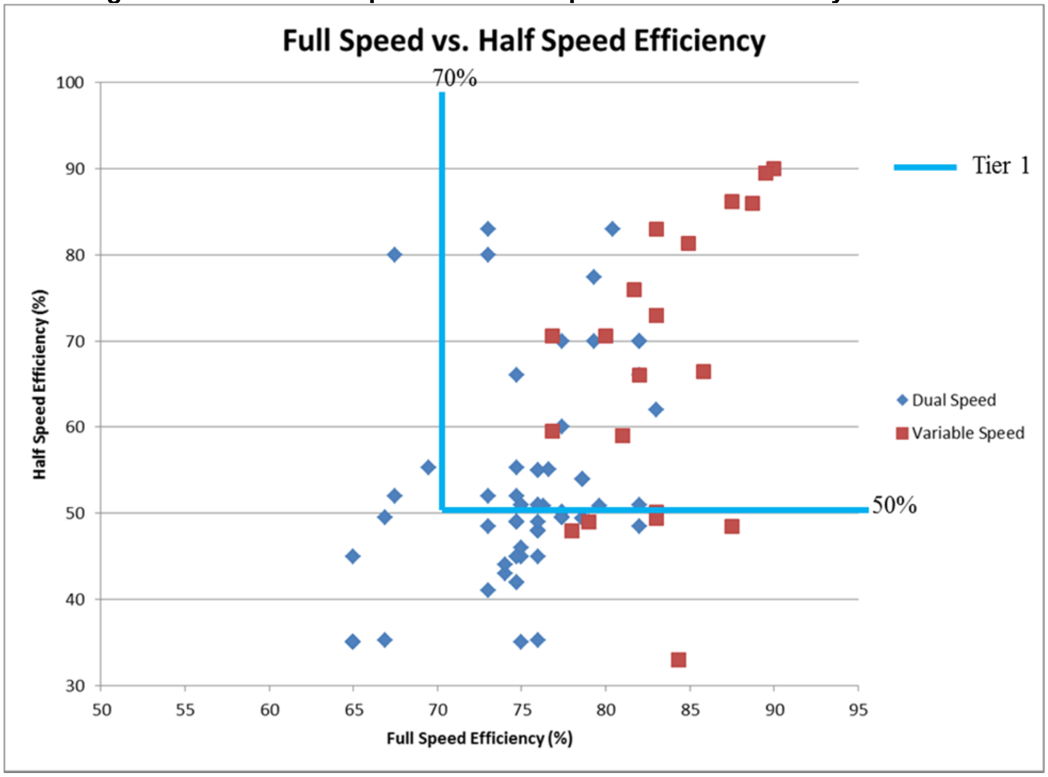
Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full Speed (3450 RPM)**	**Half Speed (1725 RPM)**
Single-Speed (up to 1 hp)	70%	N/A
Variable-Speed/Multiple-Speed/Dual-Speed (1 to 5 hp)	70%	50%

Figure 9: Tier 1 Single-Speed Motor Efficiency Standard



Staff proposes a simultaneous full-speed and half-speed minimum pool pump motor efficiency for motors between 1 and 5 hp to impose minimum performance standards on the two primary duty cycles for these motors. The minimum efficiencies are proposed to achieve significant energy savings without imposing a significant burden on the pool pump motor industry, as many products are available in the market that meet both the Tier 1 and Tier 2 standards.

Figure 10: Tier 1 Full Speed and Half Speed Motor Efficiency Standard



Tier 2

All pool pump motors that are 5 hp or less, manufactured on or after January 1, 2021, shall meet the efficiency standards outlined in **Table 7**.

Table 7: Tier 2 Proposed Standards for Pool Pump Motors

Proposed Minimum Efficiency according to modified CSA C747-09 Test Procedure		
Motor Design	**Full Speed (3450 RPM)**	**Half Speed (1725 RPM)**
Single-Speed (up to 1 hp)	80%	N/A
Variable-Speed/Multiple-Speed/Dual-Speed (1 to 5 hp)	80%	65%

The proposed standards would result in significant electricity savings with the products currently available on the market. The tiered efficiency requirements and effective dates provide adequate time for industry to align manufacturing lines and product inventories to meet consumer demand while providing a more efficient product.

Figure 11: Tier 2 Single-Speed Motor Efficiency Standard

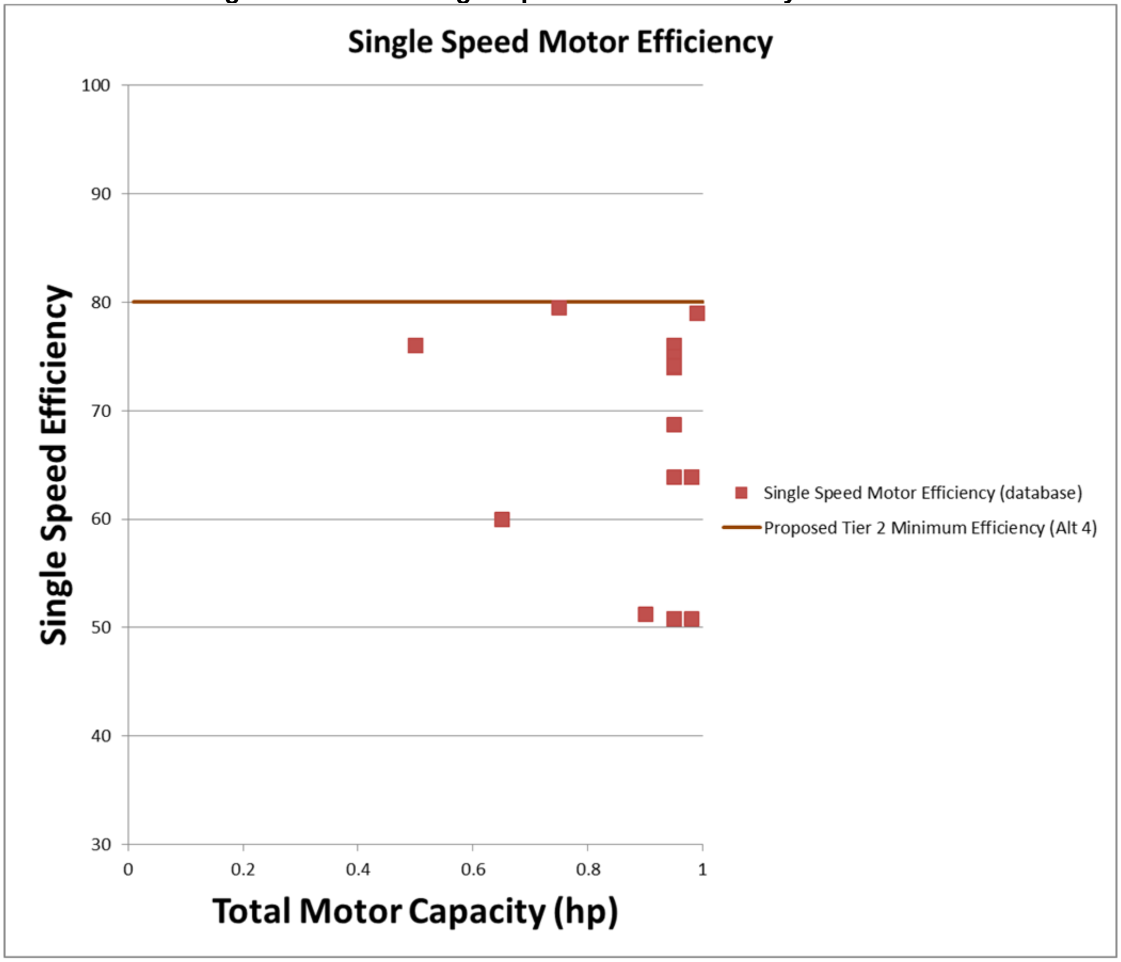
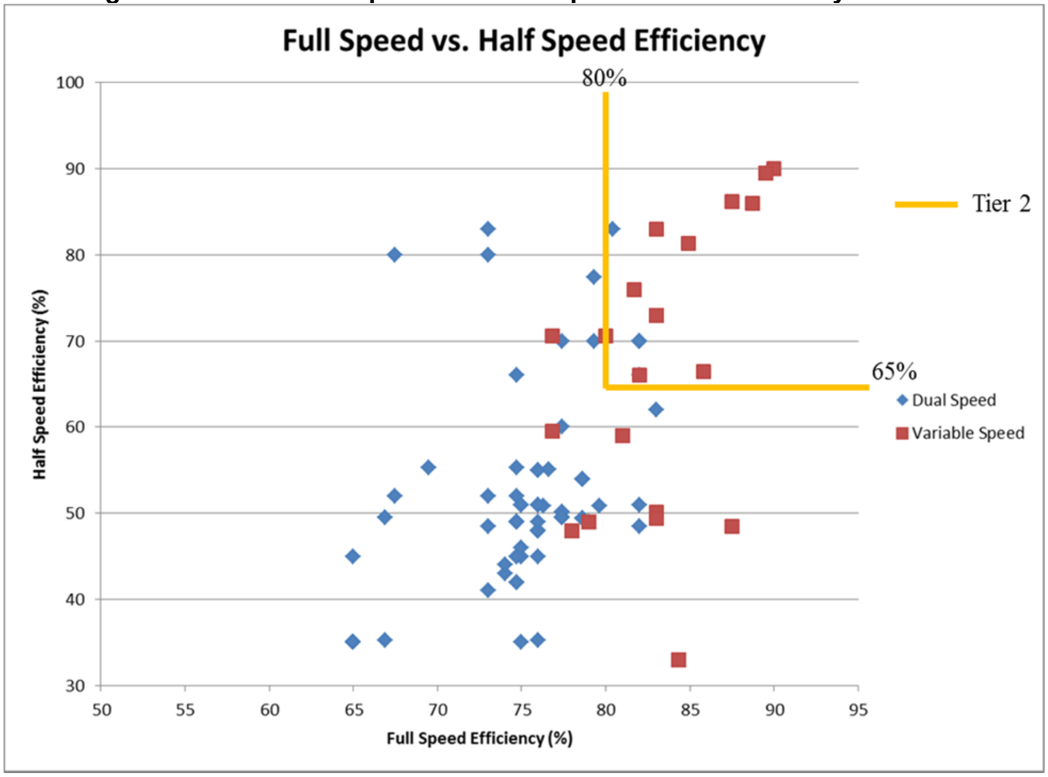


Figure 12: Tier 2 Full-Speed and Half-Speed Motor Efficiency Standard



Remove Prohibition on Split-Phase and Capacitor-Start Induction Run Motors

Staff proposes to remove the prescriptive prohibition for split-phase and capacitor-start induction run motor type, as the performance standard proposed in this staff report will exceed the energy savings from the prescriptive requirements. The prohibited motor types have full-speed efficiency in the range of 40 to50 percent, which is considerably lower than the proposed full-speed efficiency standard[46]. Staff has removed the prohibition for split-phase and capacitor-start induction run motor types because all motors must meet the efficiency standard. The previously banned motor types could be sold in California under the new proposed standard as long as they meet the minimum motor efficiency standard.

Based on its independent analysis of the available data, including that from the CASE report and manufacturers' information, staff concluded that the proposed regulations are both cost-effective and technically feasible. Staff assumptions and calculation methods are provided in **Appendix A.**

46 Davis Energy Group, Gary B. Fernstrom, *Analysis of Standards Options for Residential Pool Pumps, Motors and Controls*, 2004, p. 6.

New Proposed Pool Pump Motor Types

Staff is aware of pool pump motor types in use that do not conform to the list of acceptable types found in Title 20, Section 1606, Table X. Staff proposes to add motor types to allow certification of all pool motor types capable of meeting the motor efficiency standard.

Motor Efficiency Test Procedure

Staff proposes to amend the current motor test procedure to require all pool motors to test to the CSA 747-09, energy efficiency test methods for small motors.

The CSA 747-09 test method provides a better test method than the IEEE-114-2001. The CSA test method is intended for all types of small motors while the IEEE method only includes single-phase AC induction motors. The CSA test procedure allows for testing at multiple motor speeds while the IEEE test procedure only allows for full-speed motor testing. The CSA 747-09 test procedure is superior because it has more expansive test conditions and motor types.

The proposed standard will require manufacturers to report performance data at up to four speeds depending upon the speed capability of the pool pump motor. Single-speed motors will report performance at full speed, while dual-speed motors will report performance at full and half speed. Variable-speed motors and multi-speed motors will report performance at ¼, ½, ¾, and full speed. The new reporting requirement will improve the consistency in reported performance data by making the performance reported at uniform speeds. The reporting will allow consumers, regulators, and industry to make more meaningful side-by-side comparisons of motors at uniform speeds.

Pump Efficiency Test Procedure

The Appliance Efficiency Standard requires the pool pump for pool pump and motor combinations to be tested to the Hydraulic Institute (HI) ANSI/HI 1.6-2001, Centrifugal Pump Tests. Since the 2001 version, HI has updated and consolidated the test procedure for pumps to ANSI/HI 14.6-2011, Rotodynamic Pumps for Hydraulic Performance Acceptance Tests. The ANSI/HI-14.6-2011 incorporates the requirements for ANSI/HI 1.6. Staff seeks to update to the ANSI/HI-14.6-2011 to the current test procedure used by the industry. The test procedure is intended for factory testing of pump types used by the pool pump industry.

CHAPTER 7: Savings and Cost Analysis

The proposed standards would significantly reduce energy consumption. To determine incremental cost of a pool pump motor that meets the proposal, the CASE team gathered retail price data from pool pump and motor vendor websites. Staff performed an independent market search and confirmed the retail price data in the CASE report. The data was analyzed to estimate the cost difference to the consumer as motor efficiency increases. The CASE team determined the cost increase estimate for motor size and motor type. Staff used the CASE team analysis to estimate the incremental cost between non-compliant models and models that meet but do not exceed the proposed standard. See **Appendix A** for a detailed calculation.

Table 8: Annual Energy and Monetary Savings per Unit

Product	Design Life (years)	Electricity Savings (kWh/yr)	Incremental Cost ($)	Avg. Annual Savings ($)	Life-Cycle Savings ($)	Life-Cycle Benefit ($)
Variable-Speed Tier 1	10	0	$0	$0	$0	$0
Variable-Speed Tier 2	10	51	$18	$8	$81	$63
Dual-Speed Tier 1	10	53	$5	$9	$85	$80
Dual-Speed Tier 2	10	352	$65	$56	$564	$499
Single-Speed Residential Filtration Tier 1	10	297	$12	$48	$476	$464
Single-Speed Residential Non-Filtration Tier 1	10	157	$12	$25	$252	$240
Single-Speed Commercial Tier 1	10	682	$12	$109	$1,091	$1,079
Single-Speed Residential Filtration Tier 2	10	186	$55	$30	$297	$242
Single-Speed Residential Non-Filtration Tier 2	10	98	$55	$16	$157	$102
Single-Speed Commercial Tier 2	10	2,335	$65	$374	$3,736	$3,671

Source: CASE report, as modified by staff

The values shown in **Table 8** list the design life, incremental cost, and monetary savings in 2015 dollars, for each product. Thus, the average annual savings are the savings that consumers will receive once the product is installed.

Note: estimation of cost and benefits is conservative as it does not consider utility rebates or contractor discounted prices for installation (i.e., contractors purchase the pumps and install them at a discounted price).

The annual savings of each unit (benefits) is calculated by multiplying the annual energy savings by $0.16 per kWh[47]. The life-cycle benefit represents the savings the consumer will receive over the life of the appliance and is the product of the average annual savings multiplied by the average design life of the unit. The net life-cycle benefits are the differences between the savings and the incremental cost of each appropriate unit.

Staff used the survey results from PG&E, SCE, and SDG&E, and as reported in the CASE report for the total stock of pool pump motors by types. Approximately two million residential and commercial pools are in use in California. Most employ single-speed motors[48]. Staff assumed a 1 percent growth rate for new pool installation based upon the Energy Commission energy demand forecast and a conversation with the CASE team [49]. Assuming a 10 percent replacement rate based upon a ten-year design life, staff estimates yearly shipments of 200,000 units per year.

The savings estimates compare the baseline energy consumption for each product with their respective energy consumption under the proposed standards. For statewide estimates, these savings are multiplied by sales for first-year figures and by total California stock. The details of these calculations are available in **Appendix A.** In **Table 9**, **Table 10, and Table 11**, the potential energy savings of the proposed standards are provided. Energy savings are further separated into first-year savings and stock savings. First-year savings means the annual reduction of energy consumed associated with annual sales, one year after the standards take effect. Annual stock savings means the annual energy savings achieved after all existing stock in use comply with the proposed standards.

Staff calculations and assumptions used to estimate first-year savings and stock change savings are provided in **Appendix A**. As provided in **Table 9** and **Table 10**, staff estimated that if all pool pumps and motors complied with the proposed Tier 1 and Tier 2 standards (annual stock

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47 Energy Information Administration – electricity prices for 2013 through December 2013 http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_b.

48 CASE Report, *Analysis of Standards Proposal for Residential Swimming Pool & Portable Spa Equipment*, pp. 20-22, available at http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2F_Residential_Pool_Pumps_and_Replacement_Motors/California_IOUs_Response_to_the_Invitation_to_Submit_Proposals_for_Pool_and_Spas_2013-07-29_TN-71756.pdf.

49 Kavalec, Chris, Nicholas Fugate, Bryan Alcorn, Mark Ciminelli, Asish Gautam, Kate Sullivan, and Malachi Weng-Gutierrez, 2013. *California Energy Demand 2014-2024 Preliminary Forecast, Volume 1,* California Energy Commission, Publication Number CEC-200-2013-004-SD-V1, p. 30.

savings), California would save 1178 GWh of energy per year. Using a residential electricity rate of $0.16 per KWh, staff estimated that implementation of the proposed standards for pool pumps and motors would achieve roughly $188 million a year in reduced utility costs after full implementation.

Staff also calculated the peak power reduction to be 1178 GWh/8,760 hours, which is equal to approximately 134 MW. This calculation is based on the simplified assumption that the load profile for pool pumps and motors is completely flat and energy would be evenly generated over the entire year to provide electricity to consumers.

Table 9: Tier 1 Statewide Annual Savings

	First Year Savings		**Annual Existing and Incremental Stock Savings**	
Product	**Electricity Savings (GWh/yr)**	**Savings ($M)**	**Electricity Savings (GWh/yr)**	**Savings ($M)**
Variable-Speed	0.0	$0.0	0	$0.0
Dual-Speed	1.1	$0.2	11	$1.7
Single-Speed Residential Filtration	47.5	$7.6	475	$75.9
Single-Speed Residential Non-Filtration	8.8	$1.4	88	$14.0
Single-Speed Commercial	3.6	$0.6	836	$5.7
Total Savings	**60.9**	**$9.7**	**608.7**	**$97.4**

Source: Staff Calculation

Table 10: Tier 2 Statewide Annual Savings

	First Year Savings		Annual Existing and Incremental Stock Savings	
Product	**Electricity Savings (GWh/yr)**	**Savings ($ million)**	**Electricity Savings (GWh/yr)**	**Savings ($ million)**
Variable-Speed Tier 2	1.0	$0.2	10	$1.6
Dual-Speed Tier 2	7.2	$1.2	72	$11.6
Single-Speed Residential Filtration Tier 2	30.5	$4.9	305	$48.7
Single-Speed Residential Non-Filtration Tier 2	5.6	$0.9	56	$9.0
Single-Speed Commercial Tier 2	12.6	$2.0	126	$20.2
Total Savings	**56.9**	**$9.1**	**569.1**	**$91.0**

Source: Staff Calculation

Table 11: Tier 1 and Tier 2 Statewide Annual Savings

Product	First Year Savings		Annual Existing and Incremental Stock Savings	
	Electricity Savings (GWh/yr)	**Savings ($ million)**	**Electricity Savings (GWh/yr)**	**Savings ($ million)**
Tier 1 Total Savings	60.9	$9.7	608.7	$97.4
Tier 2 Total Savings	56.9	$9.1	569.1	$91.0
Tier 1 and Tier 2 Total Savings	**117.8**	**$18.8**	**1,177.8**	**$188.4**

Source: Staff Calculation

In conclusion, the proposed standards are clearly cost-effective as consumers will receive a net savings from the installation of compliant pump and motor combinations and replacement pool pump motors over the life of the pump.

CHAPTER 8: Pool Pumps and Motors Standard Technical Feasibility

Motor Efficiency

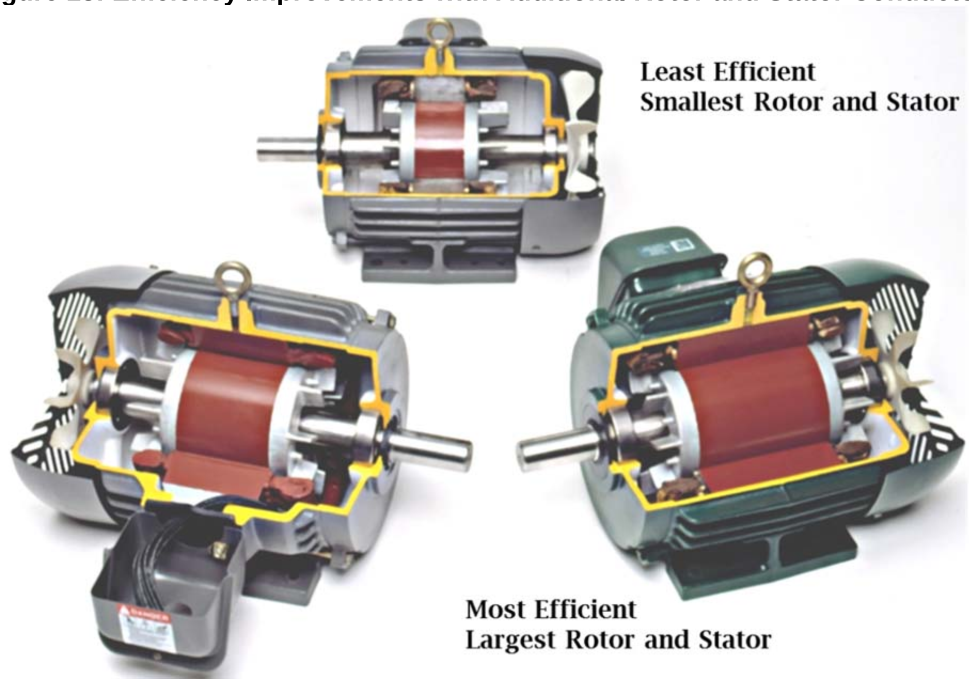
Motor efficiency is the ratio of rotational power at the motor shaft to the electrical power input to the motor. The motor efficiency will always be less than 100 percent due to losses within the motor. Energy losses within electric motors are classified as conduction losses and speed losses. Manufacturers have used a variety of approaches to achieve more efficient motor performance.

Conduction Losses

Conduction losses are due to the resistance the electric current encounters when it flows through a conductor; in this case, the winding wire inside the motor. The power is dissipated as heat rather than converted into rotational energy. The power dissipated by electrical resistance is proportional to the square of the applied current. Manufacturers have lowered the resistance within the motor by modifying the stator and rotor geometry to add more area for the wire conductors.[50] Electrical losses predominate at low speed. Other sources of motor losses at low speed such as friction are small compared to the conduction losses.

50 Machine Design, *The difference between AC induction, permanent magnet, and servomotor technologies*, available at http://machinedesign.com/motorsdrives/difference-between-ac-induction-permanent-magnet-and-servomotor-technologies.

Figure 13: Efficiency Improvements with Additional Rotor and Stator Conductors



Source: National Electrical Manufacturers Association

Speed Losses

Speed losses include hysteresis and eddy currents within the stator and rotor, frictional losses within bearings, and motor windage (the loss the motor rotor encounters as a drag force as it rotates through air)[51]. Hysteresis and eddy currents are due to the interaction between alternating electrical currents and magnetic materials within both AC induction and ECM motor stators and rotors. Losses can be reduced by minimizing stator and rotor steel laminations to reduce eddy currents and using ferromagnetic materials with properties that present less hysteresis. Bearing friction can be reduced by appropriate selection of bearings for the motor load and speed. Motor windage can be reduced by streamlining airflow within the motor and removing obstacles such as sharp edges or drastic changes in cross section[52].

Stray losses are miscellaneous losses from leakage flux, non-uniform current distribution, and mechanical imperfection in the air gaps between the rotor and windings stator. Careful design and improved manufacturing processes can minimize stray losses and improve overall motor efficiency.

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51 Vrancik, James E., *Prediction of Windage Power Loss in Alternators*, NASA Technical Note D-4849, 1968, p. 4.
52 Tong, Wei, *Mechanical Design of Electric Motors*, CRC Press, 2014, p. 402.

Motor Efficiency Market Survey

Tables 12, **13,** and **14** show existing pool pump motors compliant with Tier 1 and Tier 2 in the Energy Commission database as of June 2015. The number of models that already comply shows that the proposed efficiency standards are technically feasible for the pool pump motor industry.

Table 12: Single-Speed Pool Pump Motor Performance of Motors in Energy Commission Database - June 2015

Motor Size (hp)	Total Models	Tier 1 Compliant	Tier 2 Compliant
0.5	3	2	0
0.75	1	1	0
1.0	20	11	0

Table 13: Dual-Speed Pool Pump Motor Performance in Energy Commission Database - June 2015

Motor Size (hp)	Total Models	Tier 1 Compliant	Tier 2 Compliant
1	15	3	0
1.5	21	8	0
2	27	15	3
2.5	8	4	0
3	2	2	0

Table 14: Variable-Speed Pool Pump Motor Performance of Motors in Energy Commission Database - June 2015

Motor Size (hp)	Total Models	Tier 1 Compliant	Tier 2 Compliant
1	1	1	1
1.5	4	4	4
2	9	8	7
2.5	8	3	2
3	2	2	1

The Energy Commission database surveys show many models meeting the proposed motor efficiency standards at the Tier 1 and Tier 2 levels. The quantity of pool pumps and motors available for sale show compliant products are technically feasible. A significant market for dual-speed or variable-speed motors less than 1 hp or greater than 3 hp was not found. However, should such motors be needed, there do not appear to be any technical barriers to prevent such motors from being compliant.

The Association of Pool & Spa Professionals (APSP) pool database[53] shows two single-speed pump models less than 1 hp that meet the 80 percent efficiency Tier 2 requirement and four additional pump models above 79 percent efficiency. Staff believes the Tier 2 single-speed efficiency requirement is obtainable with a modest improvement to the motor components.

Two or More Speed Pump Requirement

All new pumps and motors between 1 and 5 hp must be capable of operating at two or more speeds. New pump and motor combinations, and replacement pool pumps between 1 and 5 hp, shall all be dual-speed, multiple-speed, or variable-speed type. The requirement will extend to all pool pumps and motors beyond the current requirement for residential filtration pumps including motors for commercial pool pumps, booster pumps, and water effect pumps.

Pumps and motors under 1 hp total capacity may be single-speed in addition to dual-, multiple-, or variable-speed.

The large quantity of pool pumps and motors available for sale (**Table 13** and **14)** from a variety of manufacturers show compliant two or more speed products that are technically feasible.

53 The Association of Pool and Spa Professionals (APSP) Energy Efficient Pool Pumps Database, http://apsp.org/resources/energy-efficient-pool-pumps.aspx.

CHAPTER 9: Environmental Impacts

Impacts

Pool owners replace pool pumps and motors at the end of their useful lives. The proposed standards would not change that, so their replacement would present no additional impact to the environment beyond their natural cycle.

Benefits

Improving the efficiency of pool pumps and motors through mandatory appliance standards will reduce overall energy consumption statewide, providing important air quality and climate benefits. Staff estimated the reduction of criteria air pollutants[54] and GHG emissions resulting from the proposed standards. The reductions are tabulated in **Table 15**.

GHG emission reductions were calculated using the estimated avoided energy savings; it was assumed that there are 690 lbs of avoided CO_2e per MWh of electricity saved[55]. For criteria air pollutants, the ARB suggested emission factors were used to estimate the cost-effectiveness of emission reductions[56]:

- Oxides of nitrogen (NO_x) = 0.07 lb per MWh,
- Sulfur dioxide (SO_x) = 0.01 lb per MWh,
- Carbon monoxide (CO) = 0.1 lb per MWh,
- Particulate matters ($PM_{2.5}$) = 0.03 lb per MWh.

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54 Criteria air pollutants are those for which a state or federal standard has been established. They include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and its precursors, oxides of nitrogen (NOx) and volatile organic compounds (VOC), particulate matter less than 2.5 microns ($PM_{2.5}$) and less than 10 microns in diameter (PM_{10}), and lead (Pb).
55 *Energy Aware Planning Guide Feb 2011*, available at http://www.energy.ca.gov/2009publications/CEC-600-2009-013/CEC-600-2009-013.pdf.
56 ARB Economic Analysis Assumptions, available at http://www.arb.ca.gov/regact/2010/res2010/res10d.pdf.

Table 15: Criteria and Greenhouse Gas Emissions Reductions

Annual Reductions (tons)	Avoided Emissions (tons)				
	Oxides of Nitrogen (NO_x)	**Sulfur Dioxide (SO_x)**	**Carbon Monoxide (CO)**	**Particulate Matter ($PM_{2.5}$)**	**Greenhouse Gas (eCO_2)**
Dual- and Variable-Speed Tier 1	0.37	0.05	0.53	0.16	3,670
Dual- and Variable-Speed Tier 2	2.87	0.41	4.11	1.23	28,333
Single-Speed Tier 1	20.93	4.33	29.90	8.97	206,329
Single-Speed Tier 2	17.04	2.43	24.35	7.30	167,993
Total Avoided Emissions	41.22	7.23	58.89	17.67	406,324

Source: Staff Calculation

As seen in **Table 15**, about 125 tons of criteria air contaminants and nearly 406 thousand tons of GHG equivalents will be avoided annually due to the savings from the proposed standards.

CHAPTER 10: Regulatory Language

The following are the proposed changes to specific Sections of Title 20 applicable to pool pumps and motors. Underline means new added text and ~~strike out~~ means deleted text.

Section 1601 Scope

…

(g) Gas pool heaters, oil pool heaters, electric resistance pool heaters, heat pump pool heaters, ~~residential~~ pool pump and motor combinations, replacement ~~residential~~ pool pump motors, and portable electric spas.

…

Section 1602(g) Pool Heaters, Portable Electric Spas, ~~Residential~~ Pool Pumps, and Motor Combinations, and Replacement ~~Residential~~ Pool Pump Motors.

"Permanent Magnet Synchronous" means a motor that has a permanent magnet rotor and windings on the stator controlled by single-phase sinusoidal alternating current.

"Polyphase induction" means an alternating current motor having polyphase (as three-phase) windings.

"Reluctance" means a motor that generates torque through the use of non-permanent magnetic poles and the reluctance phenomenon.

"Replacement ~~residential~~ pool pump motor" means a replacement motor intended to be coupled to an existing ~~residential~~ pool pump ~~that is used to circulate and filter pool water in order to maintain clarity and sanitation~~.

"~~Residential~~ ~~p~~Pool pump" means a mechanical device using suction or pressure to raise or move non-potable water.~~an impeller attached to a motor that is used to circulate and filter pool water in order to maintain clarity and sanitation~~.

"~~Residential~~ ~~p~~Pool pump and motor combination" means a ~~residential~~ pool pump motor coupled to a ~~residential~~ pool pump.

"~~Residential~~ ~~p~~Pool pump motor" means a motor that is used as a replacement ~~residential~~ pool pump motor or as part of a ~~residential~~ pool pump and motor combination.

"Shaded pole" means a motor that uses current flowing through a shading coil to delay the phase of the magnetic flux to generate a rotating magnetic field.

"Total horsepower ~~(of an AC motor)~~(of a pool pump motor)" means a value equal to the product of the motor's service factor and the motor's nameplate (rated) horsepower.

Section 1604 (g) Pool Heaters, Portable Electric Spas, ~~Residential~~ Pool Pump and Motor Combinations, and Replacement ~~Residential~~ Pool Pump Motors.

…

(3) The test method for ~~residential~~ pool pumps and motor combinations.

The test method for ~~residential~~ pool pumps and motor combinations is as follows

(A) Reported motor efficiency shall be verifiable by test method described in Section 1604 (g)(4)~~IEEE114-2001~~.

(B) ~~ANSI/HI 1.6 - 2000~~ ANSI/HI 14.6 - 2011-shall be used for the measurement of pump efficiency.

(C) Three system curves shall be calculated.

…

(D) For each curve (A, B, or C), the pump head shall be adjusted until the flow and head lie on the curve. The following shall be tested and reported ~~(i) for each curve for single - speed pumps or (ii) for each curve at both highest and lowest speeds for two - ,multi - , or variable - speed pumps~~ for the intersect point of the pump performance curve with each system curve:

1. Motor nominal speed
2. Flow (gallons per minute)
3. Power (watts and volt amps)
4. Energy Factor (gallons per watt hour)
   Where the Energy Factor (EF) is calculated as:
   EF = Flow (gpm)* 60/ power
5. Motor Efficiency (percent %)

(i) For single-speed, two-speed, or multi-speed pumps with fixed, non-adjustable speeds, test and report performance at the intersect point of the pump performance curve with each system curve (curves A, B, and C). Intersect data shall be reported for each speed and system curve.

(ii) For two-, multi-, or variable-speed pumps with adjustable speeds, test and report performance at the intersect point of the pump performance curve with each system curve (curves A, B, and C). Intersect data shall be reported for the speeds shown in Table G-3.

(4) Test Method for Pool Pump Motors

The test method for pool pump motors is as follows:

(A) Each pool pump motor shall be tested and in accordance with CSA-C747-09 with modified torque settings at different speeds as is shown in Table G-3 and G-4.

(1) Single-speed, two-speed, multi-speed, and variable-speed pool pump motors shall be tested at the speeds shown below in Table G-3.

Table G-3 - Testing Criteria for Pool Pump Motors

Motor Design	Full Speed (3450[1] RPM)	3/4 Speed (2590[1] RPM)	1/2 Speed (1725[1] RPM)	1/4 Speed (860[1] RPM)
Single-Speed	X	N/A	N/A	N/A
Dual-Speed	X	N/A	X	N/A
Variable-Speed	X	X	X	X
Multiple-Speed[2]	X	X	X	X

[1]Tolerance of +/-50 RPM.
[2]If no preset speeds exist within tolerance, then test to nearest preset speed.

(2) Torque settings and horsepower ratings for single-speed, two-speed, multi-speed, and variable-speed pool pump motors shall be calculated as shown below in Table G-4.

Table G-4 - Torque Settings for Pool Pump Motors

Speed (RPMs)		Torque Setting (N-m)	Total Horsepower (THP)
RPM_{full}	Full Speed (RPM)	T_f (per section 6.5 of CSA C747-09)	THP_{full}
$RPM_{3/4}$	Three Quarter Speed (if applicable) (RPM)	$T_{3/4} = (RPM_{3/4} / RPM_{full})^2 \times T_f$	$THP_{3/4} = (RPM_{3/4} / RPM_{full})^3 \times THP_{full}$
$RPM_{1/2}$	Half Speed (if applicable) (RPM)	$T_{1/2} = (RPM_{1/2} / RPM_{full})^2 \times T_f$	$THP_{1/2} = (RPM_{1/2} / RPM_{full})^3 \times THP_{full}$
$RPM_{1/4}$	One Quarter Speed (if applicable) (RPM)	$T_{1/4} = (RPM_{1/4} / RPM_{full})^2 \times T_f$	$THP_{1/4} = (RPM_{1/4} / RPM_{full})^3 \times THP_{full}$
RPM_x	Other Preset Speed (if applicable) (RPM)	$T_x = (RPM_x / RPM_{full})^2 \times T_f$	$THP_x = (RPM_x / RPM_{full})^3 \times THP_{full}$

The torque T_1 shall be set in accordance to CSA-C747-09.

...

The following documents are incorporated by reference in Section 1604.

…

CSA Group (CSA)

CSA C747-09	Energy efficiency test methods for small motors
Copies available from:	CSA Group 178 Rexdale Blvd Toronto, ON Canada M9W 1R3 http://shop.csa.ca/ Phone (416) 747 4044 FAX (416) 747 2510

…

HYDRAULIC INSTITUTE (HI))

…

ANSI/HI 1.6 - 2000	Centrifugal Pump Tests
ANSI/HI 14.6 - 2011	Standard for Rotodynamic Pumps for Hydraulic Performance Acceptance Tests
Copies available from:	Hydraulic Institute 9 Sylvan Way 6 Campus Drive Parsippany, NJ 07054 http://www.pumps.org/ www.hydraulicinstitute.com Phone: (973) 267-9700 FAX: (973) 267-9055

…

1605.1 (g) Pool Heaters, Portable Electric Spas, Residential Pool Pump and Motor Combinations, and Replacement Residential Pool Pump Motors.

…

(6) Energy Efficiency Standards and Energy Design Standards for Residential Pool Pump and Motor Combinations and Replacement Residential Pool Pump Motors. See Section 1605.3(g) for energy efficiency standards and energy design standards for residential pool pump and motor combinations and replacement residential pool pump motors.

…

1605.2 (g) Pool Heaters, Portable Electric Spas, Residential Pool Pump and Motor Combinations, and Replacement Residential Pool Pump Motors.

…

(2) See Section 1605.3(g) for energy efficiency standards and energy design standards for portable electric spas and ~~residential~~ pool pump and motor combinations and replacement ~~residential~~ pool pump motors.

…

Section 1605.3 (g) (5) ~~Residential~~ Pool Pump and Motor Combinations, and Replacement ~~Residential~~ Pool Pump Motors.

(A) **Motor Efficiency.**

1. ~~Pool pump motors manufactured on or after January 1, 2006 may not be split-phase or capacitor start – induction run type~~

…

~~2.~~ 1. All pool pump motors that have a total horsepower of 5 hp or less, manufactured on or after January 1, 2018, shall meet the efficiency standards in Table G-5.

Table G-5

Standards for Pool Pump Motors Manufactured on or After January 1, 2018

Motor Design	**Full Speed (3450 RPM) Minimum Efficiency**	**Half Speed (1725 RPM) Minimum Efficiency**
Single-Speed (up to 1 hp)	70%	N/A
Dual-Speed and Variable-Speed/Multiple-Speed	70%	50%

~~3.~~ 2. All pool pump motors that are 5 hp or less, manufactured on or after January 1, 2021, shall meet the efficiency standards in Table G-6.

Table G-6 - Standards for Pool Pump Motors Manufactured on or After January 1, 2021

Motor Design	**Full Speed (3450 RPM) Minimum Efficiency**	**Half Speed (1725 RPM) Minimum Efficiency**
Single-Speed (up to 1 hp)	80%	N/A
Dual-Speed and Variable-Speed/Multiple-Speed	80%	65%

(B) **Two-, Multi-, or Variable-Speed Capability for ~~Filtration~~ Pool Pump Motors.**

1. **~~Residential~~ Pool Pump Motors.** ~~Residential~~ <u>P</u>~~p~~ool pump motors with a pool pump motor capacity of 1 <u>hp</u> or greater which are manufactured on or after July 1, 2010, shall have the capability of operating at two or more speeds with a low speed having a rotation rate that is no more than one-half of the motor's maximum rotation rate. The pump motor must be operated with a pump control that shall have the capability of operating the pump at least at two speeds.

Section 1606 Table X Continued - Data Submittal Requirements

	Appliance	Required Information	Permissible Answers
G	~~Residential~~ Pool Pump and Motor Combinations and Replacement ~~Residential~~ Pool Pump Motors	<u>Pool Pump</u> Motor Construction	PSC, Capacitor Start-Capacitor Run, ECM, Capacitor Start-Induction Run, Split-Phase<u>, Permanent Magnet Synchronous, Shaded Pole, Reluctance, Polyphase Induction</u>
		<u>Pool Pump</u> Motor Design	Single-speed, dual-speed, multi-speed, variable-speed
		Frame	
		<u>Maximum</u> Speed (in RPM)	
		Motor has Capability of Operating at Two or More Speeds with the Low Speed having a Rotation Rate that is No More than One-Half of the Motor's Maximum Rotation Rate	Yes, no
		Unit Type	~~Residential~~ Pool Pump and Motor Combination, Replacement ~~Residential~~ Pool Pump Motor
		Pool Pump Motor Capacity	
		Motor Service Factor	
		Motor Efficiency <u>at full speed (3450 RPM)</u> (%)	
		<u>Motor Efficiency at ¾ speed (2590 RPM) (%) (multi-speed and variable-speed only)</u>	

		Motor Efficiency at ½ speed (1725 RPM) (%) (dual-speed, multi-speed and variable-speed only)		
		Motor Efficiency at ¼ speed (860 RPM) (%) (multi-speed and variable-speed only)		
		Nameplate Horsepower		
		Unit includes an integral pump controller.		Yes, no
		Pump Control Speed (compliance with Section 1605.3(g)(5)(B)ii~~3~~.)		Yes, no
		This information must be reported for each tested speed, as applicable (For pool pump and motor combinations only).	Flow for Curve 'A' (in gpm)	
			Power for Curve 'A' (in watts)	
			Energy Factor for Curve 'A' (in gallons per watt-hour)	
			Flow for Curve 'B' (in gpm)	
			Power for Curve 'B' (in watts)	
			Energy Factor for Curve 'B' (in gallons per watt-hour)	
			Flow for Curve 'C' (in gpm)	
			Power for Curve 'C' (in watts)	
			Energy Factor for Curve 'C' (in gallons per watt-hour)	

1606(a) (4) Declaration

…

(v) all units of the appliance are marked as required by Section 1607, and, for the following appliances, are marked as follows:

…

g. for ~~residential~~ pool pumps, each pool pump is marked permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than 1/4”, with the nameplate HP of the pump and, if manufactured on or after January 1, 2010, with the statement, “This pump must be installed with a two-, multi-, or variable-speed pump motor controller”;

h. for ~~residential~~ pool pump motors, each pool pump motor is marked permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than 1/4”, with the pool pump motor capacity of the motor.

…

1607 (d) (9) ~~Residential~~ Pool Pumps.

(A) Each ~~residential~~ pool pump shall be marked, permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than 1/4”, the nameplate HP of the pump.

(B) Each ~~residential~~ pool pump motor shall be marked, permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than 1/4”, the pool pump motor capacity of the motor.

(C) Two-, multi-, or variable-speed ~~residential~~ pool pumps certified under Section 1606 of this Article on or after January 1, 2010 shall be marked, permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than 1/4”,

APPENDIX A: Staff Assumptions and Calculation Methods

Appendix A contains the information and calculations used to characterize pool pump and motor combinations, and replacement pool pump motors in California, their current energy use, and potential savings. The source of much of the information for these tables is the CASE report submitted to the Energy Commission by the IOUs. All calculations were based on the assumption of an effective date of January 1, 2017, although the effective date is January 1, 2018. The difference in effective dates does not significantly alter the calculations.

Stock and Sales

Table A-1 lists the annual sales of each appliance, the total stock of appliances for each category, their duty cycle (annual hours of operation), and expected lifetime as surveyed by PG&E, SCE, and SDG&E, and reported in the CASE report.

Table A-1: Stock and Sales

Product	Total Stock 2012 (Thousand)	Stock Growth per Year (Thousand)	First -Year Stock 2017 (Thousand)	Total Stock 2017 (Thousand)	First -Year Stock 2020 (Thousand)	Total Stock 2020 (Thousand)	Lifetime (years)
Variable-Speed	180	2	19	189	19	194	10
Dual-Speed	190	2	20	200	21	205	10
Single-Speed Residential Filtration	1,520	15	160	1,596	164	1,642	10
Single-Speed Residential Non-Filtration	530	5	56	557	57	572	10
Single-Speed Commercial	50	1	5	53	5	54	10

Source: CASE report, p. 20 and staff calculation

Sales for 2017 and 2020 are estimated by dividing the total stock by the appliance lifetime in years. Staff projected the 2017 and 2020 stock numbers by assuming a non-compounded growth rate of 1 percent per year to the 2012 stock numbers presented in the CASE report. The 1 percent growth rate is based upon the California population forecast increase of about 1 percent[57].

57 Kavalec, Chris, Nicholas Fugate, Bryan Alcorn, Mark Ciminelli, Asish Gautam, Kate Sullivan, and Malachi Weng-Gutierrez, 2013. *California Energy Demand 2014-2024 Preliminary Forecast, Volume 1*, California Energy Commission, Publication Number CEC-200-2013-004-SD-V1, p. 30.

Residential and commercial pool pumps and motors are separated for energy consumption calculations due to different duty cycles.

Example: Variable-speed pumps total stock and sales calculation:

Total Stock 2017

$N_{2017} = N_{2012} \times 1.05\%$
$189{,}000 = 180{,}000 \times 1.05\%$

Sales 2017

$S_{2017} = N_{2017} \div L$
$18{,}900 = 189{,}000 \div 10$
where:
S_{2017} = Sales for year 2017
N_{2017} = Total stock for year 2017
N_{2012} = Total stock for year 2012
L = Product lifetime in years

Compliance Rates

Staff used the CASE report estimates for compliance to the proposed motor efficiency standards. The single-speed, dual-speed, and variable-speed Tier 1 and Tier 2 compliance rates were estimated based upon data in the Energy Commission's Appliance Efficiency Database and the CASE report. **Table A-2** lists current compliance rates for the proposed standards.

Table A-2: Compliance Rates

Product	Non-Compliant (%)	Compliance Tier 1 (%)	Compliance Tier 2 (%)
Variable-Speed	0	100	90
Dual-Speed	80	20	5
Single-Speed Residential Filtration	80	20	5
Single-Speed Residential Non-Filtration	80	20	5
Single-Speed Commercial	80	20	5

Source: CASE report, p. 22, and Energy Commission Appliance database

Duty Cycle

The duty cycle is an estimate of consumer behavior for pool pump motor combinations and replacement pool pump motors. Duty cycle describes how often and for how long the product is used. The duty cycles represent current average annual usage to make meaningful estimates of product energy consumption and savings. These figures rely on metering and behavior studies where possible, and use reasonable estimates where this type of information is unavailable.

Table A-3: Duty Cycle

Product	Full Speed (hrs/yr)	Half Speed (hrs/yr)
Variable-Speed	700	1800
Dual-Speed	700	1800
Single-Speed Residential Filtration	1700	N/A
Single-Speed Residential Non-Filtration	900	N/A
Single-Speed Commercial	8760	N/A

Source: CASE report

Baseline Energy Use

The power consumption assumptions for pool pump and motor combinations, and replacement pool pump motors are derived from the CASE report, which relies on market data gathered by utilities and pool owner surveys to determine full-speed and half-speed usage. The baseline usage was calculated for single-speed, dual-speed, and variable-speed at various motor sizes. Baseline motor efficiency was estimated by calculating the average efficiency of non-compliant models in the Energy Commission's Appliance Efficiency Database. Estimated annual energy consumption per pool pump type and size is calculated using a combination of the power of the various modes and the duty cycles of those modes. For example, the annual energy consumption of full speed is calculated by multiplying full-speed mode power by full-speed mode duty cycle. For each motor type, the average energy consumption was calculated and is shown in **Table A-4** and **A-5**. The average was weighted based upon sales data per motor size. The average annual energy consumption for a given product was calculated as follows:

The power consumption calculation is performed for both the full-speed and half-speed mode of operation with values for name plate power, motor service factor, and efficiency for full and half speed gathered from the CASE report and the Appliance Efficiency Database. Compliance rates are assumed to be same for both full and half speed since the motor must meet both standards.

Total motor power output capacity

$P_o = P_{np} \times SF$

where

P_o = Total motor power output capacity

P_{np} = Nameplate motor output
SF = Service Factor

For example total motor capacity of a 1 hp motor with 1.25 service factor is:
P_o = 1 hp x 1.25 = 1.25 hp

The half speed total motor capacity is found by observing the pump affinity laws.
$P_{half\ speed} = P_{full\ speed} \times (1/2)^3$
where
½ represents the ratio of half speed to full speed
Convert hp to kilowatts (kW) using conversion factor.
kW= .746 (kW/hp)× hp

Full speed baseline power consumption:

$P_i = (P_o \div \eta_{non\ compliant}) \times (1\text{-}C) + (P_o \div \eta_{compliant}) \times (C)$
where:
P_i = Motor power input at full speed
P_o = Motor power output at full speed
C = Compliance rate
$\eta_{non\ compliant}$ =Average motor efficiency at full speed for non-compliant units
$\eta_{compliant}$ =Average motor efficiency at full speed for compliant units

Half speed baseline power consumption:

$P_i = (P_o \div \eta_{non\ compliant}) \times (1\text{-}C) + (P_o \div \eta_{compliant}) \times (C)$
where:
P_i = Motor power input at half speed
P_o = Motor power output at half speed
C = Compliance rate
$\eta_{non\ compliant}$ =Average motor efficiency at half speed for non-compliant units
$\eta_{compliant}$ =Average motor efficiency at half speed for compliant units

Average full speed power

$P_{annual\ average} = (P_{1.0\ hp} \times \%_{1.0\ hp}) + (P_{1.5\ hp} \times \%_{1.5\ hp}) + (P_{2.0\ hp} \times \%_{2.0\ hp}) + (P_{2.5\ hp} \times \%_{2.5\ hp}) + (P_{3\ hp} \times \%_{3\ hp})$
where:
$P_{annual\ average}$ = Average full speed power per appliance type
$P_{1.0\ hp}$ = Full speed input power as calculated above for 1.0 hp motor
$P_{1.5\ hp}$ = Full speed input power as calculated above for 1.5 hp motor
$P_{2.0\ hp}$ = Full speed input power as calculated above for 2.0 hp motor
$P_{2.5\ hp}$ = Full speed input power as calculated above for 2.5 hp motor
$P_{3.0\ hp}$ = Full speed input power as calculated above for 3.0 hp motor

$\%_{1.0\ hp}$ = percent sales at 1.0 hp
$\%_{1.5\ hp}$ = percent sales at 1.5 hp

$\%_{2.0\ hp}$ = percent sales at 2.0 hp
$\%_{2.5\ hp}$ = percent sales at 2.5 hp
$\%_{3.0\ hp}$ = percent sales at 3.0 hp
Average half-speed power per appliance is calculated in a similar manner.

Average Energy consumption per appliance per motor size:

$E_{annual} = (P_{avg\ full\ speed} \times D_{full\ speed}) + (P_{avg\ half\ speed} \times D_{half\ speed})$
where:
E_{annual} = Annual energy consumption per appliance
$P_{avg\ full\ speed}$ = Power input calculated above for full-speed motor operation
$P_{avg\ half\ speed}$ = Power input calculated above for half-speed motor operation
$D_{full\ speed}$ = Duty cycle for full speed
$D_{half\ speed}$ = Duty cycle for half speed

Total stock energy consumption per motor type:

$E_{total\ baseline\ stock} = E_{annual\ baseline} \times N_{2017}$
where:
$E_{total\ stock}$ = Total baseline stock energy consumption per motor type
$E_{annual\ average}$ = Average annual energy consumption per appliance type
N_{2017} = Total stock for year 2017

Table A-4 presents baseline energy consumption prior to the Tier 1 motor efficiency standard. **Table A-5** presents the baseline energy consumption assuming 100 percent compliance with Tier 1 to show the effect of the Tier 2 regulation.

Table A-4: Tier 1 Baseline Energy Consumption

Product	Full Speed (kW)	Half Speed (kW)	Annual Energy Consumption (kWh per Appliance /yr)	Total Annual Stock Energy Use (GWh/yr)
Variable-Speed Tier 1	3.16	0.55	3,209	606
Dual-Speed Tier 1	2.34	0.43	2,403	479
Single-Speed Residential Filtration	1.09	N/A	1,860	2,969
Single-Speed Residential Non-Filtration	1.09	N/A	985	548
Single-Speed Commercial	2.32	N/A	20,345	1,068

Source: Staff Calculation

Table A-5: Tier 2 Baseline Energy Consumption

Product	Full Speed (kW)	Half Speed (kW)	Annual Energy Consumption (kWh per Appliance /yr)	Total Annual Stock Energy Use (GWh/yr)
Variable-Speed Tier 2	2.81	0.44	2,753	535
Dual-Speed Tier 2	2.30	0.40	2,331	478
Single-Speed Residential Filtration	0.91	N/A	1,553	2,549
Single-Speed Residential Non-Filtration	0.91	N/A	822	471
Single-Speed Commercial	2.23	N/A	19,540	1,055

Source: Staff Calculation

Table A-6: Sales Weight Data

Product Class	Nameplate Motor Power (hp)	Sales Weight by hp (%)
Variable-Speed	1	13
	1.5	10
	2	16
	2.7	19
	3	42
Dual-Speed	0.75	9
	1	29
	1.5	28
	2	4
	2.5	4
	3	26
Single-Speed Filtration	0.5	12
	0.75	84
Single-Speed Non-Filtration	0.5	12
	0.75	84
Single-Speed Commercial	1	30
	1.5	32
	2	20
	2.5	7
	3	11

Source: CASE report (shown in spreadsheet but not in text of CASE report)

Table A-7: Tier 1 Efficiency and Compliance Data

Product Class	Nameplate Motor Power (hp)	Full-Speed Motor Efficiency (non-compliant units)	Half-Speed Motor Efficiency (non-compliant units)	Tier 1 Full-Speed Motor Efficiency (compliant units)	Tier 1 Half speed Motor Efficiency (compliant units)
Variable-Speed	1	0.70	0.50	0.70	0.50
	1.5	0.70	0.50	0.70	0.50
	2	0.70	0.50	0.70	0.50
	2.7	0.70	0.50	0.70	0.50
	3	0.70	0.50	0.70	0.50
Dual-Speed	0.75	0.68	0.38	0.70	0.50
	1	0.66	0.41	0.70	0.50
	1.5	0.7	0.47	0.70	0.50
	2	0.7	0.49	0.70	0.50
	2.5	0.7	0.50	0.70	0.50
	3	0.7	0.50	0.70	0.50
Single-Speed Filtration	0.5	0.61	N/A	0.70	N/A
	0.75	0.56	N/A	0.70	N/A
Single-Speed Non-Filtration	0.5	0.61	N/A	0.70	N/A
	0.75	0.56	N/A	0.70	N/A
Single-Speed Commercial	1	0.66	N/A	0.70	N/A
	1.5	0.65	N/A	0.70	N/A
	2	0.67	N/A	0.70	N/A
	2.5	0.70	N/A	0.70	N/A
	3	0.70	N/A	0.70	N/A

Source: CASE report

Table A-8: Tier 2 Efficiency and Compliance Data

Product Class	Nameplate Motor Power (hp)	Full-Speed Motor Efficiency (non-compliant units)	Half-Speed Motor Efficiency (non-compliant units)	Tier 2 Full-Speed Motor Efficiency (compliant units)	Tier 2 Half-Speed Motor Efficiency (compliant units)
Variable-Speed	1	0.7	0.50	0.8	0.65
	1.5	0.7	0.50	0.8	0.65
	2	0.7	0.50	0.8	0.65
	2.7	0.7	0.50	0.8	0.65
	3	0.7	0.50	0.8	0.65
Dual-Speed	0.75	0.7	0.50	0.8	0.65
	1	0.7	0.50	0.8	0.65
	1.5	0.7	0.50	0.8	0.65
	2	0.7	0.50	0.8	0.65
	2.5	0.7	0.50	0.8	0.65
	3	0.7	0.50	0.8	0.65
Single-Speed Filtration	0.5	0.7	N/A	0.8	N/A
	0.75	0.7	N/A	0.8	N/A
Single-speed non-filtration	0.5	0.7	N/A	0.8	N/A
	0.75	0.7	N/A	0.8	N/A
Single-Speed Commercial	1	0.7	N/A	0.8	N/A
	1.5	0.7	N/A	0.8	N/A
	2	0.7	N/A	0.8	N/A
	2.5	0.7	N/A	0.8	N/A
	3	0.7	N/A	0.8	N/A

Source: CASE report

Compliant Energy Use

The power consumption of compliant products is estimated based on minimum requirements to meet the proposed regulations. For example, the proposed full-speed motor efficiency is 70 percent, so products were assumed to consume exactly the bare minimum power to accomplish this standard. It is noted those cases where the baseline power for a given mode was already less than the standard that the report does not assume that power will increase, but rather that it will remain the same. The annual energy consumption is calculated using the same methodology as baseline energy use. **Table A-6** and **A-7** show predicted energy consumption of compliant units and stock.

Table A-9: Tier 1 Compliant Energy Consumption

Product	Full Speed (kW)	Half Speed (kW)	Annual Energy Consumption (kWh per Appliance /yr)	Total Annual Stock Energy Use (GWh/yr)
Variable-Speed	3.16	0.55	3,209	606
Dual-Speed	2.31	0.41	2,349	469
Single-Speed Residential Filtration	0.92	N/A	1,563	2,494
Single-Speed Residential Non-Filtration	0.92	N/A	827	460
Single-Speed Commercial	2.24	N/A	19,663	1,032

Source: Staff Calculation

Table A-10: Tier 2 Compliant Energy Consumption

Product	Full Speed (kW)	Half Speed (kW)	Annual Energy Consumption (kWh per Appliance)	Total Annual Stock Energy Use
Variable-Speed Tier 2	2.77	0.43	2,702	525
Dual-Speed Tier 2	2.03	0.31	1,979	406
Single-Speed Residential Filtration	0.80	N/A	1,367	2,245
Single-Speed Residential Non-Filtration	0.80	N/A	724	414
Single-Speed Commercial	1.96	N/A	17,205	929

Source: Staff Calculation

Cost and Energy Savings

The annual existing and incremental stock energy savings are calculated by subtracting the compliant energy use from the baseline energy use.

Stock Energy Savings

$E_{stock\ savings} = E_{baseline\ stock} - E_{compliant\ stock}$

where:

$E_{stock\ savings}$ = Annual stock energy savings at full stock turnover

$E_{baseline\ stock}$ = Annual stock baseline energy consumption

$E_{compliant\ stock}$ = Annual stock compliant energy consumption

First Year Energy Savings

$E_{1\ year\ savings} = E_{stock\ savings} \div L$

where:

$E_{1\ year\ savings}$ = Energy savings from first years sales of compliant units.

$E_{stock\ savings}$ = Annual stock energy savings at full stock turnover

L = Product lifetime in years

Table A-11: Tier 1 Statewide Cost and Energy Savings

	First Year Savings		Annual Existing and Incremental Stock Savings	
Product	**Electricity Savings (GWh/yr)**	**Savings ($ million)**	**Electricity Savings (GWh/yr)**	**Savings ($ million)**
Variable-Speed	0.0	$0.0	0	$0.0
Dual-Speed	1.1	$0.2	11	$1.7
Single-Speed Residential Filtration	47.5	$7.6	475	$76.0
Single-Speed Residential Non-Filtration	8.8	$1.4	88	$14.1
Single-Speed Commercial	3.6	$0.6	36	$5.8
Total Savings	**61.0**	**$9.8**	**610**	**$97.6**

Source: Staff Calculation

Table A-12: Tier 2 Statewide Cost and Energy Savings

	First Year Savings		Annual Existing and Incremental Stock Savings	
Product	**Electricity Savings (GWh/yr)**	**Savings ($ million)**	**Electricity Savings (GWh/yr)**	**Savings ($ million)**
Variable-Speed Tier 2	1.0	$0.2	10	$1.6
Dual-Speed Tier 2	7.2	$1.2	72	$11.5
Single-Speed Residential Filtration	30.5	$4.9	305	$48.8
Single-Speed Residential Non-Filtration	5.6	$0.9	56	$9.0
Single-Speed Commercial	12.6	$2.0	126	$20.2
Total Savings	**56.9**	**$9.1**	**569**	**$91.1**

Source: Staff Calculation

Table A-13: Tier 1 and Tier 2 Statewide Cost and Energy Savings

	First Year Savings		Annual Existing and Incremental Stock Savings	
	Electricity Savings (GWh/yr)	**Savings ($ million)**	**Electricity Savings (GWh/yr)**	**Savings ($ million)**
Tier 1 Total Savings	61.0	$9.8	610	$97.6
Tier 2 Total Savings	56.9	$9.1	569	$91.1
Tier 1 and Tier 2 Total Savings	**117.9**	**$18.9**	**1179**	**$188.7**

Source: Staff Calculation

Unit cost savings (benefits) are calculated by multiplying the annual energy savings by $0.16 per kWh and by the design life.

Annual Unit Energy Savings

$E_{annual\ savings} = E_{annual\ baseline} - E_{annual\ Compliant}$

where:

$E_{annual\ savings}$ = Annual unit energy savings

$E_{annual\ baseline}$ = Annual unit baseline energy consumption

$E_{annual\ compliant}$ = Annual unit compliant energy consumption

Lifetime Unit Energy Savings

$B_{energy\ savings} = E_{annual\ savings} \times L$

where:

$B_{energy\ savings}$ = Lifetime unit energy savings

$E_{annual\ savings}$ = Annual unit energy savings

L = Product lifetime in years

Net unit savings are calculated by subtracting costs from benefits.

Net energy savings:

$B_{net} = B_{energy\ savings} - C_{incremental}$

where:

B_{net} = Net energy savings

$B_{energy\ savings}$ = Lifetime unit energy savings

$C_{incremental}$ = Incremental cost

Table A-14: Annual Energy and Monetary Savings

Product	Design Life (years)	Electricity Savings (kWh/yr)	Incremental Cost ($)	Average Annual Savings ($)	Life Cycle Savings ($)	Life-Cycle Benefit ($)
Variable-Speed Tier 1	10	0	$0	$0	$0	$0
Variable-Speed Tier 2	10	51	$18	$8	$81	$63
Dual-Speed Tier 1	10	53	$5	$9	$85	$80
Dual-Speed Tier 2	10	352	$65	$56	$561	$496
Single-Speed Residential Filtration Tier 1	10	297	$12	$48	$461	$449
Single-Speed Residential Non-Filtration Tier 1	10	157	$12	$25	$244	$232
Single-Speed Commercial Tier 1	10	682	$12	$109	$1,091	$1,079
Single-Speed Residential Filtration Tier 2	10	186	$55	$30	$297	$242
Single-Speed Residential Non-Filtration Tier 2	10	98	$55	$16	$157	$102
Single-Speed Commercial Tier 2	10	2,335	$65	$374	$3,736	$3,671

PART B: PORTABLE ELECTRIC SPAS

Chapter 11: Product Description

Portable electric spas are factory-built, free-standing electric spas or hot tub units that are either rigid or inflatable in design. They are defined as above-ground units that are electrically heated and not permanently installed in the ground and/or attached to a pool. They are supplied with pumps, heaters, and jets for heating, circulating, filtering, and maintenance, all of which result in a significant energy consumption statewide.

According to a 2013 APSP market report, over 1 million spas are being used in California and over 100,000 new units were sold each year in 2011 and 2012[58]. Uses vary from recreational to health and fitness use. There are various comfort features and configurations of the heating system, the pumping system, and the filtering system for portable electric spas, making them one of the highest residential electrical loads[59]. The typical components in portable electric spas include: a heating element, a pump and motor combination, a filter, insulation, a shell or tub wall, an exterior cabinet, jets, and, optionally, a spa cover (see **Figure 14**[60]). These components provide opportunities for energy efficiency improvements. The average lifetime of a portable electric spa is 10 years; a spa cover has an average lifetime of 5 years[61].

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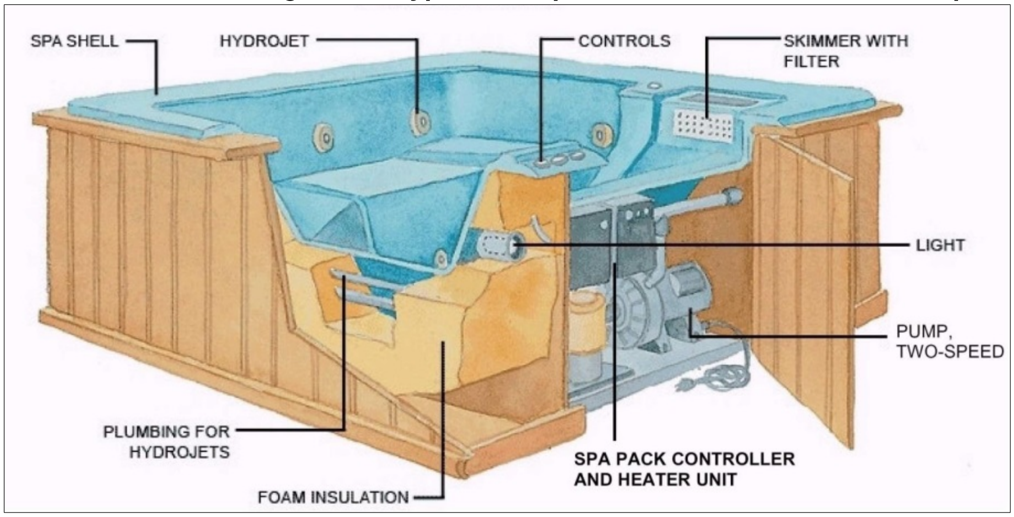
58 The Association of Pool & Spa Professionals, P.K. Data Research Industry Statistics. Retrieved from http://apsp.org/portals/0/images/APSP%20statistics%202013.jpg.
59 Davis Energy Group, Energy Solutions, (2004), *Analysis of Standards Options for Portable Electric Spas*. California: PG&E.
60 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering . San Luis Obispo: Andrew Ian Hamill.
61 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas*. Energy Solutions, PG & E. California Statewide Utility Codes and Standards Program. Retrieved July 2015.

Figure 14: Typical Components in a Portable Electric Spa.



Source: The Spa Guys, How Hot Tubs Work

As of July 2015, the Energy Commission's modernized appliance efficiency database system (MAEDBS) lists 1,180 certified portable electric spas. There are currently spas that are distinguished as hot tubs/portable spas and exercise spas/swim spas. For this report, two types of spas were analyzed: portable spas and exercise spas. Using the certified portable electric spa manufacturers in the MAEDBS as sources, the overall key differences between the two types of spas are the volume capacity (or water surface area), the type of features, and the intended use.

Portable Spas

Portable spas are mostly intended for recreational use and provide the user with a comforting warm-water massage by electrically heating and aerating the water[62]. Portable spas may include hydrotherapy or therapeutic features which use a jet system that projects streams of water at different pressure outputs in multiple locations. The volume capacity for portable spas can range from 120 gallons to more than 800 gallons[63]. Portable spas may be rigid bodied or inflatable, and typically have a temperature range between 60˚F and 104˚F[64].

Exercise Spas

Exercise spas are intended for health, fitness, and recreational use. Health and fitness uses include swimming, aquatic fitness or exercising, and hydrotherapy. The swimming mode uses a propulsion system to create a current of rushing water the user can swim against. The

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62 Jacuzzi. (2011, November 30). Jacuzzi Hot Tubs Lists the Most-Wanted Hot Tub Feature. Retrieved from Jacuzzi: http://www.jacuzzi.com/hot-tubs/about/press-releases/jacuzzi-hot-tubs-lists-most-wanted-hot-tub-feature/.
63 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas.* Energy Solutions, PG&E. California Statewide Utility Codes and Standards Program. Retrieved July 2015.
64 CEC certified portable electric spa manufacturers: Catalina Spas, Masters Spas Inc., Sundance , Dimension One Spas.

therapeutic mode offers hydrotherapy configurations for exercising or for physical therapy, thus requiring a larger volume or water surface area[65]. Exercise spas are designed to have two separate bodies of water at different temperatures called combination spas, one for swimming and the other for hydrotherapy[66]. USA Swimming and the Aquatic Exercise Association recommend a water temperature range of 78˚F to 82˚F for competitive swimming, 83˚F to 88˚F for aquatic exercise, and 90˚F to 95˚F for aquatic therapy. Most exercise spas have a built-in temperature range of 60˚F to 104˚F[67] and are capable of meeting those recommendations. The user can still select the temperature of their choice. Exercise spas have capacities that range from 900 gallons to 2,500 gallons[68].

Using the volume ranges stated above for the two types of portable electric spas and the MAEDBS, there are 33 certified exercise spas ranging from 1,058 gallons to 2,355 gallons and 29 of the these spas are designated as exercise/swim spas by the manufacturer[69]. For portable spas, there are 1,148 certified portable spas ranging from 117 to 850 gallons.

Heating System

Portable electric spas heat water electrically. The heating system accounts for the majority of the energy consumption. Most heating systems use electric resistance heaters and in some cases waste heat from the pump system to heat and maintain the water at a set temperature[70].

According to a 2012 Cal Poly study, the heater is used during startup, standby, and active use. During startup mode, the recently filled water is heated to a set temperature or temperature range with the spa cover on. The startup mode can take from 5 to over 24 hours to reach a water temperature of 102˚F. After the water has reached the set temperature, the unit is put into standby mode to maintain the set temperature, and to circulate and filter the water. When it is time for use, the spa cover is removed, and the spa is occupied. The heater is used to maintain the set temperature[71]. Most spas are kept in standby mode year round[72] when not in use, since startup mode requires a lot of time and energy. Over the lifetime of the unit, the

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65 Hartey, M. (2013). *Swim Spa Basics.* Retrieved from Pool & Spa Outdoor: http://www.poolspaoutdoor.com/hot-tubs-swim-spas/swim-spas/articles/swim-spa-basics.aspx.

66 Poolandspa.com. (2015, August 21). *What is a swim spa?* Retrieved from poolandspa.com: http://www.poolandspa.com/page6210.htm.

67 CEC certified portable electric spa manufacturers: Catalina Spas, Masters Spas Inc., Sundance , Dimension One Spas

68 Various exercise spa manufacturers: Artic Spas, Dimension One Spas, and Master Spas Inc.

69 Exercise/Swim Manufacturers: Master Spas Inc., Dimension One Spas, Blue Falls Manufacturing, Spa Manufacture Inc., Catalina Spas, Marquis Corp., L.A. Spas Inc.

70 Davis Energy Group, Energy Solutions. (2004). *Analysis of Standards Options for Portable Electric Spas.* California: PG&E.

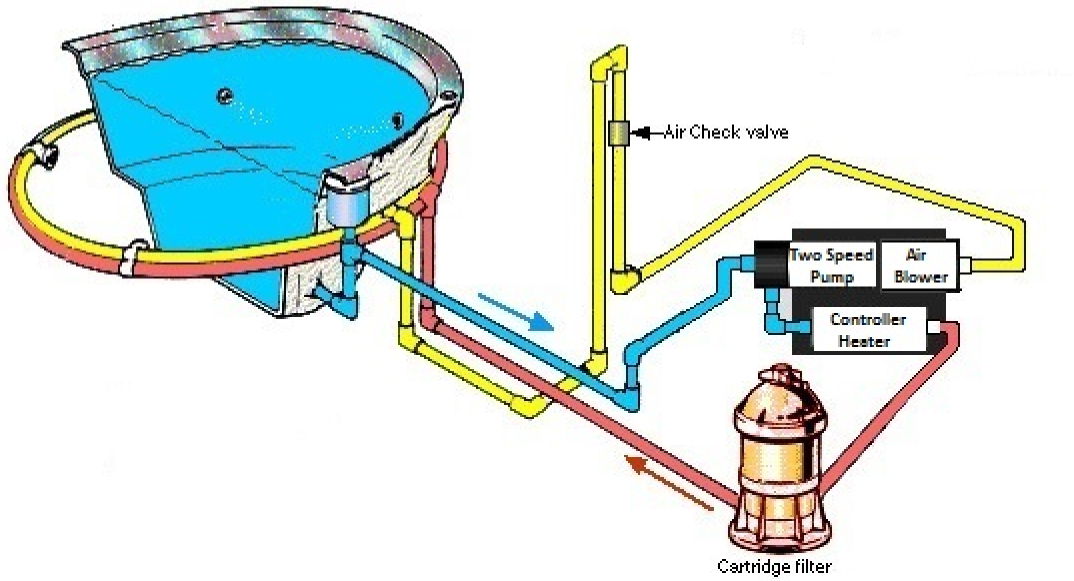
71 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering . San Luis Obispo: Andrew Ian Hamill.

72 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas.* Energy Solutions, PG&E. California Statewide Utility Codes and Standards Program. Retrieved July 2015.

standby mode represents typically 75 percent of the energy consumed by a portable electric spa[73]. Over half of the energy consumed during standby mode is due to maintaining heat[74].

The heating system functions the same through each mode. There are many configurations of the heating system, but generally the pump draws water from the footwell through a suction fitting and/or from the surface through a skimmer/filter to the heater. A general configuration is shown in **Figure 15**. The warm water is returned to the spa through the jets or a main return. The water can be filtered before or after reaching the heater.

Figure 15: Heating and Pumping System



General configuration of the heating system and pumping system in a portable electric spa.

Source: Spa Plumbing Diagrams, PoolSpasHelp.com

Electric resistance heaters are theoretically 100 percent energy efficient since all the electricity is converted to heat[75]. Resistance heaters in portable electric spas can have efficiencies of 98 percent or more[76]. Thus, the energy efficiency is already high for heaters in a portable electric spa.

73 Appliance Standards Awareness Project. (2015). *Portable Electric Spas*. Retrieved from ASAP - Appliance Standards Awareness Project: http://www.appliance-standards.org/product/portable-electric-spas.

74 Davis Energy Group, Energy Solutions. (2004). *Analysis of Standards Options for Portable Electric Spas*. California: PG&E.

75 U.S. DOE. (2015). Electric Resistance Heating. Retrieved from Energy.gov: http://energy.gov/energysaver/articles/electric-resistance-heating.

76 Davis Energy Group, Energy Solutions. (2004). *Analysis of Standards Options for Portable Electric Spas*. California: PG&E.

Pumping System

After the heating system, the pumping system is the most energy-intensive integrated part of a portable electric spa, and can account for 25 to 50 percent of the total energy consumed by the unit depending on how often different features are used. The energy consumption can vary since there are many possible configurations for the pumping system. Most portable electric spas have at least one pump with multiple speed options for filtering, circulating, aerating, and jet action. For example, some spas have a two-speed pump motor where the low-speed option is used during standby mode and the high-speed option is used for operating the jets. These pumps are not very efficient in any mode, especially during standby because the motor is lightly loaded and running at low efficiency[77]. Some models include a separate pump for specific features and/or maintenance duties which can save a significant amount of energy over the low-speed option on a larger pump[78]. Larger spas, like exercise spas, typically have multiple pumps. For example, exercise spas sold in California can have up to four pumps[79].

Depending on how the unit is setup internally, the pumping system functions nearly the same for the heating process and the filtering process. Water is pumped into the heating element and/or the filter, the water is then returned to the unit through the jets or a main return. For other maintenance duties and features, such as aeration, circulation, and hydrotherapy, the pumping system supplies water and air to the jets at varying pressures[80]. The type of jets within a system can vary as well, some supply air and water separately, but most are a combination of air and water (see **Figure 16.**) Portable electric spas that are marketed as hydrotherapy spas have multiple jets of different types. Increasing the number of jets increases the power demand of the pumping system. Thus, some units include a separate pump for jets and/or circulation[81]. The secondary pump can be used to optimize the primary pump and generate savings in standby mode.

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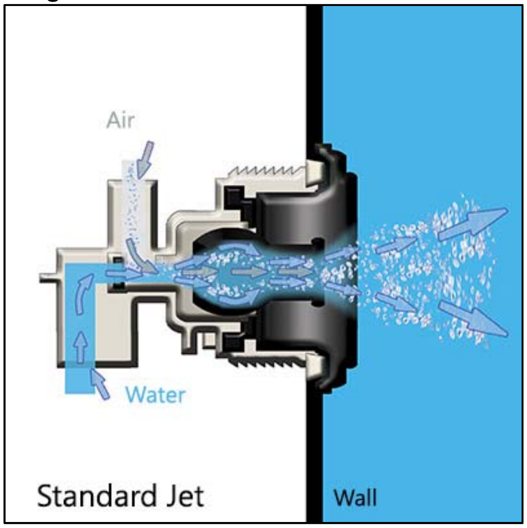
77 Western Area Power Administration. (2009). *What goes into an Energy-Efficient Spa or Hot Tub?* Lakewood: Western Area Power Administration.
78 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas.* Energy Solutions, PG&E. California Statewide Utility Codes and Standards Program. Retrieved July 2015.
79 Masters Inc. (2014). Models - H2X Swim Spas. Retrieved July 2015, from H2X Water To The Extreme, available athttp://www.h2xswimspa.com/h2x-swimspa-models.html.
80 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering . San Luis Obispo: Andrew Ian Hamill.
81 Western Area Power Administration. (2009). *What goes into an Energy-Efficient Spa or Hot Tub*? Lakewood: Western Area Power Administration.

Figure 16: Standard Jet Cross-Section



Source: H2X Swim Spas, Master Inc.

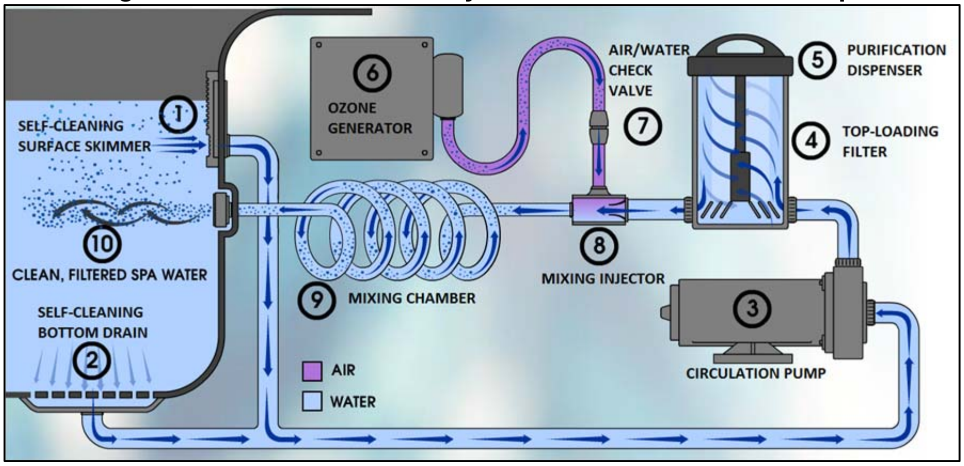
Water Treatment

The water treatment system is inclusive of the pumping system since water treatment requires circulation and suctioning of water through the filtration unit. Filtration cycles can vary from programmed settings to an all-year round continuous setting. Portable electric spas typically have one central pump that performs all operations including the filtration cycle, although some spas use a separate pump specifically for filtration and circulation[82]. Again, the filtration system can have various configurations and can include different types of water treatment mechanisms to improve water quality, such as cartridge filters with or without media, skimmers, an ozonator, UV system, and the addition of minerals and sanitizing chemicals[83]. A single cartridge filter is the most common filtration system for smaller spas. Larger spas typically have a cartridge filter and an ozone treatment system paired together (see **Figure 17**.) Untreated water is suctioned through the cartridge filter, where large particles and contaminants are removed[84]. For units that include an ozonator (an ozone system), the filtered water is injected and mixed with ozone (O_3) an oxidizing-agent that effectively treats organic

82 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas*. Energy Solutions, PG&E. California Statewide Utility Codes and Standards Program. Retrieved July 2015
83 The Spa Depot. (2015). *Hot Tub Maintenance*. Retrieved from SpaDepot.com: http://www.spadepot.com/spacyclopedia/hot-tub-maintenance.htm.
84 National Academy of Sciences. (2007). *Filtration Systems - Technologies*. Retrieved from Safe Drinking Water is Essential: http://www.koshland-science-museum.org/water/html/en/Treatment/Filtration-Systems-technologies.html#tech4.

and inorganic contaminants. The treated water is then returned to the water through the jets or a main return[85].

Figure 17: Water Treatment System in a Portable Electric Spa



A typical water treatment system which includes a cartridge filter and an ozonator.

Source: Baja Spas

Insulation and Spa Covers

Since portable electric spas circulate and heat water, reducing the energy consumption of the heating system presents an opportunity to save energy. To this end, manufacturers use good insulation and spa covers to combat heat and water loss. Insulation minimizes heat loss during operating and idle periods, while a spa cover minimizes heat loss and water loss through evaporation. Ensuring that a spa cover is being used, and improving the cover and insulation reduces the work of the heater and the pump motor needed to maintain a set temperature during idle periods.

The spa unit insulation and spa cover offer the greatest opportunity to save energy, since they help retain the heat in the water by their design and construction materials. Insulation is used within the walls of the spa unit and within the spa cover. The insulation used within the walls or the cavity between the tub wall and the cabinet enclosure is usually either foam or fiberglass. According to the Energy Commission database, over 99 percent of spas listed are fully insulated[86].

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85 National Academy of Sciences . (2007). *Chemical Disinfection/Oxidants - Technologies*. Retrieved from Safe Drinking Water is Essential: http://www.koshland-science-museum.org/water/html/en/Treatment/Chemical-Disinfection-Oxidants-technologies.html#tech3.
86 California Energy Commission. (2015). MAEDBS. Retrieved from Appliance Search http://maedbs/Pages/ApplianceSearch.aspx.

For spa covers, according to the 2009 Residential Appliance Saturation Survey, 43 percent of California spa owners did not own a spa cover[87]. Not all portable electric spas are sold with a spa cover. Consumers need to be made aware that a spa cover is a key component to their system. Using a spa cover is critical to saving energy and water (lost through evaporation.) The evaporation rate due to not using a spa cover while heating the water from 60˚F to 102˚F was calculated by using the average volume capacity in each volumetric zone to determine a typical water surface area for that volume (see **Table 16.**). Larger units typically have a greater water surface area which results in more water and heat loss than standard units. For example, a 450 gallon unit can lose more than one gallon of water per hour, whereas a 2,250 gallon can lose almost three gallons of water per hour. Looking at the evaporation rate as a relationship between the exposed surface area of water relative to the volume of the unit will separate the spas into different groups or "zones" that better represent the water losses that occur.

Table 16: Evaporation Rate Without a Spa Cover

Zone	Unit Volume Capacity (gallons)	Water Surface Area (m^2)	Evaporation Rate, w_p (gallons/hr)
Zone 1A	140	3.3	0.70
Zone 1B	240	3.9	0.83
Zone 2	450	5.7	1.21
Zone 3	750	5.8	1.23
Zone 4	1,050	8.0	1.69
Zone 5	1,350	8.7	1.85
Zone 6	1,650	10.9	2.31
Zone 7	1,950	13.0	2.76
Zone 8	2,250	14.0	2.96

The evaporation rate (w_p) due to not using a spa cover by water surface area relative to volume capacity.

Source: Design Considerations for Pools and Spas (Natatoriums) by John W. Lund, see Appendix B for calculations.

Assuming evaporation rates of 0.5 gallons to 2.96 gallons during standby operating hours (8,760 hours per year), as shown in **Table 2**, a determination can be made about the amount of energy required in a worst case scenario to heat the spa, the evaporation rate, the water wasted, and the costs associated with not using a spa cover. The energy costs range from $1,800 to $10,500 per unit per year. The amount of water that evaporates due to not using a spa cover is

87 KEMA. (2010). *California Statewide Residential Appliance Saturation Study*. Retrieved from https://websafe.kemainc.com/RASS2009/Default.aspx.

significant as well. For an evaporation rate of one gallon of water per hour, the amount of water wasted is about 8,700 gallons per year per unit (see **Table 17**.) Using a cover can reduce evaporation by 90 to 95 percent[88].

Table 17: Annual Energy and Water Waste Without a Spa Cover

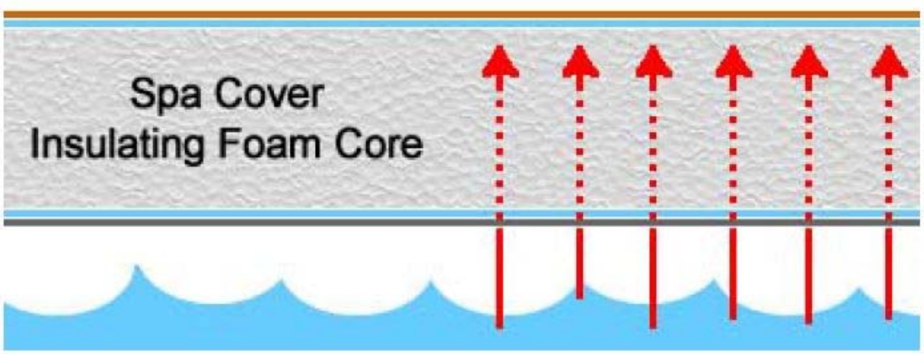
Evaporation Rate, w (gallons/hr)	Energy Consumption (kWh/year)	Water Lost to Evaporation (gallons/year)	Energy Costs for Heating Water ($)
0.5	10,844	4,380	$1,756
1	21,688	8,760	$3,511
2	43,376	17,520	$7,023
3	65,064	26,280	$10,534

Source: Building Technology: Mechanical and Electrical Systems by B. Stein

See Appendix B for calculations.

Spa covers conserve heat by reducing heat flow due to conduction, convection, radiation, and evaporation. The foam core within the spa cover acts as a thermal insulator, reducing heat transfer from the warm water to the colder air outside (see **Figure 18**[89]) The insulating material's thermal resistance, in this case the foam core, is measured or rated by the R-value, which depends on the insulation type, thickness, and density. A high R-value indicates greater resistance to heat flow[90].

Figure 18: Cross-Section of a Spa Cover



A cross-section of a typical spa cover. The arrows indicate heat loss disspating through the foam core.

Source: Duratherm, The Spa Depot

88 Azusa Light & Water. (2015, July 27). *Rebates*. Retrieved from Azusa Light & Water: http://www.ci.azusa.ca.us/index.aspx?nid=368.
89 DuraTherm -The Spa Depot. (2015). *Spa Covers*. Retrieved from SpaDepot.com: http://www.spadepot.com/docs/spa-cover-energy-conservation.pdf.
90 U.S. DOE. (2015, April 27). *Insulation*. Retrieved from Energy.Gov: http://energy.gov/energysaver/articles/insulation.

The foam core is typically made of polystyrene[91]. Polystyrene is a colorless, transparent thermoplastic[92]. There are two types of rigid polystyrene that are used as foam cores for spa covers: expanded polystyrene (EPS) and extruded polystyrene (XPS). EPS is composed of small plastic beads that are fused together by heat and pressure leaving open voids between the beads, whereas XPS begins as a molten material that is extruded into a closed cell matrix (no spaces between cells). Both have different performance properties due to their manufacturing process.

XPS is less water absorbent than EPS. The voids in EPS allow for significant water to be absorbed. When the foam absorbs water, the insulation loses its thermal resistance. Water can also freeze and thaw compromising the structural integrity of the foam. XPS also has a higher R-value than EPS when dry or wet. Dry EPS R-value ranges from 3.1 to 4.3 per inch depending on the density. The R-value varies for EPS because the smaller the voids, the higher the density, resulting in a slightly higher R-value. The R-value for XPS is a uniform 5 per inch regardless of density since the cell structure has no voids[93]. Most spa covers are made of EPS foam as they are able to provide enough insulation and keep a rigid structure while being resistant to mold, mildew, or bacteria growth[94]. They are also lightweight and require only one person to apply or remove. Thus, there is an opportunity to improve the insulation of the spa cover with highly efficient polystyrene that already exists in the market.

The R-value of a spa cover can also be increased by enclosing the foam core with a waterproof barrier, such as vinyl[95]. Other measures are available to prevent waterlogging and to reduce the conductive heat flow[96]. These options are to enclose the foam core within a polyethylene (common plastic wrap) wrap or a radiant barrier. The plastic wrap prevents water absorption and exposure to water treatment chemicals. A radiant barrier uses a highly reflective material that re-emits heat rather than absorbing it (**Figure 19**[97]) Examples of the type of enclosures and combination of barriers are shown in **Figure 20**.

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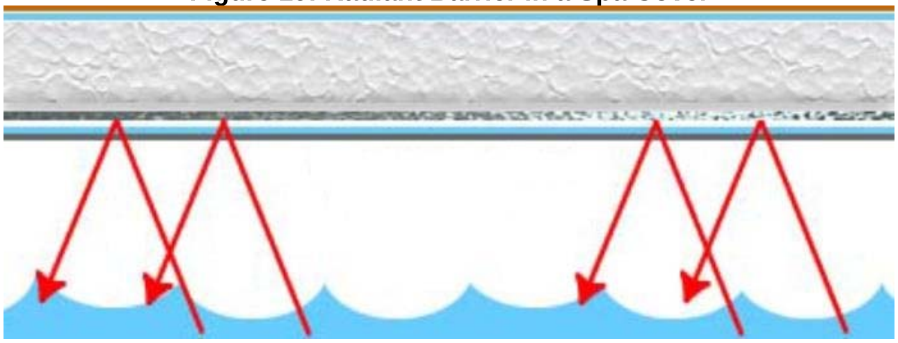
91 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering . San Luis Obispo: Andrew Ian Hamill.
92 U.S. Department of Energy. (2015, April 27). Insulation Materials. Available at Energy.Gov http://energy.gov/energysaver/articles/insulation-materials.
93 Owens Corning Foam Insulation, LLC. (2013). Technical Bulletin: For Foam Plastic Insulation, Extrusion Matters Performance Equals Resisting Water XPS Performs Better Than EPS. Toledo: Owens Corning.
94 The Foam Factory. (2012, January 18). *Insulate and Protect Your Hot Tub With a Custom Polystyrene Cover.* Retrieved from The Foam Factory at https://www.thefoamfactory.com/blog/index.php/insulate-and-protect-your-hot-tub-with-a-custom-polystyrene-cover.

95 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering . San Luis Obispo: Andrew Ian Hamill.
96 Hot Tub Covers Canada.Ca. (2015). R-Values and Insulation. Retrieved from Hot Tub Covers Canda.Ca: http://www.hottubcoverscanada.ca/our-spa-covers/hottub-cover-r-values.html.
97 U.S. DOE. (2015, April 27). *Insulation Materials.* Retrieved from Energy.Gov: http://energy.gov/energysaver/articles/insulation-materials.

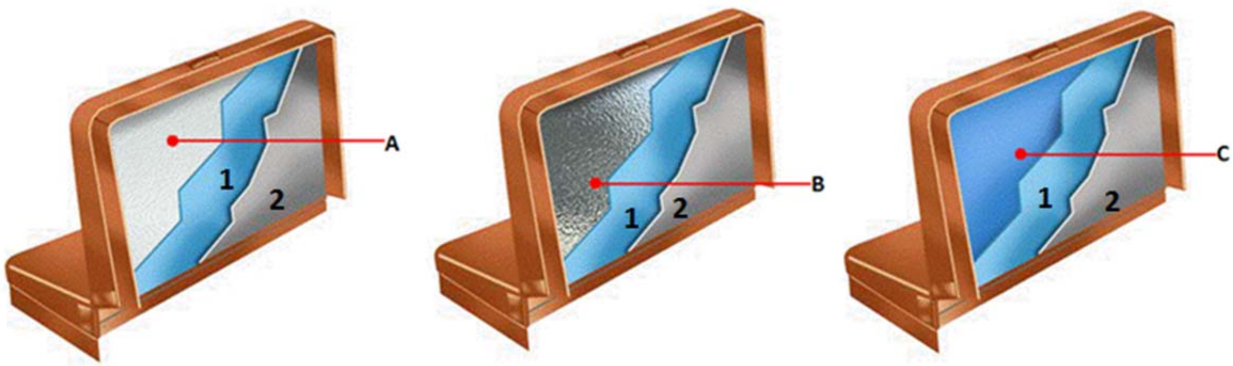
Figure 19: Radiant Barrier in a Spa Cover



Heat flow being reflected from the radiant barrier.

Source: Duratherm, The Spa Depot

Figure 20: Types of Spa Cover Enclosures



These spa covers are examples of different foam core enclosure combinations. All use a vinyl wrap, a moisture barrier (1), and a heavy duty liner (2). From left to right, the first option shows the foam core (A) being enclosed by barriers (1) and (2); the second encloses the foam core with a reflective barrier (B) and barriers (1) and (2); and the third option encloses the foam with a another moisture barrier (C) and barriers (1) and (2).

Source: Duratherm, The Spa Depot

The design and construction of spa covers varies depending on size and shape, but most covers have a hinge down the middle which allows the cover to fold in half. The hinge is typically not insulated, is about two inches wide, and runs the entire length of the cover, making it easy to fold but also allowing for significant heat loss. This type is known as a dual-hinge or double-hinge. This heat loss can be avoided by using a single-hinge design or an insulated hinge design. **Figure 21** shows a dual-hinge on the left compared to a single-hinge on the right[98].

98 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas*. Energy Solutions, PG&E. California Statewide Utility Code s and Standards Program. Retrieved July 2015.

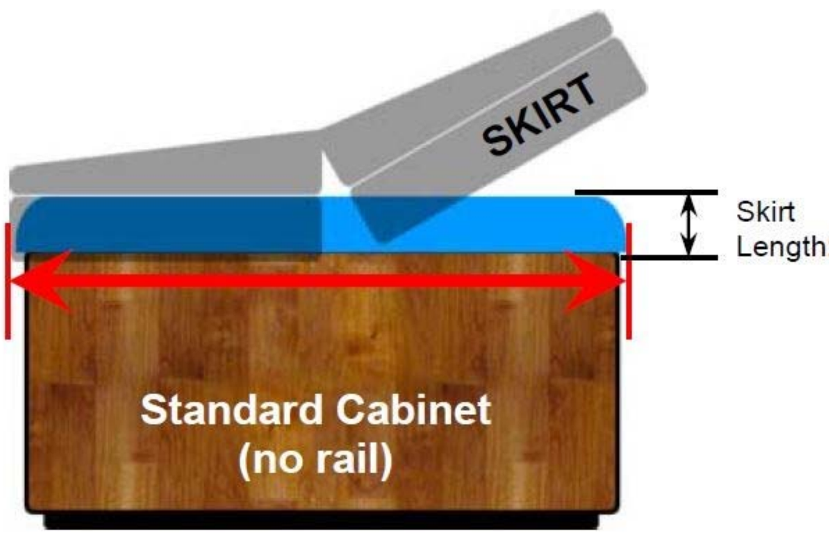
Figure 21: Dual-Hinge and Single-Hinge Spa Covers

A single-hinge avoids heat loss by elminating the gap at the hinge compared to a dual-hinge.

Source: Portable Electric Spas CASE Report 2014

Another design factor limits the seal between the spa cover and the surface of the unit's exterior. The majority of spa covers have a vinyl skirt around the perimeter that overlaps the exterior of the unit to prevent water and heat from escaping, as shown in **Figure 22**[99]

Figure 22: Spa Cover Skirt



The addition of a spa cover skirt (provided there is no obstruction from potential objects such as a mounted safety rail) reduces heat and water loss by covering the seal between the cover and the surface of the unit.

Source: Duratherm, The Spa Depot

99 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering. San Luis Obispo: Andrew Ian Hamill.

Another source of reducing energy and water consumption is the use of a floating blanket as shown in **Figure 23**. The floating blanket reduces moisture and chemical contact with the underside of the spa cover. It also acts as another barrier to prevent heat loss and evaporation[100].

Figure 23: Spa Floating Blanket

A floating blanket protects and reduces the work of the spa cover.

Source: Duratherm, The Spa Depot

Energy Use

The total energy use, according to the Title 20 test method for portable electric spas, is the total energy consumed during the default operation mode and not limited to water treatment cycles over a 72-hour period with the spa cover that comes with unit in use[101]. Andrew Ian Hamill of California Polytechnic State University, was able to determine which modes and cycles contribute most to the total standby power from his analysis of 27 different portable electric spas using the Title 20 test method. The modes, or cycles, were categorized in four groups: heater cycle, filtration cycle, pulses cycle, and constant filtration cycle.

The heater cycle uses the heater along with the pumps to maintain the water at a set temperature range. The filtration cycle uses the pumps to draw the water into the filter and circulate the water to keep the water clean for a set period. The pulses cycle uses the pumps to circulate the water for a short period. The constant filtration cycle uses the pumps to continuously circulate water providing filtration and preventing bacterial growth. Hamill's results, shown in **Table 18**, confirm that over half of the energy consumed is due to the heating

100 Lara, D. (2014, April 10). *Increasing the Energy Efficiency of Your Hot Tub or Spa*. Retrieved from Hot Tub Works: http://www.hottubworks.com/blog/increasing-the-energy-efficiency-of-your-hot-tub-or-spa/.

101 California Energy Commission, *2015 Appliance Efficiency Regulations.* Title 20, Section 1604(g)(2). May 2014.

during standby mode. The percent contribution to the standby power using the heater cycle ranged from 8 to 100 percent of total power. The power demand for the heater cycle ranged from 706 to 4,331 watts, with a median demand of 3,141 watts for spas with capacities ranging from 142 to 470 gallons[102].

Table 18: Percent Contributions to the Total Standby Power by Cycle Type

	Heater Cycle	Filter Cycle	Constant Filtration	Pulses
Average Percent Contribution to Standby Power	72	24	40	4

The percentages in the table above are not to be summed to equal one hundred percent. Each percentage describes the overall average percent contribution to each cycle type for the 27 portable electric spas that were tested during standby mode.

Source: *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas*, Andrew Ian Hamill

It is important to note the volume capacity range of the units tested because there are more than 130 portable electric spas with a volume size greater than 470 gallons and up to 2,355 gallons that would have a greater power demand during the heating cycle.

102 Hamill, A. I. (2012). *Measurement and Analysis of the Standby Power of Twenty-Seven Portable Electric Spas.* California Polytechnic State University, San Luis Obispo, Mechanical Engineering . San Luis Obispo: Andrew Ian Hamill.

Chapter 12: Regulatory Approaches

Current Title 20 Standards

In 2004, the Energy Commission adopted standards and testing procedures for portable electric spas that took effect in 2006[103]. These standards require that a spa's standby power must not exceed a sliding scale of wattage as a function of the spa's volume [5 x $Volume^{2/3}$].

Federal Approaches

Currently, there is no federal standard and no ENERGY STAR specification for portable electric spas.

Other State Approaches

In 2010, Florida adopted the ANSI/APSP/ICC-14 2011 standard for portable electric spa energy efficiency, which took effect March 15, 2012. This test procedure is based on the test procedure in the Title 20 Appliance Efficiency Regulations and elaborates more on how testing and measurements are to be performed[104].

Effective January 1, 2012, portable electric spas sold in Arizona cannot exceed a normalized standby power consumption of the spa's fill volume raised to the two-thirds power based on ANSI/APSP/ICC-14 2011[105].

Industry Standards

The spa industry, represented by the APSP, has accepted ANSI/APSP/ICC-14 2014 which was approved by the American National Standard Institute (ANSI) on September 12, 2014, a revision of ANSI/APSP/ICC-14 2011[106]. In general, the ANSI/APSP/ICC-14 2014 standard is similar to the Energy Commission's Title 20 standard, with a few exceptions: ANSI/APSP/ICC-14 requires a more stringent standby power limit, requires labels on all spas, applies to exercise spas, and modifies the test chamber certification testing. The ANSI/APSP/ICC-14 standards represent best industry practice, but are not mandatory or enforced.

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103 California Energy Commission, *2015 Appliance Efficiency Regulations.* Title 20. May 2014.

104 APSP. "*APSP Standard Becomes Federal Law Through the Virginia Graeme Baker Pool and Spa Safety Act*" August 8, 2011. APSP. September 21, 2015. <http://apsp.org/portals/0/PDfs/714.pdf>.

105 Arizona State Legislature. Title 44, Chapter 9, Article 19, 1375.02. Retrieved from http://www.azleg.gov/FormatDocument.asp?inDoc=/ars/44/01375-02.htm&Title=44&DocType=ARS.

106 APSP, American National Standards Institute. (2014). American National Standard for Portable Electric Spa Energy Efficiency. Alexandria: APSP.

The CASE Report

In July 2013, the IOUs and the Natural Resources Defense Council submitted a CASE report to the Energy Commission in response to the Commission's invitation to submit proposals[107]. In May 2014, they submitted a revised proposal for portable electric spa standards[108]. The proposal recommends adopting the ANSI/APSP/ICC-14 2014 standard, with the exception of regulating exercise spas. More specifically, they recommend adopting the test procedures, test room requirements, and a lower standby power limit [3.75 x Volume$^{2/3}$ + 40 watts] stated in the ANSI/APSP/ICC-14 2014 standard. In addition, the CASE report recommends adding requirements for original equipment and third-party spa covers, and requiring labels on spa units which will inform consumers of the tested standby power consumption, maximum allowable standby power consumption, and the spa cover make and model used during testing to achieve the displayed standby performance.

The CASE team estimates that implementing the recommended proposal would result in a reduction of about 6 GWh the first year the standards are in effect and a savings of about 64 GWh after full-stock turnover in 10 years.

107 CASE Report, *Pools & Spas* (July 29, 2013). Retrieved from: http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2F_Residential_Pool_Pumps_and_Replacement_Motors/California_IOUs_Response_to_the_Invitation_to_Submit_Proposals_for_Pool_and_Spas_2013-07-29_TN-71756.pdf.

108 CASE Report, *Portable Electric Spas.* (May 15, 2014). Retrieved from: http://www.energy.ca.gov/appliances/2013rulemaking/documents/comments/12-AAER-2G_Portable_Electric_Spa_Labeling/12-AAER-2G_Portable_Electric_Spas_Final_CASE_Report_2014-05-15_TN-73027.pdf.

Chapter 13: Alternative Considerations

Staff analyzed the proposal in the CASE report to determine whether it meets the legislative criteria for the Energy Commission's prescription of appliance efficiency standards. Staff also reviewed and analyzed state standards for three scenarios (1) maintaining current Title 20 standards, (2) incorporating the CASE report's proposal, and (3) modifying the scenario proposed by the CASE team.

Alternative 1: Maintaining Current Title 20

Staff visited residential spa show rooms at the California State Fair in 2013 and witnessed spas that were offered for sale carrying labels that described the products as "efficient" without any explanation of why or how they were rated. This type of labeling leaves consumers without any means to make an educated purchase related to the efficiency of the unit.

As mentioned earlier, dealers are not required to purchase original equipment covers to provide to consumers. Instead, they can purchase third-party spa covers and offer them to consumers as a lower cost option and for a profitable margin. Therefore, if a cover does not have the ability to prevent heat loss due to evaporation as it should, spa performance integrity (as tested and certified) may be compromised. This could undermine the effectiveness of the current portable electric spa standard.

Because of these reasons, staff believes the Title 20 standards must be updated.

Alternative 2: Incorporate CASE Team Proposal

The CASE Team proposal would establish a more efficient energy consumption standard for portable electric spas (not including exercise spas), adding requirements for specific effective spa covers, adding a labeling requirement to provide consumers with tools for informative purchases, and updating testing procedures. Specifically, the proposal recommends:

- Establishing more efficient spas by lowering standby power consumption limit. The current standard of [$5xV^{2/3}$] should be changed to [($3.75xV^{2/3}$) + 40], consistent with the most recent version of ANSI/APSP/ICC-14 2014. The new proposed standard allows reduction of heat losses from the spa surface area while supporting the minimum baseline energy consumption needed to operate other equipment, such as the pump and controller.
- Incorporating ANSI/APSP/ICC-14 2014 as the new test method and labeling template for compliance verification.
- Adding a clarifying requirement that would require new spas to be sold with a cover.
- Reporting and listing approved spa covers used during certification testing.

This proposal presents a significant opportunity for energy savings that are both cost-effective and technically feasible. A potential drawback to this alternative is the prohibition of selling spa covers with new insulation technology, third-party spa covers that are not indicated as approved by the manufacturer, or spa covers that are not listed with spa units in the Appliance Efficiency Database. If a customer could purchase only the test cover or manufacturer-approved third party cover shown in the Appliance Efficiency Database, there could be an increase in the incremental cost in addition to meeting the more stringent standby consumption standard and label requirement. Customers who would rather purchase a better-insulating cover would not have that option until after purchasing the standard cover.

Alternative 3: Updated Standby Standards with Spa Cover Reporting and Labeling

Staff evaluated the CASE team's proposal and analyzed the data of certified portable electric spas and exercise spas in the Appliance Efficiency Database to see if the proposed standby energy consumption standard could be extended to all portable electric spa types as 70 percent of the certified exercise spas sold in California would meet the new standard. Alternative 3 includes recommendations similar to the CASE Team's proposal.

- The current standard of [$5xV^{2/3}$] should be changed to [($3.75xV^{2/3}$) + 40] for all types of portable electric spas.
- Incorporate ANSI/APSP/ICC-14 2014 as the new test method as well as the labeling template included within the new test method for compliance verification.
- The label template shall display the manufacturer and model number of the test spa cover used during certification testing on the spa unit label.
- The model number of the same test cover used during testing shall be reported during the data submission process which would remain in conjunction with the current Title 20 test method requiring that each spa unit shall be tested with the spa cover that comes with the unit.

This alternative achieves a similar amount of energy savings to the CASE report while addressing the limitations posed by the spa cover. Alternative 3 would allow consumers to purchase a spa cover of their choice. Prior to purchase, the consumer would be informed of what cover should be bought with the unit to achieve the standby performance that was labeled and reported for certification and sale in California.

Chapter 14: Staff Proposed Standards for Portable Electric Spas and Exercise Spas

Energy Commission staff has analyzed the cost-effectiveness and technical feasibility of the standards proposed in the CASE report, and based on this information along with further analysis, staff proposes a similar standard with some modifications for labeling and testing spa covers. The proposed standard is for all portable electric spas, including exercise spas, manufactured on or after January 1, 2018, or one year from the adoption date, whichever is later.

Based on independent analysis of the best available data, including that from the CASE report, staff concluded that the proposed regulations are both cost-effective and technically feasible. Staff assumptions and calculation methods are provided in **Appendix B**.

Scope

Staff recommends updating the portable electric spa definition to clarify that all types of portable electric spas are included, including exercise/swim/combination spas and inflatable spas.

Test Procedure

All portable electric spas shall be tested in accordance with ANSI/APSP/ICC-14 2014, with the exception of the swim spa standby consumption limit in Section 6.3 of the test procedure. A uniform standby consumption limit will be applied to all portable electric spa types.

The proposal to use the test procedure ANSI/APSP/ICC-14 2014 is based on a collaborative effort dating back to 2005. This effort included the APSP, leading portable spa manufacturers, and the Energy Commission, Davis Energy Group, and the IOUs. The test procedures in this standard are based on that effort and the test method for portable spas described in Section 1604 of Title 20, California Code of Regulations, as amended December 3, 2008. To further support the claims in this standard, the portable spa manufacturers, working through APSP, conducted research and testing of the energy efficiency of portable spas. The standard was prepared in accordance with ANSI[109].

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109 APSP, American National Standards Institute. *American National Standard for Portable Electric Spa Energy Efficiency*. Alexandria: APSP, 2014.

Standby Power Consumption

All portable electric spas shall not exceed the normalized standby power consumption of $[(3.75xV^{2/3}) + 40]$.

Changing the standby power limit from $[5xV^{2/3}]$ to [(3.75xV2/3) + 40] will save a size-weighted average of 8 percent of energy consumption according to the CASE Team. The CASE Team selected this standard level after working with spa manufacturers and the APSP-14 Committee. As a result of their conversations with various spa manufacturers, the CASE Team, along with Energy Commission staff, believes this proposed standard "addresses industry's concerns of smaller spas being disproportionally impacted by a potential updated standard, while significantly tightening the standard on larger spas[110]."

Labeling Requirements

The label shall meet the design and specification listed in Section 7 of the ANSI/APSP/ICC-14 2014 with wording modifications (refer to Chapter 18). The spa shall be marked by the manufacturer where readily visible on the shell or front skirt panel during the point of sale. The marking shall be on a removable adhesive backed label and shall only be removed by the consumer[111].

Staff proposes using a categorical or continuous label for portable electric spas. A categorical label uses a ranking system that allows consumers to tell how energy efficient a model is by using multiple classes that progress from least efficient to most efficient or most energy consuming to least energy consuming. A continuous label uses a bar graph or line scale which allows consumers to see where the unit fits into the full range of similar models. The CASE team collaborated with APSP-14 committee and designed a spa energy label shown in **Figures 24** and **25** below[112]. For more details on the information present on the label, refer to **Appendix B**.

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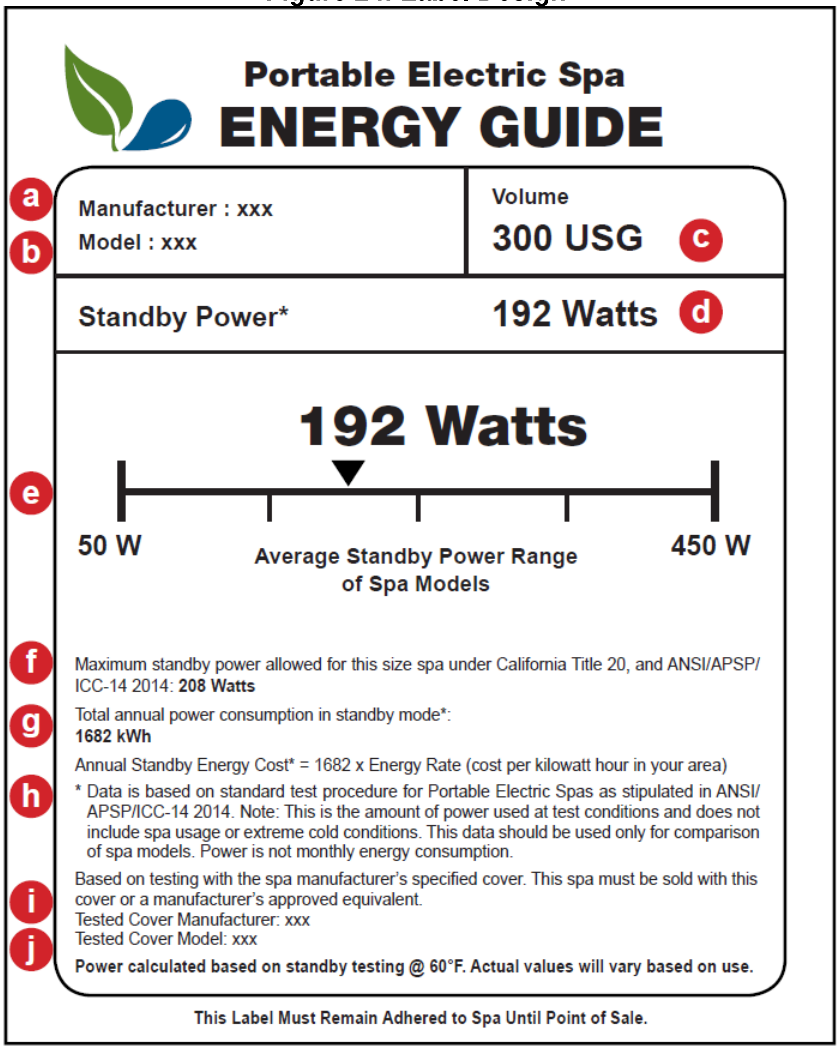
110 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas*. Energy Solutions, Pacific Gas & Electric Company. California Statewide Utility Codes and Standards Program. Retrieved July 2015.
111 APSP, American National Standards Institute. (2014). American National Standard for Portable Electric Spa Energy Efficiency. Alexandria: APSP.
112 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas*. Energy Solutions, Pacific Gas & Electric Company. California Statewide Utility Codes and Standards Program. Retrieved July 2015.

Figure 24: Label Design

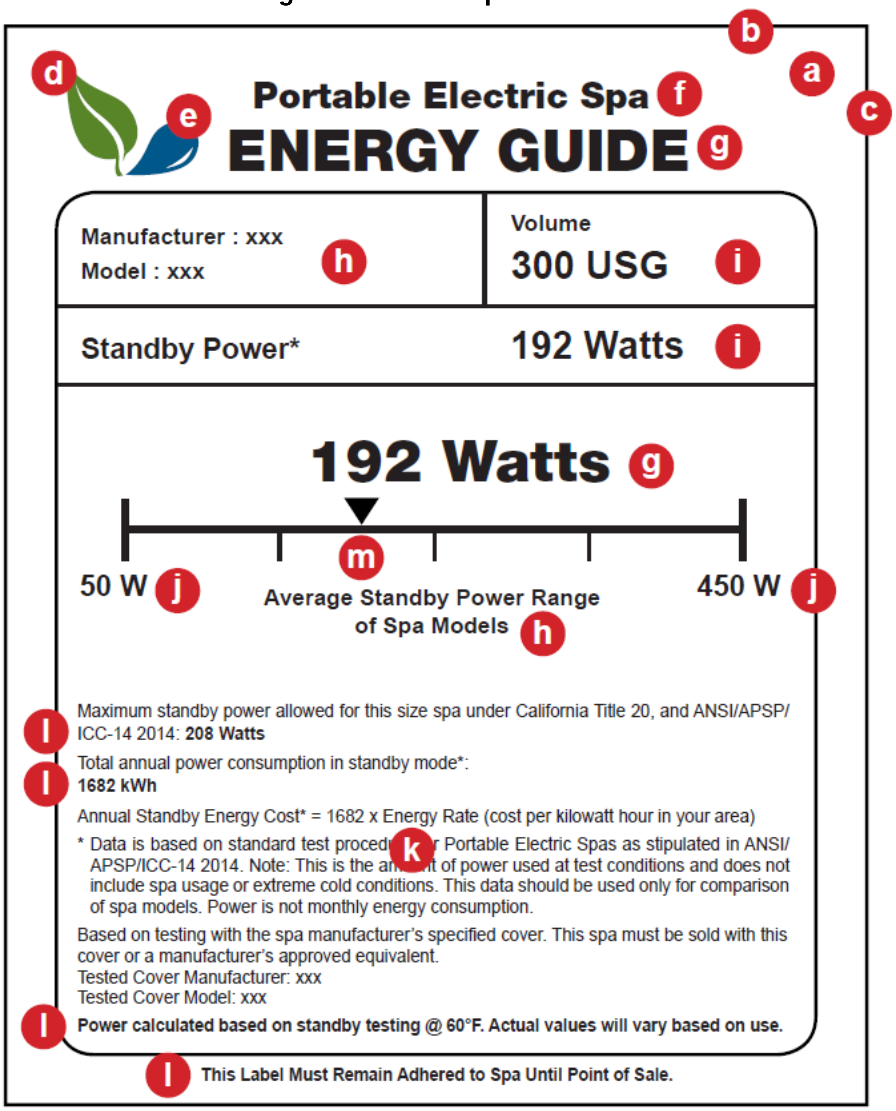


Source: ANSI/APSP-2014

Codes:

a. Spa manufacturer
b. Spa model
c. Spa volume
d. Standby power
e. Standby power chart arrow location and standby power value
f. Maximum standby power allowed
g. Total annual power consumption in standby mode
h. Annual standby energy cost
i. Specified cover manufacturer
j. Specified cover model

Figure 25: Label Specifications



Source: ANSI/APSP-2014

Figure 25 shows the design specifications for the label format.

- Label shall be printed on a removable adhesive-backed white polymer label or the equivalent.
- Text color shall be black. Leaf color: equivalent to Pantone 363 green (also permitted to be black) Water color: equivalent to Pantone 7691 blue (also permitted to be black.)
- Label codes:

  a. Label shall be printed on a white label with black text
  b. Minimum label width: 5 inches
  c. Minimum label height: 6.25 inches
  d. Leaf color: equivalent to Pantone 363 green (also permitted to be black)

e. Water color: equivalent to Pantone 7691 blue (also permitted to be black)
f. Font: Helvetica Neue Black. Character height shall not be less than 15 pt type
g. Font: Helvetica Neue Black. Character height shall not be less than 24 pt type
h. Font: Arial Bold. Character height shall not be less than 9.5 pt type
i. Font: Arial Bold. Character height shall not be less than 16 pt type
j. Font: Arial Bold. Character height shall not be less than 12 pt type
k. Font: Arial. Character height shall not be less than 8 pt type, and may be horizontally scaled to no less than 85 percent
l. Font: Arial Bold. Character height shall not be less than 8 point type, and may be horizontally scaled to no less than 85 percent
m. The standby power chart arrow shall be scaled at the appropriate location between the minimum and maximum power range using the standby power value for the spa which is being installed.

Spa Cover Labeling and Reporting Requirements

Staff will require that the same model number of the test cover displayed on the label be reported during the data reporting and certification process for the Appliance Efficiency Database.

With the current Title 20 test method, portable electric spas are tested with the “standard cover that comes with the unit.” Spa covers are typically sold with the purchase of a new spa. The cover that is sold with the unit is sometimes a cover made by a third party and not the standard cover used during testing as a way to cut costs for dealers and/or sellers. Also, many people base their purchasing choice on the lowest retail price which can have a negative effect on energy consumption and operating costs[113]. If a lower quality, less energy-efficient spa cover is purchased by the consumer or sold by a dealer with a spa certified with a higher performance cover, its certified energy consumption can be compromised[114]. Thus, labeling the unit with the cover that the spa manufacturer provides or specifies during testing will educate consumers and lead to more energy efficient purchasing decisions[115].

113 Western Area Power Administration. (2009). *What goes into an Energy-Efficient Spa or Hot Tub?* Lakewood: Western Area Power Administration.
114 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas.* Energy Solutions, PG&E. California Statewide Utility Code s and Standards Program. Retrieved July 2015.
115 Ibid.

Chapter 15: Savings and Cost Analysis

The proposed updated standards for portable electric spas would significantly reduce energy consumption, and are both cost-effective and technically feasible. **Table 22** summarizes the potential energy savings of the proposed standards. Energy savings are further separated into first-year savings and stock savings for portable spas and exercise spas. First-year savings means the annual energy reduction associated with annual sales, one year after the standards take effect. Annual stock turnover savings means the annual energy reduction achieved after all existing stock in use complies with the proposed standards. Staff's calculations and assumptions used to estimate the first-year savings and the stock change savings are provided in Appendix B.

Incremental Costs

The CASE team reported no incremental cost increase in implementing the proposed standard. However, the label could lead to improved spa covers or more efficient spa covers to go with a manufacturer's unit. Thus, staff believes there would be incremental costs when improving the spa cover and from implementing the standby energy consumption requirement. When the current standby power limit standard was being proposed in 2004, various sources estimated incremental costs for portable electric spas, shown in **Table 19.** Staff believes that over time these costs have decreased significantly. Staff will use the most recent estimated incremental costs of $100 by Nadel, deLaski, Eldridge, & Kleisch in 2006.

Table 19: Estimated Incremental Costs for Current Standard

Source	Incremental Cost	
Pope, Rainer, Fernstrom, & Eilert, 2002	$750	
Davis Energy Group, Energy Solutions, 2004	Measure	Incremental Cost
	Improved Cover	$100
	Improved Spa Insulation	$200
	Improved Motor Configurations and Efficiency	$300
	Improved Controls	$50
	Total	$650
Douglas Mahone & Heschong Mahone Group Inc., 2005	$300	
Nadel, deLaski, Eldridge, & Kleisch, 2006	$100	

The CASE report states the cost of labeling portable electric spas with a removable sticker type label is estimated to be minimal. Using the sources and assumption in the CASE report for determining labeling costs, staff has estimated the per label cost to be $0.38 per label[116]. Details of this estimation are shown in **Table 20**.

116 Ibid.

Table 20: Label Costs for Portable Electric Spas

One Time Set-Up Costs			**Units**
Engineer/Designer Time		40	Hours
Engineer/Designer Hourly Wage	$	44.36	Dollars/Hour
Set-Up Cost to each Manufacturer	$	1,774	Dollars
Number of Spa Manufacturers		43	Manufacturers
Total Set-Up Cost Statewide	$	76,299	Dollars
Material Cost			**Units**
Printing Costs		0.22	Dollars/Label
2017 Stock*		596,776	Portable Electric Spa Units
Total Printing Costs to Label Stock	$	131,291	Dollars
Labor Costs to Apply Label			**Units**
Time to adhere each Label		8	Seconds
Total time to adhere Labels to Entire Stock		1,326	Hours
Packaging and Filling Machine Operators Hourly Wage	$	13.44	Dollars/Hour
Total Labor Costs	$	17,824	Dollars
Total			**Units**
Total Cost to Label Stock	$	225,414	Dollars
Label Cost per Unit	$	0.38	Dollars/Label

Source: Staff calculation using information from Portable Electric Spas CASE Report 2014

*Stock is based on the year 2017 when the assumption for the effective was July 1, 2017.

Lifecycle costs and benefits of the proposed standard for portable electric spas and exercises spas are shown in **Table 21**. Lifecycle costs are based off the estimated incremental costs for improving the unit and labeling costs. The lifecycle benefit represents the savings the consumer should receive over the life of the appliance. Lifecycle benefits are based off of comparing the weighted-average standby power consumption under the current standard with respect to the proposed standard.

Table 21: Weighted Unit Energy Savings and Lifecycle Benefits

	Design Life (years)	**Electricity Savings (kWh/year)**	**Lifecycle Costs ($/unit)**	**Lifecycle Benefit ($/unit)**	**Lifecycle Benefit/Cost Ratio**
Portable Electric Spas	10	317	$ 100.38	$ 512	5
Exercise Spas	10	1,451	$ 100.38	$ 2,349	23

Source: Staff calculations, see Appendix B

In conclusion, the proposed standard is cost-effective as the compliant product has a high benefit-to-cost ratio.

Standby Power Efficiency Savings

As summarized in **Table 22**, if all portable electric spas complied with the proposed standards (annual stock turnover savings), California would save 61 GWh of energy per year. Using a residential rate of $0.16 per kWh of electricity, it is estimated that implementation of the proposed standards for portable electric spas would achieve roughly $10 million a year in reduced utility costs after full implementation. In more detail, exercise spas contribute 8 GWh of energy savings per year and $1 million per year in reduced utility costs after full implementation. Due to lack of market inventory and operational data for exercise spas, these estimates could be underrepresenting the actual energy savings.

Table 22: Standby Power Standard Statewide Annual Stock Savings

	First-Year Savings		Complete Turnover Savings	
	Energy Consumption (GWh/yr)	**Savings ($ million)**	**Energy Consumption (GWh/yr)**	**Savings ($ million)**
Portable Electric Spas (Zones 1-3)	4.22	0.68	53	9
Exercise Spas (Zones 4-8)	0.62	0.10	8	1
Total	4.84	0.78	61	10

Source: Staff calculation, see Appendix B

Spa Cover Savings

Savings from using a spa cover versus not using a spa cover are presented separately since the performance standard relies on a spa cover to meet the performance standard. Staff calculated evaporation rates using industry standard methods. **Table 23** presents the evaporation rate, energy lost, and energy cost for a typical five-person spa left uncovered year round.

Table 23: Energy Cost for Uncovered Spa

Evaporation Rate, w_p (gallons/hr)	Energy Consumption (kWh/year)	Water Wasted (gallons/year)	Energy Costs ($)	Estimated Spa Cover Price ($)	Design Life of Spa Cover (years)	Unit Savings with Spa Cover ($/yr)
1	21,688	8,760	$3,511	$500	5	$3,411

Source: Staff calculations, see Appendix B

Spa Labeling Savings

The MAEDBS shows that units with the same volume capacity have very different standby energy consumption values. The range can go up to 150 watts for units with the same volume capacity[117]. This wide range of standby power consumption is impacted by factors such as the spa cover, construction materials, and design of the unit. Consumers may be unaware that a wide range exists and must rely on the information given by the seller and manufacturer. Thus, consumers can benefit from having a label affixed to the unit to inform them of the energy consumption and energy savings. Labeling programs such as ENERGY STAR and "EnergyGuide" have proven to be successful at providing consumers with energy saving information which can lead to purchasing decisions that increase energy efficiency. In addition to a spa model number being listed in the Appliance Efficiency Database, a label will inform the consumers that the unit meets California's appliance efficiency standards and is certified to be sold in California[118].

Labeling portable electric spa units will lead to energy savings by educating consumers and as a result choosing a more efficient unit. However, determining how many consumers will choose a more efficient unit, how much more efficient a unit they choose, and how the label impacts that decision is somewhat more of an art than a science. An estimated 5 percent of the total energy consumption is said to be the potential savings[119]. This estimate is based on half of the 10 percent improvement in sales-weighted average efficiency for refrigerators using the categorical European Union (EU) Label scheme[120]. **Table 24** presents the savings when applying the potential 5 percent savings by affixing a label to portable electric spas[121].

117 California Energy Commission. (2015). Modernized Appliance Efficiency Database System. Retrieved from Appliance Search: http://maedbs/Pages/ApplianceSearch.aspx.
118 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas.* Energy Solutions, PG&E. California Statewide Utility Code s and Standards Program. Retrieved July 2015.
119 Ibid.
120 Bertoldi, Paolo. *Energy Efficient Equipment within SAVE: Activities, strategies, success and barriers.* Brussels: European Commission, 2000.
121 "European Union Efforts to Promote More Efficient Use of Electricity: the PACE Programme." 1996 Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council for an Energy-Efficient Economy, 1996.

Table 24: Statewide Annual Stock Savings Adjusting for Label Impact

	First-Year Savings		Complete Turnover Savings	
	Energy Consumption (GWh/yr)	**Savings (Million$)**	**Energy Consumption (GWh/yr)**	**Savings (Million $)**
Portable Electric Spas	5.7	0.9	69.6	11.2
Exercise Spas	0.8	0.1	10.4	1.8
Total	6.5	1.0	80	13

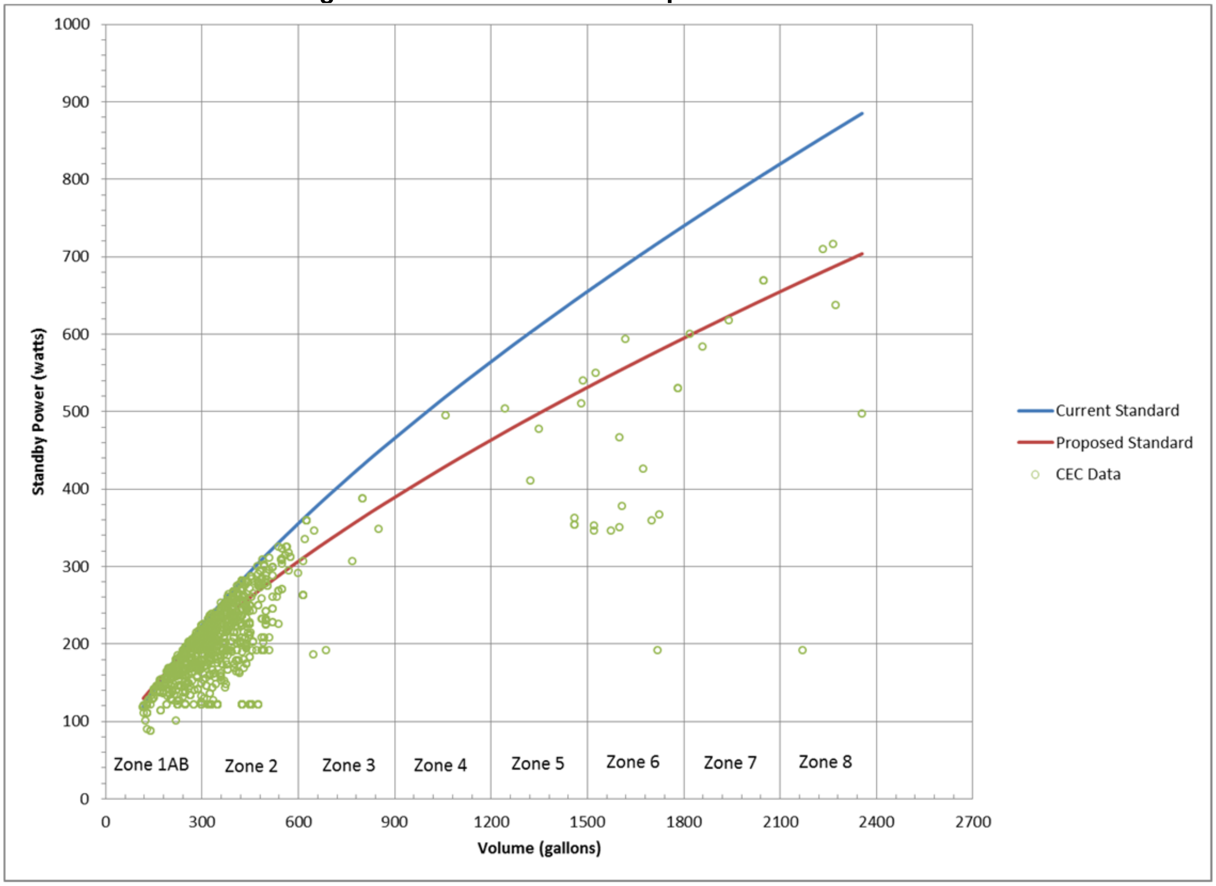
Source: Staff calculation, see Appendix B

Chapter 16: Technical Feasibility of Proposed Standards for Portable Electric Spas

As of July 2015, the Energy Commission database lists over 1,100 portable electric spas, over 70 percent of which would meet the proposed standards. **Table 25** shows a breakdown of the compliance rate for the portable electric spas in the MAEDBS. The quantity and variety of compliant spas available for sale are an indication that compliant products are technically feasible and readily available in California.

As **Figure 26** demonstrates, a significant number of existing spas would meet the proposed standard, demonstrating that it is technically feasible.

Figure 26: Portable Electric Spas in the MAEDBS



This graph displays all of the portable electric spas that are certified using the current Title 20 standard and whether they meet the proposed standard.

Source: MAEDBS, California Energy Commission

Table 25 details the compliance rate illustrated in **Figure 27**. The CASE report stated 29 percent of the portable electric spas in the MAEDBS would not meet the proposed standard limit, which is similar to the results in **Table 25**.

Table 25: Compliance Rate of Portable Electric Spas

	Zones	Compliant (%)	Non-Compliant (%)
Portable Spas	1AB to 3	72.2	27.8
Exercise Spas	4 to 8	69.7	30.3
All Certified Units	1AB to 8	72.1	27.9

Compliance rate of the proposed standard for certified portable electric spas.

Source: MAEDBS, California Energy Commission

The energy consumption of portable electric spas can be optimized by employing better insulation, better-designed covers, and the use of a more efficient pump for circulation and filtration.

Insulation

Most manufacturers already insulate the shell and base of spas using high R-value insulation materials. According to the Energy Commission database, over 99 percent of spas listed are fully insulated.

Staff found that units with the same volume capacity have very different standby energy consumption values, up to 150 watts. Staff believes the cause of this difference is in the method and materials of insulation. For example, hit and miss spots at the shell and base of spas can largely reduce the effectiveness of insulation. Therefore, improvements on the method of applying uniform insulation would improve the efficiency of the unit. Implementing this improvement would decrease energy use by up to 30 percent for a spa of average-to-low efficiency. This is also the easiest method to implement since it requires little additional engineering and design work[122].

The CASE report also identified that manufacturers use a combination of closed cell foam and radiant barriers, instead of fiberglass, which can help reduce the heat loss[123].

Spa Covers

Improvements to spa covers, such as using high R-value and less water absorbent insulation, adding radiant barriers, and better sealed covers, can reduce heat and water loss

122 Davis Energy Group, Energy Solutions. (2004). *Analysis of Standards Options for Portable Electric Spas.* California: PG&E.

123 Worth, C., & Fernstrom, G. (2014). *Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development- Analysis of Standards Proposal for Portable Electric Spas.* Energy Solutions, PG&E. California Statewide Utility Codes and Standards Program. Retrieved July 2015

from the spa, and already exist in the industry. In addition, improving the construction and design work of the spa cover such as using single-hinged or insulated hinge covers instead of double-hinged, can yield additional efficiency savings[124].

Pump and Motor

Manufacturers have used waste heat from circulation pumps to replace separate heating or to supplement heating of water, which can greatly improve the efficiency of spas[125]. Also, most spa manufacturers of large portable electric spas add a separate low-wattage circulation pump to run specific cycles. This addition can save approximately 15 percent of the energy consumption and up to half of the pumping energy used for circulation and filtering. Other options include improved pump efficiency with advanced multi-speed motor designs, and using variable-speed motors and controls. Options like these would require manufacturers to invest in product development and design work, which would most likely begin after insulation improvement[126].

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124 Ibid.
125 Ibid.
126 Davis Energy Group, Energy Solutions. (2004). *Analysis of Standards Options for Portable Electric Spas.* California: PG&E.

Chapter 17: Environmental Impacts

Environmental Impacts

Spas are replaced when they are at the end of their useful lives; replacement of these appliances would present no additional impact to the environment beyond their natural cycles.

Benefits

Staff estimates that the proposed standards will result in reductions of almost 15 tons of criteria air pollutants and 49,000 tons of GHG emissions due to the avoided energy used. Staff tabulated the criteria for air pollutant and GHG emissions reductions in **Table 26** using the annual statewide stock savings energy consumption after complete turnover values listed in **Table 22** and **24**.

Table 26: Greenhouse Gas Emissions Reductions

	Annual Avoided Emissions (tons)					
	Oxides of nitrogen (NO_x)	**Sulfur dioxide (SO_x)**	**Carbon monoxide (CO)**	**Particulate matter ($PM_{2.5}$)**	**Total Air Pollutants**	**Greenhouse Gas (eCO_2)**
Portable Electric Spas	4.3	0.6	6.2	1.8	12.9	42419
Exercise Spas	0.6	0.09	0.9	0.3	1.9	6210
Total	**4.9**	**0.69**	**7.1**	**2.1**	**14.8**	**48629**

Source: Emission factors from the ARB

Chapter 18: Regulatory Language

The following shows staff's proposed changes to the portable electric spa standard. Underlines mean new added text and ~~strike outs~~ mean deleted text.

Section 1602(g) Definitions

"Portable electric spa" means a factory-built and free-standing electric spa or hot tub, supplied with equipment capable of ~~for~~ heating and circulating the water inside a rigid, flexible, or inflatable shell.

"Combination spa" means a portable electric spa with separate bodies of water capable of heating each body of water at different temperatures.

"Exercise spa" (also known as an "endless pool" or "swim spa") means a portable electric spa designed to produce a water flow intended for water therapy or fitness training, including swimming in place.

~~"Spa volume" means the actual fill volume of the spa, under normal use, in gallons, as defined in the test method in Section 1604(g)(2)(B).~~

Section 1604(g)(2) Test Method for Portable Electric Spas.

(A) The test method for portable electric spas manufactured on or after January 1, 2006, and before January 1, 2018, is as follows:

(i) ~~(A)~~ Minimum continuous testing time shall be 72 hours.

(ii) ~~(B)~~ The spa shall be filled with water to the halfway point between the bottom of the skimmer basket opening and the top of the spa. If there is no skimmer basket, the spa shall be filled with water to six inches below the top of the spa.

(iii) ~~(C)~~ The water temperature shall be 102˚F, ± 2˚F for the duration of the test.

(iv) ~~(D)~~ The ambient air temperature shall be 60˚F, ± 3˚F for the duration of the test.

(v) ~~(E)~~ The standard cover that comes with the unit shall be used during the test.

(vi) ~~(F)~~ The test shall start when the water temperature has been at 102˚F, ± 2˚F for at least four hours.

(vii) ~~(G)~~ Record the total energy use for the period of test, starting at the end of the first heating cycle after the stabilization period specified in Section 1604(g)(2)(A~~F~~)(vi), and finishing at the end of the first heating cycle after 72 hours has elapsed.

(viii) ~~(H)~~ The unit shall remain covered and in the default operation mode during the test. Energy-conserving circulation functions, if present, must not be enabled if not appropriate for continuous, long-term use. Ancillary equipment including, but not limited to lights, audio systems, and water treatment devices, shall remain connected to the mains but may be turned off during the test if their controls are user accessible.

(ix) ~~(I)~~ The measured standby power shall be normalized to a temperature difference of 37˚F using the equation,

$$Pnorm = Pmeas \frac{\Delta T\ ideal}{\Delta T\ meas}$$

Where:

Pmeas = measured standby power during test (E/t)

Δ Tideal = 37˚F

Δ Tmeas = Twater avg – Tair avg

Twater avg = Average water temperature during test

Tair avg = Average air temperature during test

(x) ~~(J)~~ Data reported shall include: spa identification (make, model, S/N, specifications); volume of the unit in gallons; supply voltage; minimum, maximum, and average water temperatures during test; minimum, maximum, and average ambient air temperatures during test; date of test; length of test (t, in hours); total energy use during the test (E, in Wh); and normalized standby power (Pnorm, in watts).

(B) All portable electric spas manufactured on or after January 1, 2018, shall be tested in accordance with ANSI/APSP/ICC-14 2014, with the exception of Section 6.3.

Section 1605.3 (g)

(6) Portable Electric Spas

(A) The normalized standby power, as defined in Section 1604(g)(2)(A~~I~~)(ix), of portable electric spas manufactured on or after January 1, 2006, and before January 1, 2018, shall be not greater than $5(V^{2/3})$ watts where V = the fill volume, in gallons.

(B) The normalized standby power, as defined in ANSI/APSP/ICC-14 2014, of portable electric spas manufactured on or after January 1, 2018, shall not be greater than $[3.75(V^{2/3}) + 40]$ watts where V = the fill volume, in gallons.

Section 1606(a)(3)(c)

Table X – Data Submittal Requirements

G	Appliance	Required Information	Permissible Answers
	Portable Electric Spas	*Voltage	
		Volume (gallons)	
		Rated Capacity (number of people)	
		Normalized Standby Power (watts)	
		Spa Enclosure is Fully Insulated	Yes, No
		Tested Spa Cover Model	

*"Identifer" information as described in Section 1602(a).

Section 1607(d) Energy Performance Information.

(12) **Portable Electric Spas**

The spa shall be marked by the manufacturer where readily visible on the shell or front skirt panel. The marking shall be on a removable adhesive backed label and shall only be removed by the consumer. The label shall meet the design and specification listed in Section 7 of the ANSI/APSP/ICC-14 2014 with the exception of the wording in Section 7.2.1 Part I.

The label language for Section 7.2.1. Part I shall be:

This spa was tested with the spa manufacturer's specified cover:

Tested Cover Manufacturer: xxx

Tested Cover Model: xxx

The following documents are incorporated by reference in Section 1607.

Number	***Title***
THE ASSOCIATION OF POOL AND SPA PROFESSIONALS (APSP)	
ANSI/APSP/ICC-14 2014	American National Standard for Portable Electric Spa Energy Efficiency
Copies available from:	The Association of Pool and Spa Professionals 2111 Eisenhower Avenue Alexandria, VA 22314-4695 www.apsp.org Phone: (703) 838-0083

Appendix B: Staff Assumptions and Calculation Methods

Appendix B discusses the information and calculations used to characterize portable electric spas in California, the current energy use, and potential savings. The source of much of this information is the CASE report submitted to the Energy Commission. All calculations were based on the assumption of an effective date of January 1, 2017, although the effective date is January 1, 2018. The difference in effective dates does not significantly alter the calculations. After careful review, staff has altered some of the figures from the CASE report as appropriate to fit staff's approach to energy consumption and savings.

Table B-1: Summary of Values and Assumptions

Value	Description	Source
5.0 %	Average Percent of New Units in California	APSP, 2012-2013 (see Table B-2)
44.0%	Average percentage of California Spa Owners that own an outdoor, above-ground spa	KEMA, 2010 (see Table B-3)
8,760 hrs/year	Standby mode operating hours	Worth & Fernstrom, 2014
102°F ± 2°F	Surface water temperature required for Title 20 test method	Title 20, Section 1604 (g)(2)
60°F ± 3°F	Air temperature required for Title 20 test method	Title 20, Section 1604 (g)(2)
6.95 kPa	P_w, saturation vapor pressure taken at a surface water temperature of 38.89°C or 102°F	Brice & Hall, 2014
1.768 kPa	P_a, saturation vapor pressure at room temperature of 15.56°C or 60°F	Brice & Hall, 2014
0.10 m/s	Recommended air velocity over water surface	Lund, 2000
1.0	Activity factor for whirlpools and spas	Lund, 2000
43	Number of Manufacturers who have certified portable electric spas in the MAEDBS	MAEDBS July 2015
0.1619 $/kWh	Average Residential Retail Price in California for Electricity	U.S. Energy Information Administration, 2013
5.0%	Label Impact Rate Savings	Assumption made by CASE Team, Portable Electric Spas CASE Report 2014
0.07 lb/MW	Oxides of nitrogen emission factor	California Air Resources Board, 2010
0.01 lb/MW	Sulfur Dioxide emission factor	California Air Resources Board, 2010
0.10 lb/MW	Carbon Monoxide emission factor	California Air Resources Board, 2010
0.03 lb/MW	Particulate matters emission factor	California Air Resources Board, 2010
690.00 lb/MW	Carbon Dioxide emission factor	Energy Aware Planning Guide as cited in Staff Analysis of Water Efficiency Standards for Showerheads 2015 Report

Stock and Sales

Table B-2 lists annual stock and annual sales for portable electric spas in California during 2011 and 2012.

Table B-2: Number of Portable Electric Spa Units in California

Year	Stock in California	New Units Sold/Installed in California	Percent of New Units in California
2011	1,488,016	71,525	4.8%
2012	1,142,352	58,922	5.2%
		Average	5.0%

Units include commercial, in-ground, and above-ground.

Source: APSP - U.S. Swimming Pool and Hot Tub 2012 and 2013 Market Reports

Table B-3 lists the number of outdoor, above-ground spas in California from the 2003 and 2009 Residential Appliance Saturation Study (RASS).

Table B-3: Outdoor and Above-ground Spas in California

Building Type	2003	2009
Single Family	356,265	443,731
Townhouse, Duplex, Row House	8,368	5,725
Apt Condo 2-4 Units	2,002	5,498
Apt Condo 5+ Units	531	3,877
Mobile Home	6,181	8,162
Other	1,366	227
Total Outdoor and Above-ground spas	374,713	467,220
Total of California Residents that own a spa	804,660	1,102,560
Percent of California Spa Owners that own an outdoor, above-ground spas	47%	42%
Average		44%

Source: California Statewide Residential Appliance Saturation Study

Using information from the Residential Energy Consumption Survey (RECS) database by U.S. Energy Information Administration from 1993 to 2009, APSP U.S. Swimming Pool and Hot Tub Market Reports, and the 2009 Residential Appliance Saturation Study, staff estimated the annual stock and sales in California, shown in **Table B-4.**

Table B-4: Estimated Annual Stock and Sales

Year	Stock of Spas in California[1]	Stock of Portable Electric Spas in California	Sales
2012	1,142,352	508,026	25,312
2013	1,182,265	525,776	26,196
2014	1,222,178	543,526	27,080
2015	1,262,091	561,276	27,965
2016	1,302,004	579,026	28,849
2017	1,341,917	596,776	29,733
2018	1,381,830	614,526	30,618
2019	1,421,743	632,276	31,502
2020	1,461,656	650,026	32,387
2021	1,501,569	667,776	33,271
2022	1,541,482	685,526	34,155
2023	1,581,395	703,276	35,040
2024	1,621,308	721,026	35,924
2025	1,661,221	738,776	36,808
2026	1,701,134	756,527	37,693
2027	1,741,047	774,277	38,577
2028	1,780,960	792,027	39,462
2029	1,820,873	809,777	40,346
2030	1,860,786	827,527	41,230

[1]Stock includes commercial, in-ground, and above-ground units
[2]Stock of units outdoor and above-ground using RASS reports esimates.
[3]Using APSP report estimates.

Source: See **Table B-2** and **Table B-3**, RECS database

Design Life

The design life is an estimate of the length of a product's typical operation usefulness. The design life figures were taken from the CASE report and are shown in **Table B-5**.

Table B-5: Estimated Design Life of Non-Inflatable, Portable Electric Spas

Component	Design Life (years)
Spa Cover	5
Portable Electric Spa	10

Source: Portable Electric Spa CASE Report 2014

Compliance Rates

Compliance rate is the percentage of compliant units over the total stock units. **Table B-6** lists the estimated or reported compliance rates. A compliance rate is percentage indicates the ratio of compliant appliances to the total market or stock. Thus, a compliance rate of 40 percent means that 40 percent of that particular appliance already meets the proposed standard.

Table B-6: Compliance Rate for Portable Electric Spas

	Zones	Compliant (%)	Non-Compliant (%)
Portable Spas	1AB to 3	72.2	27.8
Exercise Spas	4 to 8	69.7	30.3
All Certified Units	1AB to 8	72.1	27.9

Compliance rate of the proposed standard for certified portable electric spas.

Source: MAEDBS, California Energy Commission

Table B-7 lists the estimated compliances rates for each zone.

Table B-7: Unit Population and Compliance Rate for each Zone

Zones	Compliant Units	Non-Compliant Units	Total Units	Units per Zone (%)	Compliant (%)	Non-Compliant (%)
1A*	59	0	59	5	95	5
1B	281	54	335	28.4	83.9	16.1
2	479	257	736	62.37	65.1	34.9
3	9	8	17	1.44	52.9	47.1
4*	0	1	1	0.08	5	95
5	6	2	8	0.68	75	25
6	12	2	14	1.19	85.7	14.3
7	2	3	5	0.42	40	60
8	3	2	5	0.42	60	40
		Total	1,180	100		

***Conservative compliance rate**

Source: MAEDBS, California Energy Commission

Duty Cycle

The duty cycle of an appliance is an estimate of consumer behavior for that particular appliance. It is directly tied to how often the appliance is used and for how long. In the context of this report, the duty cycle is the usage of the regulated standby mode or cycle of the unit. The duty cycle used in this report are taken directly from the CASE report and applied to both portable electric spas and exercise spas.

Table B-8: Duty Cycle

Unit	Operating Hours
Portable Electric Spas	8,760 hrs/yr
Exercise Spas	8,760 hrs/yr

Source: Portable Electric Spas CASE Report 2014

Baseline Energy Use

After applying the proposed standby power limit to the certified units in the MAEDBS displayed in **Figure 27**, the graph shows a high saturation of data on the lower left which could cause some discrepancies in calculating energy consumption. Also, the CASE report does not include portable electric spas with a volume of more than 800 gallons, which is taken into account. The units currently in the MAEDBS are certified under the current Title 20 standard and will fall below the current standard curve. There are cases where units do not pass the current standard and are not represented in the graph. There could also be instances in the future where current units will be upgraded or discontinued, therefore being removed from the MAEBDS. These cases will modify the data, thus using an average of the standby power consumption of the units in the database as the base for our calculations would be an inaccurate representation of the energy consumption. Instead of using a weighted-average of the standby power consumption, we will use a weighted-average of the maximum allowable standby power from the current and proposed standard equations.

The current standby power limit equation is as follows:

$$P = 5 \times V^{2/3}$$

where
P = maximum allowable standby power (watts)
V = volume (gallons).

The proposed standby power limit equation is as follows:

$$P = \left(3.75 \times V^{2/3}\right) + 40$$

where

P = maximum allowable standby power (watts)

V = volume (gallons).

Table B-9 lists the volume used in the equations above and is the average volume of the volume range in each zone.

Table B-9: Average Volume used for Calculations

Zone	Volume Range (gallons)	Average Volume (gallons)
1A	100-180	140
1B	181-300	240
2	301-600	450
3	601-900	750
4	901-1,200	1,050
5	1,201-1,500	1,350
6	1,501-1,800	1,650
7	1,801-2,100	1,950
8	2,101-2,400	2,250

Source: Staff calculation

Figure B-1displays the results of inputting the average volume of each zone into the standby power limit equation for the current and proposed standard. The graph also displays the standby power limit for the proposed standard when applying the 5 percent potential savings as a result of adding a label to portable electric spas.

Sample Calculation (Zone 2, V = 450 gallons):

Current Standard:

$$P = 5 \times V^{2/3}$$

$$P = 5 \times (450\ gallons)^{2/3} = 293.62\ watts \approx 294\ watts$$

Proposed Standard:

$$P = \left(3.75 \times V^{2/3}\right) + 40$$

$$P = \left(3.75 \times (450\ gallons)^{2/3}\right) + 40 = 260.21\ watts \approx 260\ watts$$

Proposed Standard + Label:

$$P = \left(3.75 \times V^{2/3}\right) + 40$$

$$Unit_{Label\ Savings} = P \times 5\%\ Potential\ Savings$$

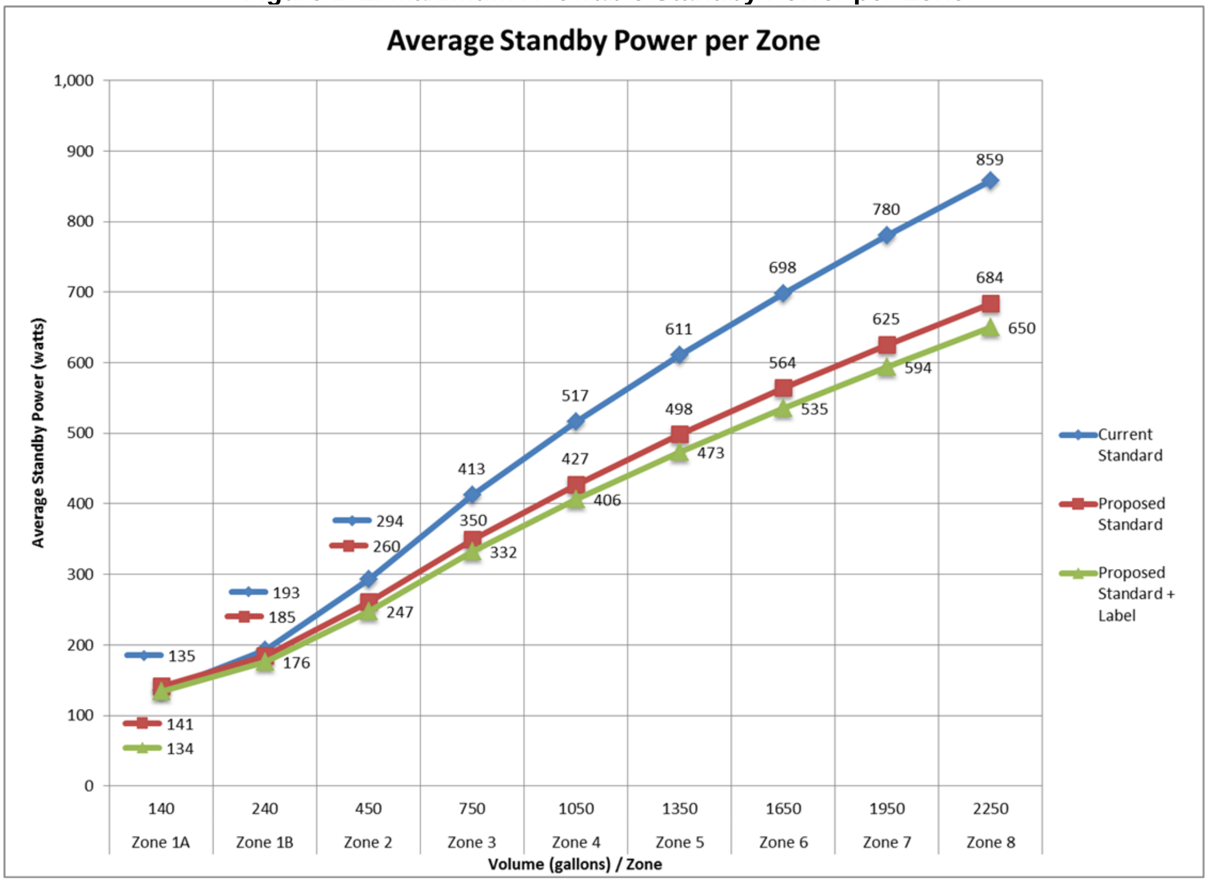
$$P_{Label} = P - Unit_{Label\ Savings}$$

$$P = \left(3.75 \times (450\ gallons)^{2/3}\right) + 40 = 260.21\ watts$$

$$Unit_{Label\ Savings} = 260.21\ watts \times 5\%\ Potential\ Savings = 13.01\ watts$$

$$P_{Label} = 260.21 - 13.01 = 247.2\ watts$$

Figure B-1: Maximum Allowable Standby Power per Zone



The baseline average energy consumption of the appliance is the estimate of energy consumed by the market representative ratio of compliant and non-compliant units. For example, the annual energy consumption of a portable electric spa is calculated by multiplying the average maximum allowable standby power by the duty cycle and by the compliancy rate for each zone. **Table B-10** lists the baseline energy consumption without the labeling impact for the purpose of explaining the calculations in this study.

Table B-10: Baseline Energy Consumption without label savings

Zones	Compliant Energy Use (Wh/yr)	Non-Compliant Energy Use (Wh/yr)	Total Energy Use (Wh/yr)	Sales Weighted Average Energy Consumption (Wh/yr)
1A*	1,173,402	59,130	1,232,532	61,627
1B	1,359,683	272,199	1,631,883	463,455
2	1,482,718	898,829	2,381,546	1,485,370
3	1,621,914	1,704,021	3,325,935	47,893
4*	187,026	4,302,474	4,489,500	3,592
5	3,271,860	1,338,090	4,609,950	31,348
6	4,234,128	874,371	5,108,499	60,791
7	2,190,000	4,099,680	6,289,680	26,417
8	3,595,104	3,009,936	6,605,040	27,741

Zone 2 in this table will be used as the basis of explaining the calculations in this study.

Sample Calculations (Zone 2):

Proposed Standard:

$$E_{Annual} = (Average\ Standby\ Power\ Consumption\ Limit) \times (Duty\ Cycle) \times\ (Compliant\ Rate\ \%)$$

$$E_{Annual} = (260\ watts) \times \left(8{,}760 \frac{hr}{yr}\right) \times\ (0.651) = 1{,}482{,}718\ Wh/yr$$

Current Standard:

$$E_{Annual} = (Average\ Standby\ Power\ Consumption\ Limit) \times (Duty\ Cycle) \times\ (Non\ Compliant\ Rate\ \%)$$

$$E_{Annual} = (294\ watts) \times \left(8{,}760 \frac{hr}{yr}\right) \times\ (0.349) = 898{,}829\ Wh/yr$$

Total Energy Consumption for Zone 2:

$$E_{Annual} Zone\ 2 = (E_{Annual} Proposed + E_{Annual} Current)$$

$$E_{Annual} Zone\ 2 = (1{,}482{,}718 + 898{,}829) = 2{,}381{,}546\ Wh/yr$$

The baseline average energy consumption for portable electric spas was calculated by multiplying the energy consumption by the percent of units in each zone.

$$Average\ Energy\ Consumption_{Zone} = (E_{Annual} Zone\#) \times (Unit\ Population\ \%_{Zone})$$

Sample Calculations (Zone 2):

$$Average\ Energy\ Consumption_{Zone2} = (2{,}381{,}546\ Wh/yr) \times (0.6237) = 1{,}485{,}370\ Wh/yr$$

The annual stock energy consumption for portable electric spas is the product of average energy consumption and the annual stock in 2017.

$$Annual\ Stock\ Energy\ Consumption_{Zone} = (Ave.Energy\ Consumption_{Zone}) \times (2017\ Stock) \times 10^{-9}$$

Sample Calculations (Zone 2):

$$Annual\ Stock\ Energy\ Consumption_{Zone2} = \left(1{,}485{,}370\frac{Wh}{yr}\right) \times (596{,}776\ units) \times 10^{-9} = 886\frac{GWh}{yr}$$

The total annual stock energy consumption is the addition of the annual stock energy consumption for each zone. **Table B-11** lists the baseline total annual stock energy consumption for years 2017 and 2026. Calculations for year 2026, when full implementation is complete, are similar.

Table B-11: Baseline Energy Use

Year	Stock	Total Annual Energy Consumption (GWh/yr)
2017	596,776	1,318
2026	756,527	1,671

Source: Staff calculation

Compliant Energy Use

The power consumption of compliant products is estimated based on minimum requirements to meet the proposed regulations. The annual energy consumption is calculated using the same methodology as baseline energy use. **Table B-12** lists the compliant total annual stock energy consumption for years 2017 and 2026.

Table B-12: Compliant Energy Use

Year	Stock	Total Annual Energy Consumption (GWh/yr)
2017	596,776	1,313
2026	756,527	1,609

Source: Staff calculation

Cost and Savings

Table B-13 lists the energy savings for portable electric spas once the proposed standard becomes effective in 2017and when complete implementation has occurred in 2026.

Table B-13: Standby Power Standard Statewide Annual Stock Savings

	First-Year Savings		Complete Turnover Savings	
	Energy Consumption (GWh/yr)	**Savings ($ Million)**	**Energy Consumption (GWh/yr)**	**Savings ($ Million)**
Portable Electric Spas (Zones 1-3)	4.2 (87%)	0.7	53 (87%)	9
Exercise Spas (Zones 4-8)	0.6 (13%)	0.1	8 (13%)	1
Total	4.8 (100%)	0.8	61 (100%)	10

Source: Staff calculation

The energy savings are calculated by subtracting the compliant energy use from the baseline energy use.

$$E_{Annual\ Savings} = E_{Annual\ Baseline} - E_{Annual\ Compliant}$$

Sample Calculation:

$$E_{Annual\ Savings} = (1{,}317.84 - 1{,}313)\frac{GWh}{yr} = 4.84\frac{GWh}{yr}$$

The cost savings (benefits) are calculated by multiplying the annual energy savings by $0.1619 per kWh.

$$B_{Savings} = \frac{\$0.1619}{kWh} \times E_{Annual\ Savings}$$

Sample Calculation:

$$B_{Savings} = \frac{\$0.1619}{kWh} \times 4.84\frac{GWh}{yr} \times \frac{10^6 kWh}{1GWh} = \$783{,}596\ or\ \$0.78\ Million$$

The cumulative energy and costs savings when the proposed standard has reached complete implementation is the summation of savings from each year beginning in 2017 and ending in the year 2026.

Table B-14 lists the energy savings and cost savings for labeled portable electric spas once the proposed standard becomes effective in 2017 and when complete implementation has occurred in 2026. The savings in the table below assumes the standard is completely implemented for the first-year and after complete turnover.

Table B-14: Statewide Annual Stock Savings Adjusting for Label Impact

	First-Year Savings		Complete Turnover Savings	
	Energy Consumption (GWh/yr)	**Savings ($ million)**	**Energy Consumption (GWh/yr)**	**Savings ($ million)**
Portable Electric Spas	5.7	0.9	69.6	11.2
Exercise Spas	0.8	0.1	10.4	1.8
Total	6.5	1.0	80	13

The total energy consumption savings are calculated by applying the 5 percent potential label savings to the total compliant annual energy consumption for 2017 and 2026 (refer to **Table B-11** and **Table B-12**).

$$First\ Year\ Energy\ Consumption\ Savings = Compliant\ AEC \times 100\%\ Standard\ Implementation \times 5\%\ Label\ Savings \times 10\% Design\ Life\ Rate$$

$$Complete\ Turnover\ Energy\ Consumption\ Savings = Compliant\ AEC \times 100\%\ Standard\ Implementation \times 5\%\ Label\ Savings$$

Sample Calculation:

$$First\ Year\ Energy\ Consumption\ Savings = 1313\frac{GWh}{yr} \times \frac{100\%}{100} \times \frac{5\%}{100} \times \frac{10\%}{100} \approx 6.5\ GWh/yr$$

$$Complete\ Turnover\ Energy\ Consumption\ Savings = 1609\frac{GWh}{yr} \times \frac{100\%}{100} \times \frac{5\%}{100} \approx 80\frac{GWh}{yr}$$

The energy consumption savings for each type of portable electric spa (i.e., portable electric spas and exercise spas) is calculated by using the ratio of the energy consumption savings of each type to the total energy consumption savings based on the standby power standard only (see **Table B-13**) and then applying it to the total energy consumption savings from the label savings (**Table B-14**). **Table B-15** summarizes the ratio for each type of portable electric spa.

Table B-15: Percentage of Energy Consumption after Applying the Standby Power Standard

Type	Percentage
Portable Electric Spas	87%
Exercise Spas	13%

$$Portable\ Electric\ Spa\ Energy\ Consumption\ Savings = Total\ Energy\ Consumption\ \times 87\%$$

$$Exercise\ Spa\ Energy\ Consumption\ Savings = Total\ Energy\ Consumption\ \times 13\%$$

Sample Calculation:

$$Exercise\ Spa\ Energy\ Consumption\ Savings_{CompleteTurnover} = 80\frac{GWh}{yr} \times \frac{13\%}{100} = 10.4\frac{GWh}{yr}$$

The cost savings are calculated by multiplying the energy consumption savings by the California retail price of electricity.

$$Cost\ Savings = Energy\ Consumption\ Savings\ \times \frac{\$0.1619}{kWh} \times Unit\ Converter$$

Sample Calculation:

$$Cost\ Savings_{TotalAfterCompleteTurnover} = 80\frac{GWh}{hr} \times \frac{\$0.1619}{kWh} \times \approx \$13\ Million$$

Table B-16 lists the weighted unit energy savings, lifecycle costs, and lifecycle benefits.

Table B-16: Weighted Unit Energy Savings and Lifecycle Benefits/Costs

	Design Life (years)	Energy Savings (kWh/year)	Lifecycle Costs ($/unit)	Lifecycle Benefit ($/unit)	Lifecycle Benefit/Cost Ratio
Portable Electric Spas	10	317	$ 100.38	$ 512	5
Exercise Spas	10	1,451	$ 100.38	$ 2,349	23

The calculation for energy savings per unit is the difference between the baseline and compliant consumption per unit which is similar to the calculations in the previous steps. The lifecycle benefit is the product of the energy savings per unit, the life of unit, and the average retail price of electricity.

The total set-up cost is calculated by multiplying the set-up cost for each manufacturer by the number of manufacturers in the MAEDBS system.

$$Total\ Set-Up\ Cost\ Statewide = (Engineer\ Time) \times (Engineer\ Hourly\ Wage) \times (No.of\ Manufacturers)$$

The total printing costs to label stock are calculated by multiplying the printing cost per label by the stock in 2017.

$$Total\ Printing\ Costs\ to\ Label\ Stock = (\$0.22\ per\ label) \times (2017\ stock)$$

The total labor costs are calculated by multiplying the total time to adhere labels to the entire stock by the packaging and filling machine operators' hourly wage.

$$Total\ Labor\ Costs = (2017\ Stock) \times (Time\ to\ adhere\ label) \times (Operator\ Hourly\ Wage)$$

The total cost to label stock is the addition of total set-up cost, total printing costs, and total labor costs.

$$Total\ Cost = (Total\ SetUp\ Cost) + (Total\ Printing\ Costs) + (Total\ Labor\ Costs)$$

The label cost for each portable electric spa is calculated by dividing the total cost to label stock by the 2017 stock.

$$Label\ Cost\ per\ Unit = \frac{Total\ Cost\ to\ Label\ Stock}{2017\ Stock}$$

Table B-17 lists approximate water surface area's based on the average volume of each zone and the evaporation rate based on the approximate water surface area.

Table B-17: Evaporation Rate without a Spa Cover

Zone	Unit Volume Capacity (gallons)	Water Surface Area (m^2)	Evaporation Rate[127], w_p (gallons/hr)
Zone 1A	140	3.3	0.70
Zone 1B	240	3.9	0.83
Zone 2	450	5.7	1.21
Zone 3	750	5.8	1.23
Zone 4	1,050	8.0	1.69
Zone 5	1,350	8.7	1.85
Zone 6	1,650	10.9	2.31
Zone 7	1,950	13.0	2.76
Zone 8	2,250	14.0	2.96

The evaporation rate is determined from using an equation found in the *Design Considerations for Pools and Spas (Natatoriums)* by John W. Lund.

$$w_p = \frac{A(p_w - p_a)(0.089 + 0.0782V)F_a}{\text{Y}}$$

where,
w_p=evaporation rate (kg/s)
A=area of pool surface (m^2)
p_w=saturation vapor pressure taken at surface water temperature (kPa), 6.95 kPa
p_a=saturation pressure at room air dew point (kPa), 1.768 kPa
V=air velocity over water surface (m/s), 0.1 m/s
F_a=activity factor, 1
Y=latent heat required to change water to vapor, 2257 kJ/kg

Staff Sample Calculations for Zone 2 (Average Volume =450 gallons):

$$w_p = \frac{5.7 \times (6.95 - 1.768)kPa \times \left(0.089 + 0.0782 \times 0.1\frac{m}{s}\right) \times 1}{2257\frac{kJ}{kg}} = 0.001267\frac{kg}{s}$$

Convert kilogram per second to gallons per hour

$$w_p = 0.001267\frac{kg}{s} \times \frac{0.26417\ gallons}{1\ kg} \times \frac{60\ sec}{1\ min} \times \frac{60\ min}{1\ hr} = 1.21\ \frac{gallons}{hr}$$

127 Lund, John W., *Design Considerations for Pools and Spas (Natatoriums).* Klamath Falls: Geo-Heat Center Oregon Institute of Technology, 2000.

Table B-18 lists the total energy and the total power required to heat a certain amount of water. In this case, this amount of water is an assumption of how much water would evaporate due to not having a spa cover.

Table B-18: Total Energy and Power Required to Heat Evaporated Water

Evaporation Rate, w (gallons)	Energy Required to Heat Water to 104˚F (kJ)	Energy Required to Vaporize Water (kJ)	Total Energy[128] (kJ)	Total Power Required (kW)
0.5	185	4,272	4,456	1
1	369	8,544	8,913	2
2	738	17,088	17,826	5
3	1,107	25,632	26,739	7
4	1,476	34,176	35,652	10
5	1,845	42,719	44,565	12

The energy required to heat water to 102˚F is calculated by using the specific heat relationship.

$$Q_{HW} = c \cdot m \cdot \Delta T$$

where,

$$Q_{HW} = energy\ required\ to\ raise\ temperature\ of\ water\ (kJ)$$
$$c = specific\ heat,\ 4.186\,\frac{kJ}{kg - ℃}$$
$$m = evaporation\ loss\ (kg)$$
$$\Delta T = T_2 - T_1\ (℃)$$
$$T_1 = 15.6℃\ (60℉)$$
$$T_2 = 38.89℃\ (102℉)$$

The energy required to vaporize water is based on the latent heat.

$$Q_{VP} = m \cdot L$$

where,

$Q_{VP} = energy\ required\ to\ vaporize\ water\ (kJ)$

$m = evaporation\ loss\ (kg)$

$L = latent\ heat\ of\ vaporization\ of\ water,\ 2257\ \frac{kJ}{kg}$

128 Stein, Benjamin. *Building Technology: Mechanical and Electrical Systems.* New York: John Wiley and Sons, Inc., 1997.

The total energy is calculated by adding the energy to heat water to 102˚F and the energy to vaporize water.

$$Total\ Energy\ (kJ) = Q_{HW} + Q_{VP}$$

The total power required is the total energy over a period of an hour.

$$Total\ Power\ (kW) = \frac{Total\ Energy\ (kJ)}{3600s}$$

Table B-19 lists the annual energy consumption and annual water consumption based on the total power required to heat the evaporated water listed.

Table B-19: Annual Energy and Water Consumption

Evaporation Rate, w (gallons/hr)	Energy Consumption (kWh/year)	Water Wasted (gallons/year)	Water Costs ($/1000 gallons)	Energy Costs ($)
0.5	10,844	4,380	33	1,756
1	21,688	8,760	66	3,511
2	43,376	17,520	131	7,023
3	65,064	26,280	197	10,534

Source: Building Technology: Mechanical and Electrical Systems by B. Stein.

The energy consumption is calculated by multiplying the total power by the duty cycle.

$$Energy\ Consumption = Total\ Power\ (kW) \times 8{,}760\ standby\ mode\ operating\ hours\ per\ year$$

The water wasted or water loss is calculated by multiplying the evaporation rate by the duty cycle.

$$Water\ Loss = Evaporation\ Loss\ \times 8{,}760\ standby\ mode\ operating\ hours\ per\ year$$

The energy costs are calculated by multiplying the energy consumption by the average retail price of electricity.

$$Energy\ Costs = Energy\ Consumption \left(\frac{kWh}{year}\right) \times \$0.1619\ per\ kWh$$

The water costs are calculated by multiplying the water loss by the delivery charge and treatment charge of water.

$$Water\ Costs = Water\ Loss\ \left(\frac{gallons}{year}\right) \times \left(\frac{\$2.82}{1000\ gallons} + \frac{\$4.66}{1000\ gallons}\right)$$