Pools & Spas

Codes and Standards Enhancement (CASE) Initiative
For PY 2013: Title 20 Standards Development

Analysis *of* Standards Proposal for
Residential Swimming Pool & Portable Spa Equipment

Docket #12-AAER-2F and #12-AAER-2G

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1 Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards.

This CASE report proposes updates and revisions to the standards for residential swimming pool filtration pumps, new and replacement single phase pump motors under 5 horsepower (HP), controllers, portable electric spas, as well as expanding the scope of the current standards to include light emitting diode (LED) pool lighting. Since these standards were first adopted on December 15th, 2004, the range of products available has changed and improved significantly. The Association of Pool and Spa Professionals (APSP) recently adopted a voluntary national energy efficiency standard, APSP 15, which reflects the current market of products. Since most new equipment is not addressed by current Title 20 standards, we propose that the CEC update and expand the scope to align more with APSP 15. In other words, an opportunity exists for California to reap greater energy savings through the adoption of more comprehensive Title 20 standards for residential swimming pools.

The key recommendations discussed in this report include:

- Replace the current prescriptive pool pump motor design standard with a performance-based standard for single phase pool pump motors under 5HP. New and replacement dedicated purpose pool pump motors must meet minimum performance efficiency levels as follows:
    - Single-speed pump motors: 70 percent full-load efficiency.
    - Dual-speed pump motors: 70 percent full-load efficiency and 55 percent efficiency at half or "low" speed.
    - Variable-speed and multi-speed pump motors: 80 percent full-load efficiency and 70 percent efficiency at half or "low" speed.
- Extend the standard to cover all single phase dedicated purpose pool pump motors under 5 HP, whether new (Original Equipment Manufacturer), or for replacement, whether residential or not, and whether for filtration or not.
- Bring Title 20 into alignment with the new APSP 15 Voluntary National Residential Swimming Pool Energy Efficiency Standard, in regards to test procedures, definitions, and labeling, and improve its applicability to variable-speed pump products.
- Improve variable-speed pump testing, reporting, and listing requirements to include performance specifications at various operating points on CEC Pool System Curves A, B, and C.

- Change prescriptive pump requirements for residential filtration pumps over 1 Total Horsepower (THP) from being dual, multi or variable speed to having an Energy Factor of 3.8 or greater on CEC Curve A.
- Ensure that the measured capacity of OEM pool pump motors is not greater than the reported HP, SF and motor capacity (THP) values.
- Add a testing, reporting, and listing requirement for new (OEM) and replacement pool pump motors.
- Update and clarify the pool pump controller language, testing, reporting and listing to better cover variable-speed pump controller features and to understand standby power consumption.
- Require the testing, reporting, and listing of Light Emitting Diode (LED) pool underwater lights, so their relative performance can be known.
- Require that portable electric spas be marked with a consumer facing label displaying their energy efficiency performance and certification of compliance with Title 20.

For pool pump motors, the CASE Team projects that the proposed standards will result in approximate electric energy and demand savings of 63 gigawatt hours (GWh) and 12 megawatts (MW) in the first year, and 630 GWh and 120 MW after full stock turnover in 10 years. This is estimated to represent approximately 1 percent and 10 percent of statewide energy consumption for these products, respectively. This also corresponds to a per-pump net present value of approximately $500. Further, it will create a statewide net present value of $100 million in the first year and $1,050 million after full stock turnover in 10 years.

For portable electric spa labeling, the CASE Team estimates that the proposed standards will conservatively achieve electric energy and demand savings of 0.5 GWh and 0.1 MW in the first year, and 5 GWh and 1MW after full stock turnover in 10 years. This will create a statewide net present value of $0.8 million in the first year and $8.1 million after full stock turnover in 10 years. Please note that this proposal contains a separate section for portable electric spas. (See Section 9)

2 Products Description

2.1 Pool Systems Overview

Pool pumps are used to circulate and filter swimming pool water, and operate pool features. Most pool pumps are centrifugal pumps, driven by a small single phase motor, typically 0.5 to 3 motor nameplate horsepower for residential and small commercial applications. DOE reported average pool pump life of 10 years (DEG & ES 2004a, 10). See Figure 2.1 and Figure 2.2 for visuals of a pool pump with attached motor. Figure 2.3 shows a basic schematic for a simple pool filtration system.

Figure 2.1 Pentair Intelliflo VF High Performance Pump

Source: PENTAIR 2013

Figure 2.2 Pentair Booster Pump

Source: PENTAIR 2013

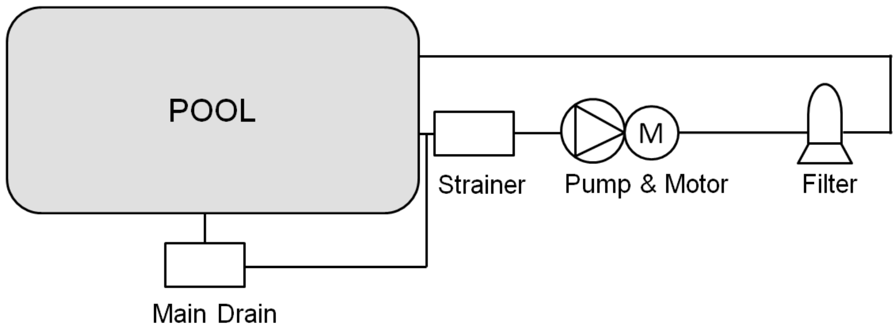


Figure 2.3 Simplified Piping Diagram for a Pool Filtration System

2.2 Cleaning and Filtration Systems

There are four principal types of cleaning systems: booster pump powered cleaners, filtration pump suction side cleaners, filtration pump discharge side cleaners and robotic cleaners which have small integral pumps. Side skimmer baskets also pick up large floating debris while the filter picks up smaller debris and impurities. The pool filtration pump will typically include a strainer basket on the suction side to prevent large debris from passing through the pump. Pool filters can use diatomaceous earth (DE), cartridges made of cloth or paper, or sand (DEG & ES 2004a, 2).

Contractors and retailers interviewed in a 2009 review of PG&E rebate programs noted that about 90 percent of pool owners have working pool cleaning systems, and 60 percent of those have pressure or return side systems with a booster pump (KEMA 2009, 5-56, Table A.11). Booster pumps are typically single-speed and slightly larger than one total horsepower, and are usually connected to the filtration pump discharge so the pool control systems typically run the filtration pump at high speed whenever the booster pumps are also running.

Estimated daily filtration pump operation times for residential pools vary between 1500 and 2500 hours per year depending on the source. Yearly hours of operation and other characteristics assumed in this report are in Table 2.1. Due to health codes, commercial pools require continuous filtration yielding operation times upwards of 8,760 hours per year.

Table 2.1 Pool Pump Operating Characteristics

	Average Motor Nameplate HP [a]	Average Pump kW [b]	Single Speed: Average Hours (Res) [c]	Single Speed: Average Hours (Com)	Multi speed: Average Hours High Speed	Multi speed: Average Hours Low Speed
Filtration Pumps	1.4	1.4	2000	8760	700	1800
Booster Pumps	0.75	1.1	900	-	-	-

[a] Average motor HP weighted average (ADM 2002 3-1, 3-2, 5-1). See Table A.1 and Table A.2.
[b] Average pump kW extrapolated from IOU program reported data (ADM 2002 3-2, 5-1). See Table A.3 and Table A.6.
[c] Average filtration pump and booster pump operating hours weighted average from PG&E program reported data (KEMA 2009 5-50, 5-57). See Table A.10 and Table A.12.

Pumps are rated according to their energy factor (EF) which is in units of gallons per watt-hour (gal./Wh) and can be calculated by dividing the gallons pumped by the watt-hours used (gpm*60/watt-hours/hour). For single-speed pumps, this is tested by adjusting pump head to lie on one of three separate flow-vs.-head pool system curves, measuring the speed, flow, and power on each curve. For dual or variable speed pumps, the same test is performed twice on each curve at the lowest and highest pump speeds (CEC 2010). Energy factor is influenced by pump and motor size, pump and motor efficiency in operation, and by the pool system hydraulic characteristics. A system with high resistance to the flow of water (head pressure, total dynamic head TDH) will have a lower energy factor for any given flow rate. For a pool pump to earn the ENERGY STAR® certification is must have an Energy Factor of 3.8 or greater on CEC Curve A at its most efficient speed.

2.3 Pool Pump Motors

Pool pump motors installed in California pools are typically single phase and run on alternating current (AC). Typical designs are capacitor-start capacitor-run (CSCR), permanent-split capacitor (PSC), or three-phase induction; or direct current (DC): electronically commutated (EC) / permanent magnet type which require “drives”, that convert utility supplied single phase AC to the power form that the motor actually utilizes. Rated motor efficiency ranges of motors reported in the CEC and APSP databases are presented in Table 2.2. Title 20 requires that pump motors at or above one THP be dual-speed and prohibits the use of split-phase induction, shaded-pole, or capacitor-start induction-run (CSIR) motors in residential filtration pool pumps (CEC 2010). Pool pump motors are typically two-pole and operate at 3450 revolutions per minute (RPM) full speed.

Table 2.2 Pool Pump Motor Designs, Construction and Efficiency Ranges

Motor Design	Motor Construction	Efficiency Range (High Speed)
Single Speed	Permanent Split Capacitor	47% - 84%
	Capacitor-Start, Capacitor-Run	62% - 83%
Dual Speed	Permanent Split Capacitor	57% - 84%
	Capacitor-Start, Induction-Run	65% - 75%
	Capacitor-Start, Capacitor-Run	72% - 83%
Variable/Multi Speed	Permanent Split Capacitor	83%
	Electronically Commutated	77% - 92%

Source: CEC 2012a,_ASAP 2012a, ASAP 2012b

The Department of Energy (DOE) estimates that average small electric motor life is seven years (30,000 hours) for capacitor-start type (DOE 2011 8-22, 8-23). Motors that are run fewer hours per day will have a longer application lifetime. Past CASE analyses (DEG & ES 2004a, 10; PG&E & SCGC 2007, 13) assumed that pool pumps and motors have approximately the same lifetime, about ten years.

2.4 Pool Pump Controllers and Other Pool Controls

Variable and multi-speed motors must use a motor controller or drive to modulate speed. Specialized controls allow the installation contractor to set the appropriate low and high speed operation times for filtration and cleaning functions respectively. Low-speed operation is appropriate for pool filtration. Higher speed is required for operating sweeps or bottom crawlers for a few hours per day, backwashing filters, or for priming the pump. Most controls manufacturers currently offer two-speed or variable-speed control options, with automatic or manual override to allow higher-speed, high-flow operation for cleaning no longer than 24 hours (DEG & ES 2004a, 7).

Variable speed pumps now commonly offer integral controls on the pump to allow choice of speeds and times. More sophisticated controls can manage auxiliary pool components such as spas, waterfalls, and lights.

2.5 Pool Lighting

Pool lamps can be of several types with incandescent reflector lamps (IRLs) and parabolic aluminized reflector (PAR) as common lamp types. Typical wattages for IRL/ PAR pool lamps range from 300 to 500 watts. The lamp housings are placed in a pool light “niche” in the side of the pool.

Lamps for pools and spas face unique design challenges. The light fixture must be well-sealed to prevent corrosion or leaks. The difficulty of replacement makes a long burn life important. They may face space constraints; certain spa IRLs are called “shorts” because they are limited to a maximum overall length in order to fit into a niche.

Recently, LED pool underwater lights have become an available alternative to traditional underwater lamps. Some of their benefits include better efficacy, lower wattage (45-65 watts), longer lifetime, and better visibility due to the spectrum of light provided. In addition, LED lamps do not “burn out” in the same way that traditional fluorescent or incandescent lamps do. Instead of burning out immediately, they become dimmer over time. Performance over lamp lifetime can be rated by lamp lumen depreciation (LLD), a measure of mean lumens over the lamp’s operational life divided by rated lumens.

3 Manufacturing and Market Channel Overview

For specific market data (number of shipments and stock), see Section 0 of this report, covering Market Saturation and Sales.

3.1 Pool Pumps, Motors, and Controllers

Pool pumps are manufactured and distributed by a variety of companies: Hayward Pool Products, Pentair Water Pool and Spa, Inc. (including Sta-Rite Pumps), Speck Pumps, Waterway Plastics Inc., and Jandy Pool Products, Inc. (merged with Zodiac Pool Systems, Inc.). New and replacement pool motors are manufactured by SNTech (Marathon Electric brand), and Regal Beloit (formerly Century/A.O. Smith), and Nidec Motor Corporation (formerly Emerson Electric).

There are two typical market channels for pool equipment: the distributor model and the retail model. In the distributor model, a pool contractor or serviceperson buys equipment directly from a distributer and installs the equipment. In the retail model, homeowners purchase the equipment directly and install it themselves.

4 Energy Usage

4.1 Test Methods

4.1.1 Current Test Methods

IEEE 114-2001: IEEE Standard Test Procedure for Single-Phase Induction Motors

This test procedure determines the performance characteristics (motor efficiency) of single-phase induction motors, including non-excited synchronous motors and is intended for single speed motors. Title 20 references Standard 114-2001; The Institute of Electrical and Electronics Engineers (IEEE) has since published an updated version of the standard.

HI 1.6-2000: Centrifugal Pump Test

This test procedure determines the pump efficiency for centrifugal pumps. Title 20 references Standard 1.6-2000; the Hydraulic Institute has since published an updated version of the standard.

Title 20 Section 1604(g)(3): CEC Test Method for Residential Pool Pumps

This test procedure tests and reports pool pump speed, flow, power, and Energy Factor (EF, Gal/Wh) for three system curves. It draws on IEEE 114 and HI 1.6 to determine motor efficiency and pump efficiency. The existing test procedure is similar, but not identical, to APSP 15 Section 4.1.2: Test Method for Pool Pumps. The APSP 15 test procedure has been recently updated to match the newest IEEE test procedure which made a minor correction from its last version.

4.1.2 Proposed Test Methods

IEEE 114-2010: IEEE Standard Test Procedure for Single-Phase Induction Motors

Update Title 20 reference to most recent version with appropriate modification to address variable speed motors with drives and controls.

Note: The CASE Team will be reaching out to the CEC to propose slight modifications to this test procedure to better account for variable speed motors after submittal of this CASE report.

HI 1.6-2011: Centrifugal Pump Test

Update Title 20 reference to most recent version.

Title 20 Section 1604(g)(3): CEC Test Method for Residential Pool Pumps

We propose changes to this test procedure to better align with APSP 15. Specific test procedure language is in Section 0 of this report.

4.2 Energy Use per Unit for Non-Qualifying Motors

This section presents the average energy use for non-qualifying products—products that do not meet the proposed standard described further in more detail Section 0. Pump and motor energy use can be calculated using standard pump energy equations. This requires understanding the system head and flow. The equations below illustrate how energy consumption of a pool pump motor is calculated.

Equation 4.1: Brake Horsepower

$$\text{Brake Horsepower (BHP)} = Q * \rho * g * H / \eta_p = Q * H / 3960 / \eta_p$$

Where Q = flow (GPM)
H = system head (ft)
ρ = fluid density
g = gravitational constant
η_p = pump efficiency

Equation 4.2: Energy Consumption of a Motor

$$\text{Energy (kWh)} = \text{BHP} * 0.746 * h / \eta_m$$

Where h = number of hours of operation
η_m = motor efficiency

In this report, the Unit Energy Consumption (UEC) for non-qualifying motors of various categories has been calculated using field measured demand (kW) data that was collected as part of the 2001 Summer Initiatives Pool Pump Program. This program included PG&E, SCE, and SDG&E service areas (ADM, 2002). Nameplate horsepower and measured demand data were plotted to create a linear equation relating the two variables enabling the extrapolation of actual demand across different pumps and motors.

Annual operating hours used in the UEC calculation are weighted based on number of hours spent at high speed versus low speed for multi-speed motors. For single speed motors the average annual hours is a weighted average based on run hours for booster pumps versus filtration pumps. These values are shown in Table 2.1 of this report. Table 4.1 and Table 4.2 present pool pump and motor data from the APSP and CEC databases for both replacement and new non-qualifying products.

It should be noted that certain motor designs at particular horsepower levels already meet the current standard. In this case, the non-qualifying products are considered to be the minimum proposed standards.

The equation below describes how UEC is calculated for a non-qualified single speed motor.

Equation 4.3: UEC for Non-Qualifying Single Speed Motors

$$kWh_{non\text{-}stds} = kW_{base} * h_{high}$$

The equation below describes how UEC is calculated for a non- qualified variable or dual speed motor.

Equation 4.4: UEC for Non-Qualifying Dual and Variable Speed Motors

$$kWh_{non\text{-}stds} = (kW_{base} * h_{high}) + (kW_{base} * h_{low} * 25\%)$$

Where:
kW_{base} = Kilowatt hours (power) consumption of non-qualified product.
h_{high} = Number of hours at high speed
h_{low} = Number of hours at low speed
25% = Assumes that, at half speed, pump and motor will use 25% power. This is due to conservative application of pump affinity laws.

For example, for a non-qualifying 1hp variable speed pump replacement motor, the UEC would be calculated as follows:

Equation 4.5: Sample UEC Calculation for Non-Qualifying Variable Speed Motor

$$kWh_{non\text{-}stds} = (kW_{base} * h_{high}) + (kW_{base} * h_{low} * 25\%)$$
$$kWh_{non\text{-}stds} = (1.2\ kW * 700\ hours) + (1.2\ kW * 1{,}800\ hours * .25)$$
$$kWh_{non\text{-}stds} = 1{,}380\ kWh$$
$$kWh_{non\text{-}stds(rounded)} = 1{,}400\ kWh$$

Table 4.1 Per Unit Energy Use of Non-qualifying Products: Replacement Pump Motors

Product Class	Nameplate Motor Capacity (HP)	Average Total Pump Capacity (HP)[a]	Average Actual Pump Demand (kW)[b]	Average Annual Pump Run Hours[c]	Average Full-Load Efficiency (%)[a]	Average Low Speed Efficiency (%)[a]	Pump UEC (kWh)[d]
Variable-Speed	1	1.9	1.2	2,500	77%	68%	1,400
	2.7	2.7	2.1	2,500	80%	70%	2,400
Dual-Speed	0.75	1.2	1.1	2,500	66%	48%	1,200
	1	1.4	1.2	2,500	65%	50%	1,400
	1.5	1.9	1.5	2,500	70%	49%	1,700
	2	2.3	1.7	2,500	70%	53%	2,000
	3	3.3	2.3	2,500	70%	55%	2,600
Single-Speed[e]	0.5	0.8	0.9	1,700	61%	N/A	1,500
	0.75	0.9	1.1	1,700	64%	N/A	1,800
Single-Speed (Com)[f]	1	1.3	1.2	8,760	66%	N/A	10,400
	1.5	1.8	1.5	8,760	65%	N/A	12,800
	2	2.4	1.7	8,760	67%	N/A	15,200
	2.5	2.8	2.0	8,760	70%	N/A	17,600
	3	3.7	2.3	8,760	70%	N/A	20,000

[a] HP and efficiency data are straight averages from databases: CEC 2012a, APSP 2012a, APSP 2012b. Baseline characteristics are determined by analyzing products that do not qualify with the standard.

[b] Average pump kW extrapolated from IOU program reported data (ADM 2002 3-2, 5-1). See Table A.3 and Table A.6.

[c] Annual pump-run hours include both low speed and high speed, see Table 2.1 for breakdown of pump-run hours.

[d] Pump power at low speed calculated using a conservative application of the pump affinity laws to account for motor losses i.e. $(50\%)^2 = 25\%$. While theoretically, this should be $(50\%)^3 = 12.5\%$, to account for motor efficiency losses at lower speeds, the former calculation was used.

[e] Single-speed pump UEC for .5 and .75hp motors are weighted to account for the market share of booster pumps.

[f] Single-speed pool pump motors larger than 1 hp are only allowed in commercial applications. 75% of commercial pools were assumed to be residential scale (less than 5 Total Horsepower).

Table 4.2 Per Unit Energy Use of Non-qualifying Products: New Pumps with Integral Motors

Product Class	Nameplate Motor Capacity (HP)[a]	Average Total Pump Capacity (HP)[a]	Average Actual Pump Demand (kW)[b]	Average Annual Pump Run Hours	Average Full-Load Motor Efficiency (%)[a]	Average Low Speed Motor Efficiency (%)[a]	Pump UEC (kWh)[c]
Variable-Speed	1	1.9	1.2	2,500	77%	68%	1,400
	1.5	1.7	1.5	2,500	80%	70%	1,700
	2	2.3	1.7	2,500	80%	63%	2,000
	2.7	2.7	2.1	2,500	80%	63%	2,400
	3	3.9	2.3	2,500	77%	63%	2,600
Dual-Speed	0.75	1.2	1.1	2,500	68%	49%	1,200
	1	1.4	1.2	2,500	67%	49%	1,400
	1.5	1.9	1.5	2,500	68%	53%	1,700
	2	2.3	1.7	2,500	70%	49%	2,000
	2.5	2.5	2.0	2,500	70%	49%	2,300
	3	3.3	2.3	2,500	70%	49%	2,600
Single-Speed [e]	0.5	0.8	0.9	1,700	62%	N/A	1,500
	0.75	0.9	1.1	1,700	63%	N/A	1,800
Single-Speed (Com)[f]	1	1.3	1.2	8,760	66%	N/A	10,400
	1.5	1.8	1.5	8,760	65%	N/A	12,800
	2	2.4	1.7	8,760	67%	N/A	15,200
	2.5	2.8	2.0	8,760	70%	N/A	17,600
	3	3.7	2.3	8,760	70%	N/A	20,000

[a] HP and efficiency data are straight averages from databases: CEC 2012a, APSP 2012a, APSP 2012b. Baseline characteristics are determined by analyzing products that do not qualify with the standard.
[b] Average pump kW extrapolated from IOU program reported data (ADM 2002 3-2, 5-1). See Table A.3 and Table A.6.
[c] Annual pump-run hours include both low speed and high speed, see Table 2.1 for breakdown of pump-run hours.
[d] Pump power at low speed calculated using a conservative application of the pump affinity laws to account for motor losses i.e. $(50\%)^2 = 25\%$. While theoretically, this should be $(50\%)^3 = 12.5\%$, to account for motor efficiency losses at lower speeds, the former calculation was used.
[e] Single-speed pump UEC for .5 and .75hp motors are weighted to account for the market share of booster pumps.
[f] Single-speed pool pump motors larger than 1 hp are only allowed in commercial applications. 75% of commercial pools were assumed to be residential scale (less than 5 Total Horsepower).

4.3 Efficiency Measures: Pool Pump Motors

Pool pump motors can reduce energy consumption by being more efficient (%, the ratio of shaft output power over the electrical input power), or by making pumps more efficient by operating at multiple or variable-speeds to take advantage of affinity laws. Affinity laws state that, for centrifugal machines, speed or flow is related to the cube of power. Therefore, a 50 percent reduction in motor speed will create an ideal reduction in power of 85 percent or more.

Certain motor types are inherently less efficient than others; this is why Title 20 currently prohibits split-phase induction, shaded-pole, and CSIR motors in residential pool pumps. Two-speed PSC and CSCR motors are much less efficient on low speed than at high speed, although a few manufacturers are starting to produce lines of two-speed motors with efficient low-speed operation. Variable-speed ECM motors are also less efficient at low speeds than at high speeds, but to a lesser degree than two-speed motors. They also have increased flexibility as they are able to operate at nearly any partial speed.

The proposal for pool pump motors is to replace the current prescriptive motor standard with performance based standards for single, dual and variable speed motors. This is explained in greater detail in Section 0.

4.4 Energy Use per Unit for Qualifying Motors

This section presents the energy use for qualifying motors—products that meet the proposed standard described below and further in more detail in Section 11.1. To calculate the UEC for qualifying products, the CASE Team utilized the same field measured demand data as described Section 4.2. As motor efficiency is intrinsically incorporated in the field measured demand data, a ratio of non-qualifying and qualifying motor efficiencies was applied to the field measured data to determine the relative energy use for qualifying products.

The proposed standard levels for pool pump motors are shown below:

- Single-speed pump motors: 70 percent full-load efficiency;
- Dual-speed pump motors: 70 percent full-load efficiency and 55 percent efficiency at half or "low" speed; and
- Variable-speed and multi-speed pump motors: 80 percent full-load efficiency and 70 percent efficiency at half or "low" speed.

The equation below describes how UEC is calculated for a qualified single-speed motor.

Equation 4.6: UEC for Qualifying Single Speed Motors

$$kWh_{stds} = kW_{base} * [h_{high} * (\eta_{base\text{-}high} / \eta_{stds\text{-}high})]$$

The equation below describes how UEC is calculated for a qualified variable or dual-speed motor.

Equation 4.7: UEC for Qualifying Dual and Variable Speed Motors

$$kWh_{stds} = kW_{base} * [h_{high} * (\eta_{base\text{-}high} / \eta_{stds\text{-}high}) + h_{low} * 25\% * (\eta_{base\text{-}low} / \eta_{stds\text{-}low})]$$

Where:
kW_{base} = Kilowatt hours (power) consumption of non-qualified product.
h_{high} = Number of hours at high speed
h_{low} = Number of hours at low speed
$\eta_{base\text{-}high}$ = Efficiency of non-qualifying motor (high speed)
$\eta_{stds\text{-}high}$ = Efficiency of qualifying motor (high speed)
$\eta_{base\text{-}low}$= Efficiency of non-qualifying motor (low speed)

$\eta_{stds\text{-}low}$ = Efficiency of qualifying motor (low speed)
25% = Assumes that, at half speed, pump and motor will use 25% power. This is due to conservative application of pump affinity laws.

Annual hours used for qualifying UEC are the same as described in Section 4.2.

For example, for a qualifying 1hp new variable-speed pump replacement motor the UEC would be calculated as follows:

Equation 4.8: Sample UEC Calculation for Qualifying Variable Speed Motor

$$kWh_{stds} = kW_{base} * [h_{high} * (\eta_{base\text{-}high} / \eta_{stds\text{-}high}) + h_{low} * 25\% * (\eta_{base\text{-}low} / \eta_{stds\text{-}low})]$$
$$kWh_{stds} = 1.2kW * [700 \text{ hours} * (77\% / 80\%) + 1{,}800 \text{ hours} * 25\% * (68\%/73\%)$$
$$kWh_{stds} = 1309 \text{ kWh}$$
$$kWh_{stds\ (rounded)} = 1{,}300 \text{ kWh}$$

Table 4.3 Per Unit Energy Use of Qualifying Products: Replacement Pump Motors

Product Class	Nameplate Motor Capacity (HP)	Average Total Pump Capacity (HP)[a]	Average Actual Pump Demand (kW)[b]	Average Annual Pump Run Hours [c]	Average Full-Load Efficiency (%)[a]	Average Low Speed Efficiency (%)[a]	Pump UEC (kWh)[d]
Variable-Speed	1	1.9	1.2	2,500	80%	73%	1,300
	2.7	2.7	2.1	2,500	82%	70%	2,400
Dual-Speed	0.75	1.2	1.1	2,500	74%	57%	1,100
	1	1.4	1.2	2,500	74%	57%	1,200
	1.5	1.9	1.5	2,500	75%	57%	1,500
	2	2.3	1.7	2,500	79%	57%	1,800
	3	3.3	2.3	2,500	79%	57%	2,400
Single-Speed [e]	0.5	0.8	0.9	1,700	76%	N/A	1,200
	0.75	0.9	1.1	1,700	76%	N/A	1,500
Single-Speed (Com)[f]	1	1.3	1.2	8,760	76%	N/A	9,000
	1.5	1.8	1.5	8,760	76%	N/A	10,900
	2	2.4	1.7	8,760	79%	N/A	12,800
	2.5	2.8	2.0	8,760	77%	N/A	15,900
	3	3.7	2.3	8,760	79%	N/A	17,700

[a] HP and efficiency data are straight averages from databases: CEC 2012a, APSP 2012a, APSP 2012b. Baseline characteristics are determined by analyzing products that do not qualify with the standard.
[b] Average pump kW extrapolated from IOU program reported data (ADM 2002 3-2, 5-1). See Table A.3 and Table A.6.
[c] Annual pump-run hours include both low speed and high speed, see Table 2.1 for breakdown of pump-run hours.
[d] Pump power at low speed calculated using a conservative application of the pump affinity laws to account for motor losses i.e. $(50\%)^2 = 25\%$. While theoretically, this should be $(50\%)^3 = 12.5\%$, to account for motor efficiency losses at lower speeds, the former calculation was used.
[e] Single-speed pump UEC for .5 and .75hp motors are weighted to account for the market share of booster pumps.
[f] Single-speed pool pump motors larger than 1 hp are only allowed in commercial applications. 75% of commercial pools were assumed to be residential scale (less than 5 Total Horsepower).

Table 4.4 Per Unit Energy Use of Qualifying Products: New Pumps and Integral Motors

Product Class	**Nameplate Motor Capacity (HP)**	**Average Total Pump Capacity (HP)[a]**	**Average Actual Pump Demand (kW)[b]**	**Average Annual Pump Run Hours[c]**	**Average Full-Load Efficiency (%)[a]**	**Average Low Speed Efficiency (%)[a]**	**Pump UEC (kWh)[d]**
Variable-Speed	1	1.9	1.2	2,500	85%	77%	1,200
	1.5	1.7	1.5	2,500	84%	77%	1,600
	2	2.3	1.7	2,500	84%	83%	1,800
	2.7	2.7	2.1	2,500	84%	84%	2,100
	3	3.9	2.3	2,500	91%	83%	2,100
Dual-Speed	0.75	1.2	1.1	2,500	75%	61%	1,100
	1	1.4	1.2	2,500	75%	62%	1,200
	1.5	1.9	1.5	2,500	75%	60%	1,500
	2	2.3	1.7	2,500	78%	63%	1,700
	2.5	2.5	2.0	2,500	79%	70%	1,900
	3	3.3	2.3	2,500	82%	73%	2,100
Single-Speed[e]	0.5	0.8	0.9	1,700	77%	N/A	1,200
	0.75	0.9	1.1	1,700	76%	N/A	1,500
Single-Speed (Com)[f]	1	1.3	1.2	8,760	76%	N/A	9,000
	1.5	1.8	1.5	8,760	76%	N/A	10,900
	2	2.4	1.7	8,760	79%	N/A	12,800
	2.5	2.8	2.0	8,760	77%	N/A	15,900
	3	3.7	2.3	8,760	79%	N/A	17,700

[a] HP and efficiency data are straight averages from databases: CEC 2012a, APSP 2012a, APSP 2012b. Baseline characteristics are determined by analyzing products that do not qualify with the standard.
[b] Average pump kW extrapolated from IOU program reported data (ADM 2002 3-2, 5-1). See Table A.3 and Table A.6.
[c] Annual pump-run hours include both low speed and high speed, see Table 2.1 for breakdown of pump-run hours.
[d] Pump power at low speed calculated using a conservative application of the pump affinity laws to account for motor losses i.e. $(50\%)^2 = 25\%$. While theoretically, this should be $(50\%)^3 = 12.5\%$, to account for motor efficiency losses at lower speeds, the former calculation was used.
[e] Single-speed pump UEC for .5 and .75hp motors are weighted to account for the market share of booster pumps.
[f] Single-speed pool pump motors larger than 1 hp are only allowed in commercial applications. 75% of commercial pools were assumed to be residential scale (less than 5 Total Horsepower).

Yearly UEC (unit energy consumption) values range between 1,000 and 2,600 kilowatt hours (kWh) for a single residential pool pump, or 3,300 kWh for an average residential pool with both a 1.5 nameplate hp dual-speed pump and 0.75 nameplate hp booster pump. This is consistent with RASS reported data of 3,500 kWh for an average residential pool with a filtration and booster pump (KEMA 2010) and past CASE Reports reporting a range of 1,000 to 3,900 kWh and averaging at 2,600 kWh for a single pool pump (DEG & ES 2004a, 4-5). Single speed pumps in commercial applications use significantly more energy due to their long duty cycles (typically 24 hours a day, 7 days a week).

4.5 Other Pool Efficiency Measures

4.5.1 Pool Pumps

Improving pump operating efficiency may involve changes to the pump, the motor, or the system. Pump operation is defined using pump curves, which define pump total dynamic head (TDH) at a specific flow or capacity. A single-speed pump will operate along its curve to match required system flow. Typically, the best efficiency (wire to water) for the pump will occur between 60 and 80 percent of max flow. See Figure 4.1 for an example of a pump series of different sizes (total horsepower), each with a different flow curve. The overlaid curves of constant efficiency indicate the operating points at which the pump will have the same efficiency; the peak efficiency will be at the focus of the efficiency curve (for example, at approximately 70 GPM and 70 feet of head, for Curve J in Figure 4.1).

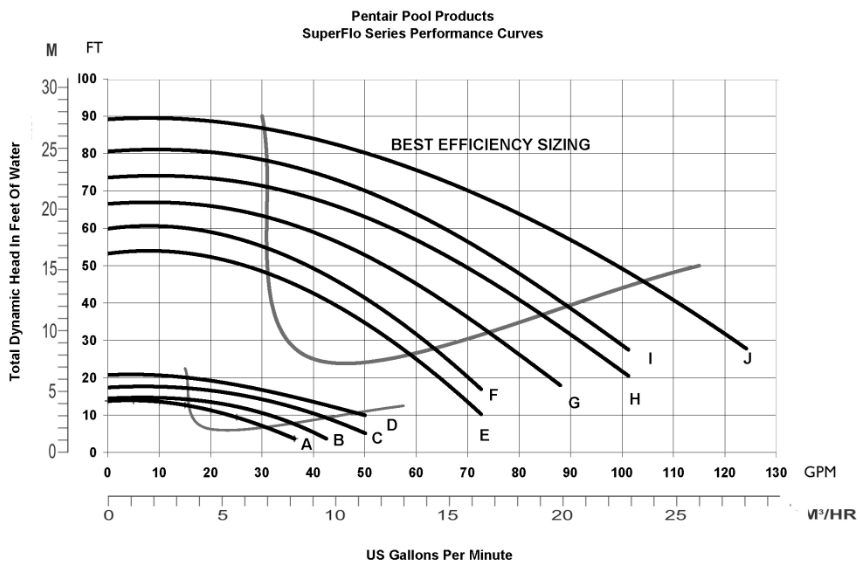


Figure 4.1 Pentair SuperFlo Pump Family Curve

Source: PENTAIR 2013

For a variable-speed pump, decreasing pump speed decreases the amount of flow and head the pump must manage. See Figure 4.2 for an example of pump curves for one VS pump at different speeds.

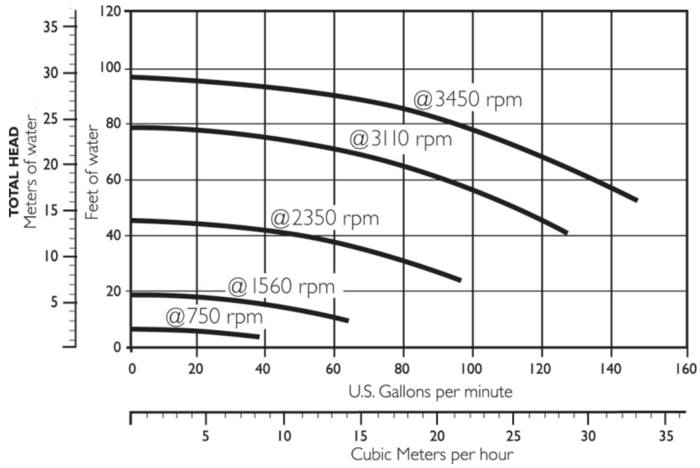


Figure 4.2 Pentair Variable-speed IntelliFloVS Pump Curve

Source: PENTAIR 2013

Every pool system will have a unique system curve, depending on a variety of system characteristics (total flow required, number and placement of filters and other equipment, piping layout and friction). Head for pumped systems typically varies as a square of flow, consistent with affinity laws. See Figure 4.3 for the system curves at which pool pumps are tested under Title 20 and APSP 15.

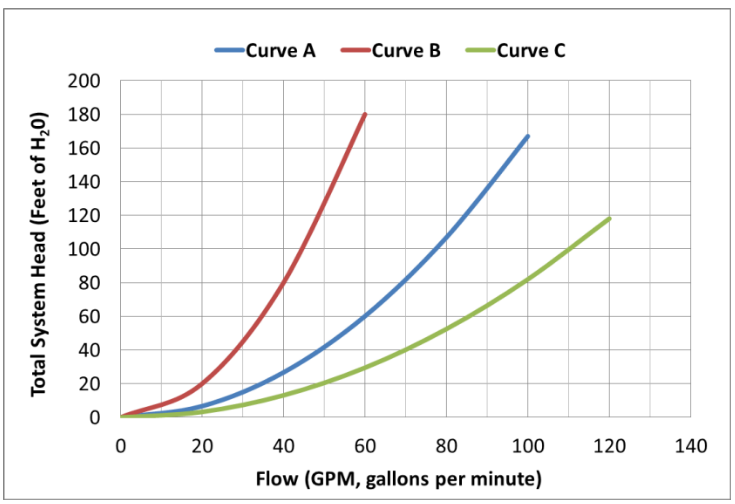


Figure 4.3 Title 20 and APSP 15 System Test Curves for Pool Pumps

Source: CEC 2012a

Ways to improve pool pump efficiency include:

- For dual-speed motors, improve low speed motor design to maintain high efficiency at low speed as well as high speed. Currently, low speed efficiency is typically half that at full speed. (See Section 4.2)

- Operating the pump at low speed using a dual, multi, or variable-speed motor. This incurs savings due to affinity laws.
- Proper system sizing. Appropriately matching the pump size to the total system flow and head. Improper sizing will cause the pump to provide too much or too little flow, or operate outside of its peak efficiency range.
- Making changes in the pool cleaning system. Removing the pool cleaner booster pump or hydraulic cleaner by installing an independent robotic cleaner. This would avoid two speed or variable speed pumps having to operate at a higher speed and for powering pool cleaners.

4.5.2 Pool Pump Controllers

Pool pump controllers are already subject to a Title 20 design standard specifying the capability to operate pumps on at least two speeds and return to the normal filtration speed within no more than one normal period (24 hours) when set to high speed for cleaning or maintenance. This is intended to assure that the default speed of two-speed pumps is set at the lowest speed, and that the controller returns the pump to normal operation within no more than 24 hours after cleaning or maintenance (in contrast to remaining on high speed until manually reset).

A timer can schedule particular functions on or off according to a preset schedule, to avoid running equipment during peak hours or when not needed. California's Title 24 Building Energy Standards currently require that pools have a time switch or other control to allow all pumps to be set or programmed to run only during the off-peak electric demand period.

4.5.3 Pool Lighting

LEDs, with their low wattages, high efficacy, and long lifetimes, are the most efficient type of light source available on the market. Unlike other LED applications, manufacturers of underwater LEDs do not specify the performance of these new integral and replacement lamps. Better specification (labeling and marking) can improve consumer awareness and acceptance.

5 Market Saturation & Sales

5.1 Current Market Situation

5.1.1 Total Stock and Shipments

According to the CEC's Residential Appliance Saturation Survey (RASS) (KEMA 2010), 16 percent of single-family residences in California have pools (approximately 1.25 million). P.K. Data (2012) reports a slightly higher number of 1.31 million in-ground and 0.54 million above-ground pools (PK Data 2012). Specifically, they report a total of 29,500 new residential pools constructed in 2012 (10,800 in-ground and 18,700 above-ground). This number is lower than past years presumably due to the economic recession (PK Data 2012). Between 2003 and 2009, the number of pools reported in California RASS survey data increased from 0.87 million to 1.21 million or a rate of 57,000 new pools per year (KEMA 2010). P.K. Data also state there are roughly 46,000 commercial pools in California with approximately 450 new commercial pools built each year.

Given the relatively slow growth of pools in recent years, the CASE Team assumes a zero growth rate in our analysis.

Pool Pumps and Motors

In 2009, pool contractors and retailers in PG&E service territory estimated that 76 percent of the pools they service have single-speed pumps, 10 to 11 percent have two-speed pumps, and 12 to 14 percent have variable-speed pumps. See Table A.8 Distribution of Pool Pump Type, PG&E Service Area in Appendix. Average nameplate pump motor size was reported to be 1 to 1.5 HP (KEMA 2009, 5-9), and is consistent with investor owned utility (IOU) program reports (see Table A.1, Table A.2, and Table A.9 in Appendix A:).

Table 5.1 California Stock – 2012

	Stock
Product Class	Units (millions)
Residential Pools	1.9
Commercial Pools [A]	0.05
Residential Filtration Pumps and Motors	1.9
Variable-speed Motor	0.18
Two-Speed Motor	0.19
Single-Speed Motor	1.52
Non-Filtration Pumps and Motors[B]	0.53

Source: P.K. Data 2012, EIA 2012, KEMA 2009, KEMA 2010

[A] 75% of commercial pools are estimated to use residential scale equipment and have single speed

pumps.
[B] All non-filtration (booster) pumps are assumed to be single speed and slightly larger than 1 total hp.

Table 5.1 and Table 5.2 summarize the data for existing California stock and sales for pool pumps and motors products. Replacement sales for pool pumps are from RASS-reported data of pump replacements (KEMA 2010). New 2012 sales are from PK Data (PK Data 2012). Aboveground pools and small commercial pools are assumed to have no Booster pumps while 40 percent of residential pool systems are assumed to have a booster pump (ADM 2002). Our analysis reveals a significant shift of the existing stock being single speed pumps to variable speed pumps in new sales. This shift reflects the effect of California's existing pump standards coming into effect, IOU incentive programs, and the overall dramatic market shift toward highly efficient variable speed pumps in recent years.

It should also be noted that in our analysis, 75 percent of commercial pools are assumed to use residential size equipment (under 5 THP) and would therefore be covered by the proposed standards.

Table 5.2 California Annual Sales – 2012

Product Class	**California Annual New Sales** (thousands)	**California Annual Replacement Sales**[A] (thousands)
Residential Pools	30	N/A
Commercial Pools	0.4	N/A
Residential Filtration Pumps and Motors	35	190
Variable-speed Motor	22	64
Two-Speed Motor	9	26
Single-Speed Motor[C]	18	99
Non-Filtration Pumps and Motors[B]	12	53

Source: P.K. Data 2012, EIA 2012, KEMA 2009, KEMA 2010, PG&E & SCGC 2007
[A] Assuming 10-year lifetime for pool pumps and motors.
[B] All non-filtration (booster) pumps are assumed to be single speed and less than 1 total hp.
[C] All commercial pool pump motors are assumed to be single speed and greater than 1 total hp.

Table 5.3 provides estimates for statewide energy consumption of pool pumps and motors, based on existing stock size and usage characteristics. Statewide energy consumption of 6,000 GWh is in the range of RASS 2009 estimates of 6,600 GWh (KEMA 2010).

Table 5.3 California Statewide Pool Pump Energy Use – 2013

Product Class	For First-Year Sales Peak Demand (MW)	For First-Year Sales Annual Energy Consumption (GWh/yr)	For Entire Stock[a] Peak Demand (MW)	For Entire Stock[a] Annual Energy Consumption (GWh/yr)
Variable-speed	32	170	320	1,700
Two-Speed	12	61	120	600
Single-Speed	71	380	710	3,700
Total	**120**	**600**	**1,200**	**6,000**

Source: Table 2.1, Table 4.1, Table 4.2, Table 5.1, Table 5.2.

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction),the simultaneous peak load for all end users, as defined by Koomey and Brown (2002).

5.1.2 Market Share of High Efficiency Options

Pool Pumps and Motors

Data that distinguish between shipments of qualifying versus non-qualifying pool pumps and motors are not available. Qualifying and non-qualifying products were therefore identified using available product data in the APSP and CEC databases, which is not shipment-weighted.

Multi-speed and variable-speed pool pumps and motors are the most efficient option currently available on the market, both in terms of operation (ability to operate at low speed) and pure efficiency (motor efficiency, wire-to-water pump efficiency) at both full and low speeds. Nearly all multi-speed and variable-speed pool pumps and motors listed in the APSP and CEC databases will meet the proposed standards.

Based on the proposed standards, the CASE Team estimates 20 percent saturation of qualifying single and dual speed pool pump motors.

Given the high efficiency of variable speed pool pump motors, saturation of qualifying products is roughly 90 percent, as most of the market already meets the efficiency standards.

5.2 Future Market Adoption of High Efficiency Options

Pool Pumps and Motors

Anecdotal evidence suggests that variable-speed pumps and motors are becoming more popular, as consumers now typically have more options for controlling pool operation and pool features. In the absence of updated standards, it may be reasonable to assume that variable-speed motors and pumps may nonetheless slowly increase in market penetration. However, this market movement may also be in response to the existing Title 20 requirements for dual-speed or multi-speed pumps. Ensuring consistent high efficiency for single-speed, dual-speed and variable-speed pumps even in low-speed operation is the intent of the proposed standards described in this report.

6 Savings Potential

6.1 Statewide California Energy Savings

Table 6.1 and Table 6.2 show statewide energy consumption associated with pool pumps in a non-standards scenario and an adopted standards scenario, respectively. Statewide energy consumption for first-year sales is calculated through multiplying annual new and replacement sales numbers, shown in Table 5.2, by the standards and non-standards average unit energy consumptions, as shown in Section 4. Peak demand values are calculated using the same methodology as described above for energy consumption, with the addition of incorporating an assumed peak load factor of 60 percent (Brown & Koomey 2002, 849). Peak demand and energy consumption values are based on an expansion of the results for first-year sales using an estimated product lifetime of 10 years. Energy savings associated with the adoption of the proposed standard, presented in Table 6.3, are the difference between values presented in Table 6.1 and Table 6.2, which assumes a market shift from the non-standards scenario to standards scenario starting in the implementation year.

Table 6.1 California Statewide Non-Standards Case Energy Use – After Effective Date (2015)

	First-Year Sales		**After Entire Stock Turnover**	
Product Class	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)
Variable-speed	32	170	320	1,700
Two-Speed	12	61	120	600
Single-Speed	71	380	710	3,700
Total	**120**	**600**	**1,200**	**6,000**

Table 6.2 California Statewide Standards Case Energy Use - After Effective Date (2015)

	For First-Year Sales		**After Entire Stock Turnover**	
Product Class	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)	Coincident Peak Demand (MW)	Annual Energy Consumption (GWh/yr)
Variable-speed	32	170	320	1,700
Two-Speed	10	50	100	540
Single-Speed	61	320	610	3,200
Total	**100**	**540**	**1,000**	**5,400**

Table 6.3 California Statewide Energy Savings for Standards Case – After Effective Date (2015)

	For First-Year Sales		After Entire Stock Turnover [a]	
Product Class	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)
Variable-speed	0.5	3	5	30
Two-Speed	1	7	14	80
Single-Speed	10	52	100	530
Total	**12**	**63**	**120**	**630**

[a] Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by Koomey and Brown (2002).

6.2 State or Local Government Costs and Savings

There are no known additional costs to state or local governments from the implementation of the standards proposal, given the CEC's existing authority for establishing appliance standards and staffing to administer the process. Energy savings are expected for local and state governments from the purchase of more efficient products as a result of the proposed standard, with the savings amount dependent on the volume of products purchased.

7 Economic Analysis

7.1 Incremental Cost

Pool pump and motor price vary by pump and motor size, efficiency, speed capabilities, frame size, installation type (above-ground vs. below-ground), among other features. An analysis of a selection of pool pump and motor prices from online retailers (n=141),[1] cross-checked against CEC and APSP reported efficiency data, found that pump and motor price correlated most strongly with pump size (R^2=0.67). Pump and motor full-load efficiency correlated with pump size (R^2=0.63) but only weakly with price (R^2=0.47). In general, correlations involving efficiency were weaker for replacement pump motors than for new pump and motor combinations.

Based on this analysis, we estimated incremental cost of efficiency improvements to new pumps and replacement motors. Table 2.2 displays these estimated incremental costs in terms of price per percent efficiency improvement and rated power ($ / %-hp).

This data should be evaluated with the understanding that there appears to be a stronger correlation between motor efficiency and size, and motor size and price, than motor price and efficiency (i.e., efficiency is not the primary driver of price).

Furthermore, this analysis does not account for the fact that most pool equipment are likely purchased by contractors and installers at a discount, nor does it account for possible variations in installation (which we expect to be minor).

Table 7.1 Estimated Incremental Costs for Pool Pumps and Motors ($/%-hp)

Incremental Cost per Full-Rated Efficiency New Integral Pump and Motor Combinations			
	($/%-hp)		
Rated Motor Size	Variable Speed	Dual Speed	Single Speed
0.5	-	$-	$6.90
0.75	-	$-	$5.60
1.0	$10.00	$ 5.80	$5.20
1.5	$4.40	$4.00	$3.80
2.0	-	$3.90	$3.30
2.5	-	$4.00	$3.70
3.0	$3.00	$3.40	$3.00

[1] www.lesliespool.com, www.poolsupplyworld.com, www.poolcenter.com

Incremental Cost per Full-Rated Efficiency Replacement Pump Motors			
	($/%-hp)		
Rated Motor Size	Variable Speed	Dual Speed	Single Speed
0.5	-	-	$ 2.70
0.75	-	$ 3.80	$ 3.50
1.0	-	$ 3.20	$2.80
1.5	-	$ 2.30	$2.10
2.0	-	$ 2.40	$1.80
2.5	-	-	$2.00
3.0	$ 4.30	$ 1.80	$1.70

7.2 Design Life

Table 7.2 displays estimated design life for each pool or spa component. See Section 2.1 of this report for references.

Table 7.2 Estimated Design Life

Component	Life (years)
Pool Pumps	10
Pool Pump Motors	10
Pool Pump Controllers	N/A
Pool Lighting	N/A
Portable Electric Spas	10

7.3 Life Cycle Costs and Benefits

Table 7.3 and Table 7.4 show lifecycle costs and benefits of the proposed standards for pool pumps and motors. Net present value is determined by subtracting costs from savings. Statewide net present value is determined by multiplying weighted per-unit net present value against projected sales.

Table 7.3 Costs and Benefits per Unit for Qualifying Products

Product Class	Design Life (years)	Lifecycle Costs per Unit (Present Value $) Incremental Cost	Add'l Costs[a]	**Total PV Costs**	Lifecycle Benefits per Unit (Present Value $) Energy Savings[b]	Add'l Benefits[c]	**Total PV Benefits**
Variable-speed	10	$73	$ -	**$73**	$564	$ -	**$564**
Two-Speed	10	$56	$ -	**$56**	$474	$ -	**$474**
Single-Speed	10	$51	$ -	**$51**	$630	$ -	**$630**

PV = Present Value

[a] No additional costs (e.g. maintenance) assumed.

[b] Calculated using the CEC's average statewide present value statewide energy rates that assume a 3% discount rate (CEC 2012b).

[c] No additional benefits assumed.

Table 7.4 Lifecycle Costs and Benefits for Standards Options

Product Class	**Lifecycle Benefit / Cost Ratio [a]**	**Net Present Value [bd]** Per Unit ($)	First Year Sales (Million $)	Stock Turnover (Million $) [c]
Variable-speed	8	$491	$4.2	$45
Two-Speed	8	$418	$11.5	$121
Single-Speed	12	$579	$84	$884
Total			**$100**	**$1,050**

[a] Total present value benefits divided by total present value costs.

[b] Positive value indicates a reduced total cost of ownership over the life of the appliance.

[c] Stock Turnover NPV is calculated by taking the sum of the NPVs for the products purchased each year following the standard's effective date through the stock turnover year, i.e., the NPV of "turning over" the whole stock of less efficient products that were in use at the effective date to more efficient products, plus any additional non-replacement units due to market growth, if applicable. For example, for a standard effective in 2015 applying to a product with a 5 year design life, the NPV of the products purchased in the 5th year (2019) includes lifecycle cost and benefits through 2024, and therefore, so does the Stock Turnover NPV.

[d] For price of electricity, average annual rates were used, starting in the effective year (see Appendix B: for more details). It should be noted that while the proposed standard is cost-effective, it may be more cost-effective if using alternative rate structures. For example, marginal utility rates may more accurately reflect what customers save on utility bills as result of the standard.

8 Acceptance Issues

8.1 Infrastructure issues

Our analysis was performed using pool pumps and motors listed in the APSP and CEC databases. Since there are many products available on the market that already meet the proposed standard, the proposed standards should not affect pump installation or performance while installed.

Both PG&E and SCE currently offer rebate programs for variable-speed pool pumps with controllers. We do not anticipate that these will be directly affected, since the proposed motor efficiency standards do not uniquely apply to variable-speed pumps.

Compliance with the existing 2008 standards for pool pumps and motors is estimated at 94 percent, plus or minus 4 percent, based on 2009 evaluations by the California Public Utilities Commission's (KEMA et al 2010, 139), though many pool professionals assume the compliance number to be much lower. The scope of this proposal will surely increase compliance, as all pool pump motors, OEM or replacement, residential or commercial, for filtration or other use will be covered.

8.2 Federal Preemption Concerns

It is the belief of the CASE Team that there are no federal DOE preemption issues in the CEC setting efficiency standards for single-phase dedicated purpose pool pump motors. This determination is based on conversations with two of the largest motor manufacturers as well as significant investigation into DOE product definitions and scope.

As of July 2013, DOE has two regulations that affect electric motors. One set of standards is for larger, general purpose, 3 phase motors and the other is for small electric motors, including single phase motors. Given that the large motor regulation applies only to 3 phase motors and that all pool pump motors are served by single phase power, these DOE regulations do not conflict with the proposed standards. Regarding small motor standards, DOE regulations do not include definite/special purpose motors, such as pool pump motors. Furthermore, DOE regulations apply to single speed induction motors, thereby excluding dual, multi and variable speed motors.

Additionally, in regards to the electric motors test procedure rulemaking that DOE is currently undergoing (as of July 2013), there are three elements of the test procedure scope that exempt the motors covered in this proposal (single phase, less than 5 THP) from the scope of DOE's test procedure:

- The test procedure scope is limited to "induction" motors
- The test procedure scope is limited to "polyphase" motors
- DOE has tentatively decided not to consider adding test procedures for "definite-purpose inverter-fed electric motor(s)." While most variable speed pool pump motor designs use permanent magnet motors, a small number may use conventional single speed, 3 phase induction designs. While these could run directly from the utility grid, in this application they are primarily intended and exclusively sold with inverter-feed, thus providing the variable frequency and variable speed capability.

While we believe that though DOE has the authority to set standards for small definite purpose motors such as pool pump motors, they have not chosen to do so at this time.

8.3 Existing Standards

ANSI/APSP/ICC-15 2011: American National Standard for Residential Swimming Pool and Spa Energy Efficiency: This voluntary standard provides recommended minimum guidelines for the energy efficiency of permanently installed above-ground and in-ground swimming pools and in-ground spas. Acceptance issues are not anticipated because this report proposes language changes to better align with APSP 15.

ANSI/APSP/ICC-14 2011: American National Standard for Portable Electric Spa Energy Efficiency: This voluntary standard provides recommended minimum guidelines for the energy efficiency of above-ground portable electric spas. Acceptance issues are not anticipated.

California's Building Energy Efficiency Standards: Title 24, Part 6, Section 114 of the California Code of Regulations (California's Building Energy Efficiency Standards) contains mandatory requirements for pool and spa systems and equipment. It contains certification requirements for pool heaters and equipment, which reference the Title 20 Appliance Efficiency Regulations regarding efficiency, on-off switches, and instructions. Title 24 also bans electric resistance heating for pool heaters with exceptions. Finally, Title 24 contains system-wide installation requirements for outdoor covers, piping for future addition of solar heating equipment, and directional inlets and time switches.

It will be necessary to update Title 24 to reflect any relevant changes in Title 20. However, no changes are being proposed in this report that would be relevant to Title 24. Therefore, no acceptance issues are anticipated.

8.4 Stakeholder Positions

The Association of Pool and Spa Professionals is a key stakeholder. APSP 15, a voluntary national standard for pool and spa efficiency, overlaps significantly with California's Title 20 regulations. However, it is important to bring Title 20 into better alignment with the new APSP 15 to improve compliance and acceptance. The CASE Team has already been working jointly with the APSP and its members (pool equipment manufacturers) to refine these new code proposals and ensure that they are feasible and reasonable.

The CASE Team also expects significant feedback from the Independent Pool and Spa Service Association (IPSSA), which represents the pool service industry. The nature of the proposed pump motor regulations should not significantly impact installation and maintenance of pool pumps. However, they may make some pool pumps and motors incrementally more expensive, which may impact contractors' bottom lines.

During the 2005 Title 20 rulemaking proposing the current pool and spa regulations, the California Spa & Pool Industry Education Council (SPEC), a California pool and spa advocacy organization, submitted comments to the CEC expressing concern about the impact of the proposed regulations on pool and spa safety and cost impact. The CASE Team plans to reach out to SPEC to ensure that these new proposed regulations address key concerns.

9 Portable Electric Spas

9.1 Product Description

Portable electric spas are aboveground, self-contained, factory-built spas or hot tubs, with equipment to heat and circulate water. The term "portable" refers to the fact that these units are above-ground, not permanently installed. Portable electric spas are typically a few hundred (200-400) gallons in volume (DEG & ES, 2004b, 1). New portable electric spas have an average life of 10 years including the motor and controls and five years for the spa cover (DEG & ES, 2004b, 13).

Like a pool, a portable electric spa uses one or more water pumps to circulate water for circulation, filtration, heating and jet action. While water is flowing across the heater, electric resistance heating elements are energized to provide heat to meet the thermostat set point.

9.2 Current Market Situation

According to the RASS (2009), 10 percent of California residences own a spa or hot tub (portable and non-portable); 92 percent of these (approximately 1.0 million spas) are at single-family homes. Of these, about 50 percent are heated by natural gas and 45 percent are heated by electricity, with the remainder heated by a combination of solar power, natural gas, bottled gas, or electricity. About 46 percent (0.46 million units) are outdoor above-ground, 47 percent are outdoor in-ground, and the remainder are indoor (KEMA 2010). The market reality is that almost all above ground spas are portable electric spas, with a simple plug for a 120 or 240-V AC socket. It should be noted that the recommendations within this CASE Report apply only to portable electric spas.

9.3 Existing Test Methods and Standards

Portable electric spas are tested according to section 1604 (g) and regulated under section 1605.3 (g) of the current Title 20 standards, with normalized standby power (Watts) and other basic information reported to the CEC. The standard states:

> "The normalized standby power, as defined in Section 1604(g)(2)(I), of portable electric spas manufactured on or after January 1, 2006, shall be not greater than $5(V^{2/3})$ watts where V = the fill volume, in gallons." (CEC 2012)

APSP has also adopted this as their voluntary spa standards set forth in APSP-14-2011.

9.4 Labeling Opportunity

Since the 2006 spa standard was established, all portable electric spas that have reported into the CEC database have met the standard, with many far exceeding the standard (as is represented by the red line in Figure 9.1 below). There are numerous spas with the same volume, but some use half of the normalized standby power as other spas as can be seen in Figure 9.1.

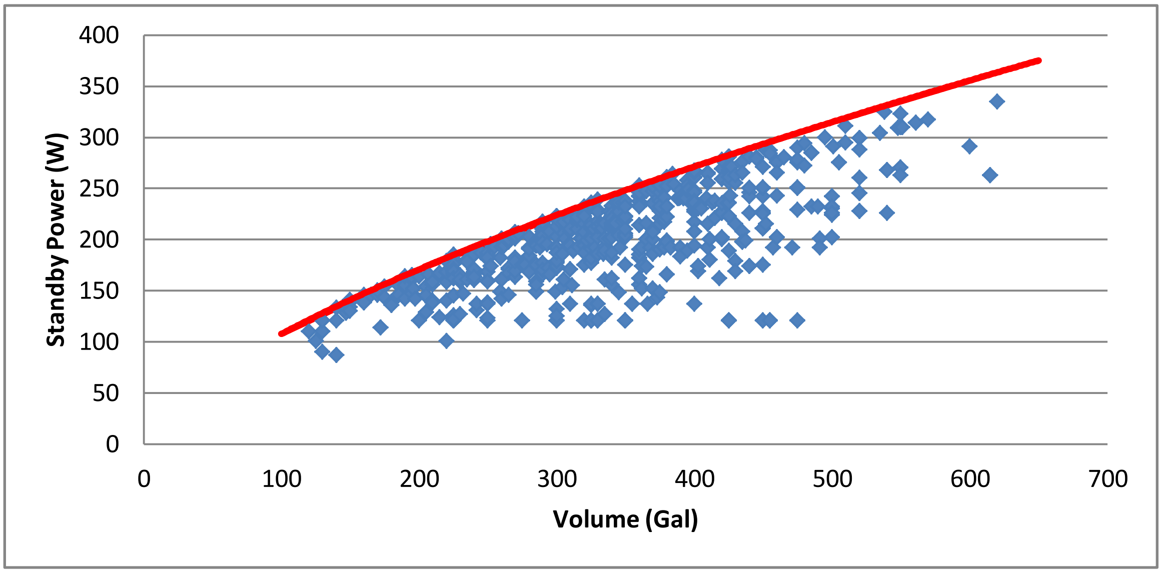


Figure 9.1 Current Portable Electric Spa Standby Energy Use and 2006 Standard (Red)

Source: CEC2012a

9.4.1 Improved Compliance

While all reported portable electric spas in the CEC Appliance Database currently meet the CEC standard, it is unknown whether some spas are being sold in California that are not listed on the CEC database as there is no marking or label to confirm compliance. A visible label on the spa shell would inform spa dealers, consumers, and the CEC as to whether spas were compliant and permitted for sale in California.

9.4.2 Better Informed Consumers

Currently, purchasers of portable electric spas have no way of understanding the energy consumption of different spas on a showroom floor. While some manufacturers do report their energy efficiency and other "green" features, there is no consistency as to how this information is displayed and whether it is accurate.

Energy labeling programs such as "ENERGY STAR®" and "Energy Guide" have proven to be successful at providing consumers simple information which can lead to more energy efficiency purchasing decisions. In addition, categorical based labels, such as those used in the European Union (EU), have helped shift the market significantly with respect to efficiency. An evaluation of the EU labeling scheme demonstrated a 10 percent improvement in the sales-weighted average efficiency of refrigerators between 1994 and 1999 due to the label (Bertoldi, 2000, 9). The "Categorical" type label and respective market shift as a result can be seen below in Figure 9.2.

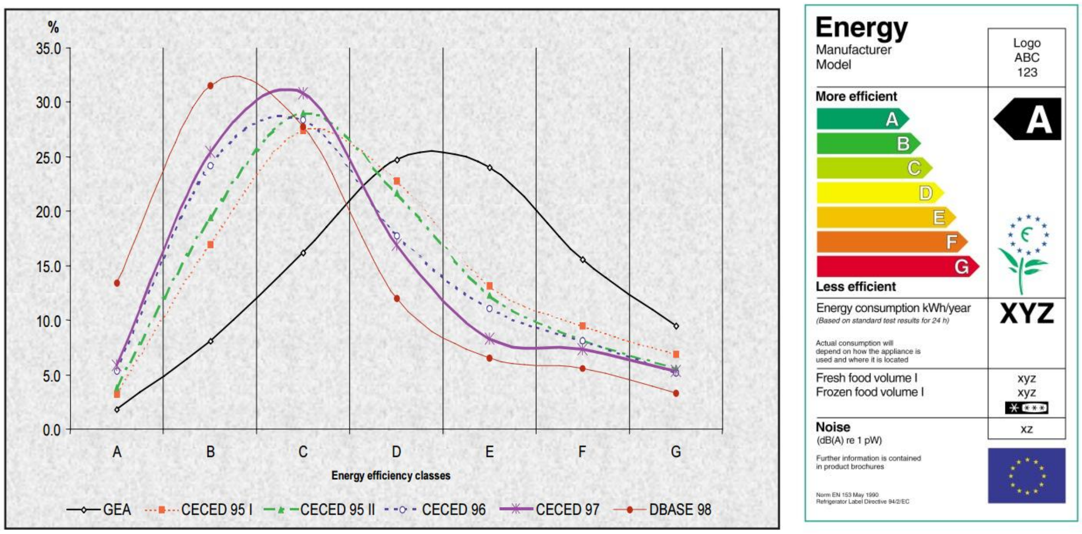


Figure 9.2 EU Energy Label and Market Shift in Consumer Purchasing

Source: Bertoldi 2000, 9

9.4.3 Types of Labels

There are many types of labels used by various agencies and other countries to display information to consumers about the energy impacts of products. Two of the most effective types of labels are continuous and categorical.

Continuous Labels

Continuous labels use bar or line graphs to show the range of models available on the market. The scale allows consumers to see where the labeled unit fits into the full range of similar models without sorting performance into specific categories (see the Energy Guide Label in Figure 9.3 below).

Categorical Labels

Categorical labels use 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 (see Figure 9.3).

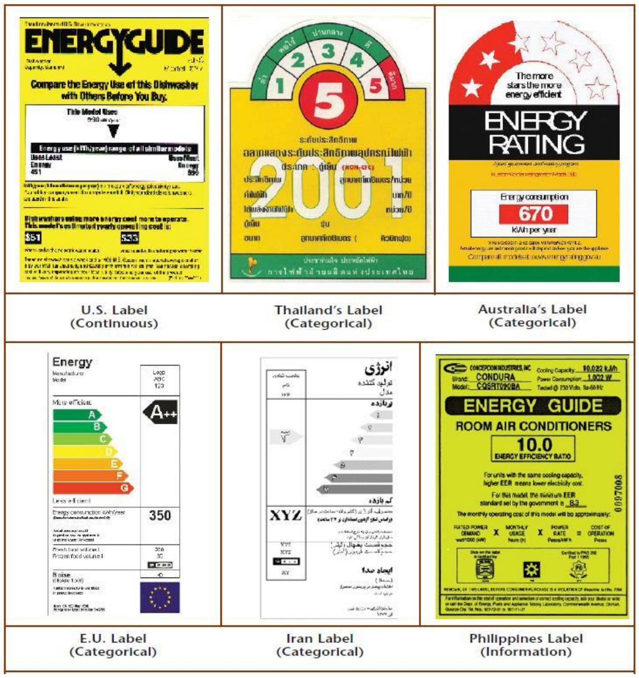


Figure 9.3 Various Label Designs from Other Countries

Source: CLASP 2013

Given the large range of spa efficiencies and the effectiveness of energy labels in helping consumers choose more efficient products, the CASE Team believes that portable electric spas are well suited for a consumer facing energy label.

9.4.4 Proposed Label Designs

The CASE team has developed two proposed label designs for portable electric spas sold in California. The first label (shown in Figure 9.4 Proposed Continuous Spa Label) is a continuous label showing the relative energy efficiency performance compared to California's 2006 Title 20 standards. The second label (shown in Figure 9.5) is a categorical label, again showing the relative energy efficiency performance but bucketed into stars.

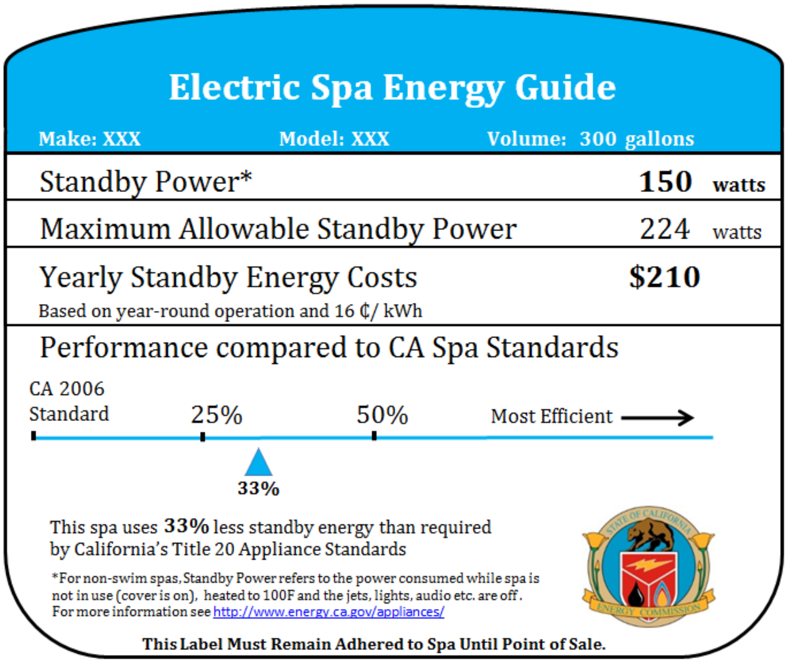


Figure 9.4 Proposed Continuous Spa Label

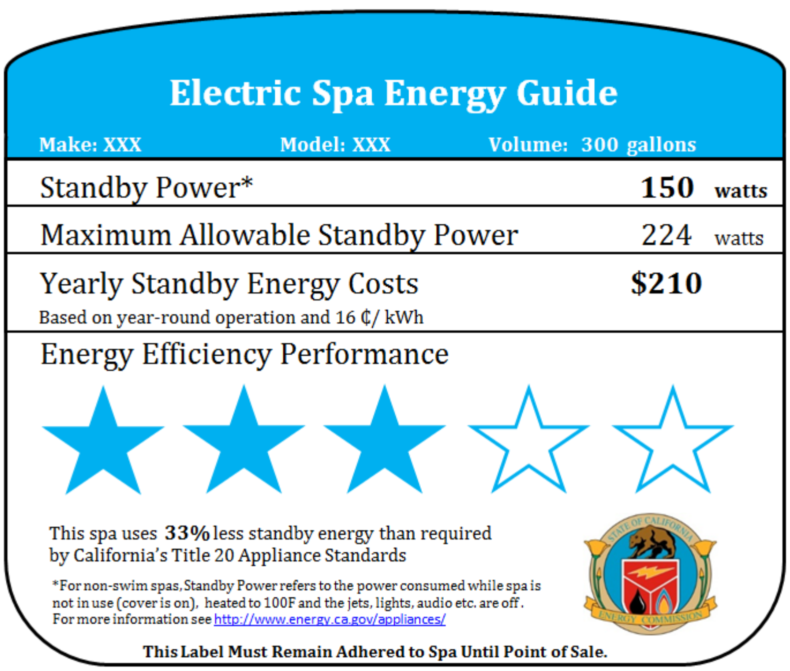


Figure 9.5 Proposed Categorical Spa label Using Star Rating System

Though each label has its advantages, the CASE Team prefers the categorical based label, as we believe it is easier to quickly interpret the relative energy performance, particularly if placed on a large product like a portable electric spa. In this categorical label design, each star represents 12.5

percent of improvement over current Title 20 standards. Because the Title 20 spa standards calculate maximum allowable standby energy as a function of volume, by calculating the "percentage better than Title 20," the data can be normalized regardless of the size of the spa. This is illustrated in Figure 9.6 below. For example, if a spa is 33 percent more efficient than is required by Title 20 standards, it would fall in the 25 percent to 37.5 percent bucket, earning a rating of three stars.

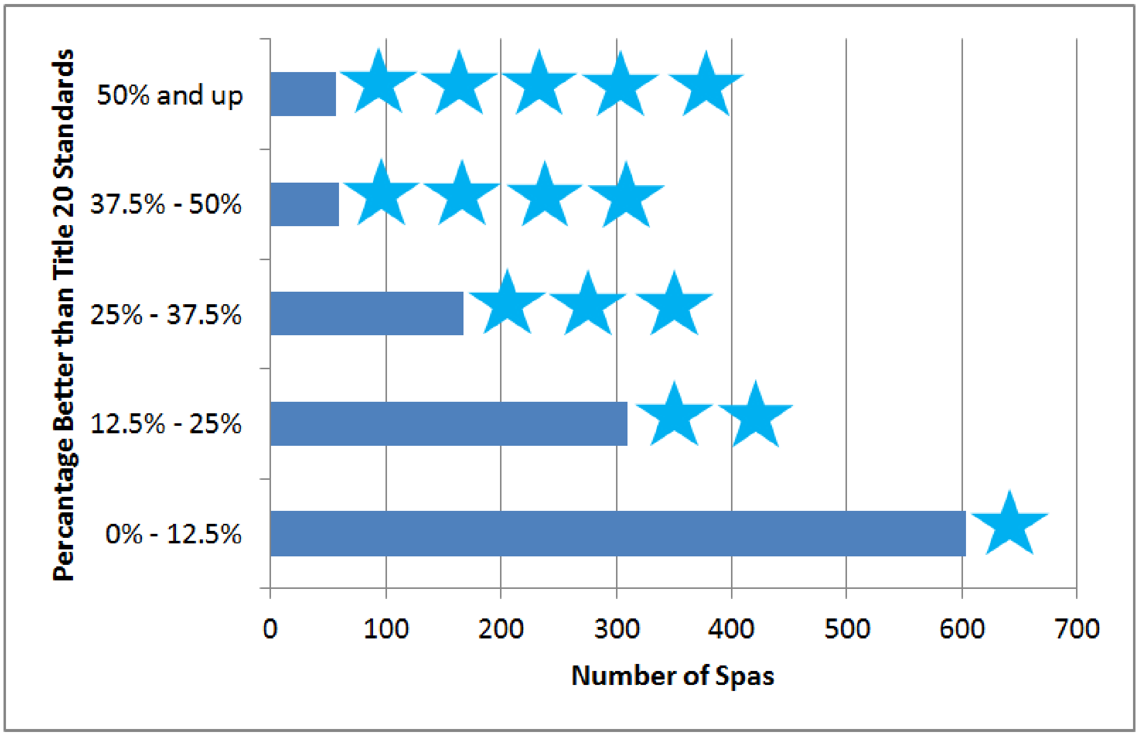


Figure 9.6 Proposed "Star" Breakdown for Categorical Label with CEC Spa Data

Source: CEC2012a

9.5 Energy Usage

The energy consumption for portable electric spas varies depending on usage, whereas the standby power consumption of a spa is more of a function of design, spa cover, circulation pump, controls, and insulation.

Table 9.1 Unit Energy Consumption for Portable Electric Spas

Product Class	**Power Draw (W)**	**Annual Low Speed Operating Hours**	**Unit Energy Consumption (kWh/yr)**
Average Spa Standby Power[A]	200	8,760	1,800
"1 Star Up" Average Standby Power[B]	180	8,760	1600

[A] Average of all standby power of spas in CEC database. (CEC 2012a)
[B] "1 Star Up" assumes an improvement of roughly 12.5%, or 1 Star in the proposed labeling scheme.

As can be seen in Table 9.1 above, the average annual standby energy consumption for spas in the CEC database, assuming year round operation, is 1,800 kWh, which is very close to PG&E's 2004 Field Test of Spas of 1,879 kWh/ year (DEG & ES, 2004b, 9). This value also corresponds with the UEC of 2,500 kWh/year used in the 2004 Portable Electric Spa CASE Report for all spa energy use including standby and active energy consumption (DEG & ES, 2004b, 9).

The average annual standby energy consumption of the "1 Star Up" product class assumes an improvement of roughly 12.5 percent over the average spa standby energy. This is explained further in Section 9.7.

9.6 Cost of Labeling

The cost of labeling portable electric spas with a removable sticker type label on the shell of the spa is estimated to be minimal compared to even the most modest savings estimates. The CASE Team conservatively estimates the per label cost to be $0.40 per label, when labeling the entire stock of 460,000 portable electric spas in CA over the course of 10 years. These costs are further detailed below in Table 9.2.

Table 9.2 Spa Labeling Costs

One Time Set-Up Costs		
Engineer/ Designer Time	40	Hours
Engineer/ Desiger Hourly Wage	$44.36	Dollars
Set-Up Cost to each Manufacturer	$1,774	Dollars
Number of Spa Manufacturers	40	Manufacturers
Total Set-Up Cost Statewide	*$70,976*	*Dollars*
Material Cost		
Printing Costs	$0.22	Per Label
Total printing costs to label stock	*$101,200*	*Dollars*
Labor Costs to Apply Label		
Time to adhere each Label	8	Seconds
Total time to adhere Labels to Entire Stock	1,022	Hours
Packaging and Filling Machine Operators Hourly Wage	$13.44	Dollars
Total Labor Costs	*$13,739*	*Dollars*
Total		
Total Cost to Label Stock	**$185,915**	Dollars
Label Cost per unit	***$0.40***	*Dollars/ Label*

Source: FTC 2013, UPRINT 2013

To reduce manufacturer burden in spa labeling, the CASE Team has developed an easy to use Microsoft Excel-based tool to create the proposed label in which only the make, model, volume and standby watts need to be entered in (see Table 9.3 below). This tool will then generate a label as shown in Figure 9.4 and Figure 9.5 which can be printed and adhered to the spa.

Table 9.3 Manufacturer Input Fields to Generate Spa Labels with Tool

Manufacturers Modify Yellow Cells	
Make	XXX
Model	XXX
Volume	265
Standby Watts	176

9.7 Economic Analysis & Savings Potential

The CASE Team believes that using a categorical "Star" label on portable electric spas in California will improve compliance, enable better consumer purchasing, and lead to cost-effective energy savings. To determine the potential energy savings from this label, the CASE Team made a conservative assumption that 5 percent of annual spa purchasers would buy a spa "1 Star Up" or 12.5 percent more efficient than in cases where no label exists. The following conservative energy and cost savings are calculated based on this assumption (see Table 9.4).

Table 9.4 Estimated California Statewide Energy Savings and Peak Demand Reduction of Spa Labeling

	For First-Year Sales		**After Entire Stock Turnover**[a]	
Product Class	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)	Coincident Peak Demand Reduction (MW)	Annual Energy Savings (GWh/yr)
Portable Electric Spa Labels	0.1	.51	1	5.1

[a]Statewide demand (and demand reduction) is quantified as coincident peak load (and coincident peak load reduction), the simultaneous peak load for all end users, as defined by (Koomey and Brown 2002).

Table 9.5 Net Present Value of Spa Labeling

	Net Present Value	
Product Class	First Year Sales ($ million)	After Stock Turnover ($ million)
Portable Electric Spa Labels	0.8	8.1

10 Environmental Impacts

10.1 Hazardous Materials

There are no known incremental hazardous materials impacts from the efficiency improvements as a result of the proposed standards for pools and spas.

10.2 Air Quality

This proposed measure is estimated to reduce total criteria pollutant emissions in California by 110,000 lbs/year in 2024, after stock turnover, as shown in Table 10.1 due to 635 GWh in reduced end user electricity consumption with an estimated value of $5,200,000. Criteria pollutant emission factors for California electricity generation were calculated per MWh based on California Air Resources Board data of emission rates by power plant type and expected generation mix [CARB 2010]. The monetization of these criteria pollutant emission reductions is based on CARB power plant air pollution emission rate data times the dollar per ton value of these reductions based on Carl Moyer values where available, and San Joaquin Valley UAPCD "BACT" thresholds for sulfur oxides (SOx). These dollar per ton values vary significantly for fine particulates, as discussed in Appendix C: (CARB 2011a, CARB 2013a and San Joaquin Valley UAPCD).

Table 10.1 Estimated California Criteria Pollutant Reduction Benefits (lbs/year) After Stock Turnover

	lbs/year	Carl Moyer $/ton (2013)	Monetization
ROG	17,000	$ 17,460	$ 150,000
Nox	60,000	$ 17,460	$ 520,000
Sox	6,300	$ 18,300	$ 57,000
PM2.5	26,000	$ 349,200	$ 4,500,000
Total	**110,000**		**$5,200,000**

10.3 Greenhouse Gases

Table 10.2 shows the annual and stock GHG savings by year and the range of the societal benefits as a result of the pool pump motor standards and the spa labeling scheme. By stock turnover in 2024, this standard would save 280,000 metric tons of CO2e, equal to between $16,000,000 and $48,000,000 of societal benefits. The total avoided CO2e is based on CARB's estimate of 437 MT CO2e/GWh of energy savings from energy efficiency improvements, and includes additional electrical transmission and distribution loses estimated at 7.8% (CARB 2008). The range of societal benefits per year is based on a range of annual $ per metric ton of CO2 (in 2013 dollars) sourced from the U.S. Government's Interagency Working Group on Social Cost of Carbon (SCC) (Interagency Working Group 2013). The low end uses the average SCC, while the high end incorporates SCC values which use climate sensitivity values in the 95th percentile, both with 3% discount rate. It is important to note that this range can be lower and higher, depending on the approach used, so policy judgments should consider this uncertainty. See Appendix D: for more details regarding this and other approaches.

Table 10.2 Estimated California Statewide Greenhouse Gas Savings and Cost Savings for Standards Case

Year	Annual GHG Savings (MT of CO2e/yr)	Stock GHG Savings (MT of CO2e/yr)	Value of Stock GHG Savings - low ($ in millions)	Value of Stock GHG Savings - high ($ in millions)
2015	28,000	28,00	$1.3	$3.7
2016	28,000	55,000	$2.7	$7.7
2017	28,000	83,000	$4.1	$12
2018	28,000	111,000	$5.6	$16
2019	28,000	140,000	$7.1	$21
2020	28,000	170,000	$8.7	$26
2021	28,000	190,000	$10	$31
2022	28,000	220,000	$12	$37
2023	28,000	250,000	$14	$42
2024	28,000	280,000	$16	$48

11 Recommendations

11.1 Recommended Standards Proposal

11.1.1 Performance Standard for New and Replacement Pump Motors

When the original prescriptive motor design standards were proposed and adopted, manufacturers expressed a preference for minimum energy efficiency performance specifications, which would allow more flexibility in achieving the efficiency goals. Unfortunately, pool pump motor performance specifications on which to base recommended performance levels were not available at the time. Now, new pump efficiency data is reported to the CEC and APSP and replacement motor data is reported to APSP.

We recommend that the prescriptive design requirement be changed to an energy efficiency performance specification, with the following proposed minimum levels:

- Single-speed pump motors: 70 percent full-load efficiency;
- Dual-speed pump motors: 70 percent full-load efficiency and 55 percent efficiency at half or "low" speed;
- Variable-speed and multi-speed pump motors: 80 percent full-load efficiency and 70 percent efficiency at half or "low" speed.

These levels were chosen to provide meaningful savings while maintaining ample product availability.

We also recommend that the proposed motor efficiency standards apply to all pool pump motors, including non-filtration pump motors and pump motors used in commercial applications. There is no integral distinction in design between single phase pool pumps and motors under 5 HP between residential and commercial pools or those used for filtration and those used for other purposes. The key distinctions are in size and operating characteristics (e.g., hours, flow, head, and speed). Since this distinction does not currently exist in Title 20, this presents a potential loophole in the standards for pool pump motors sold in California, unless the standards explicitly apply to all pool pump motors. More importantly, improving motor efficiency is cost effective across all markets and applications.

Lastly, the CASE Team believes the current IEEE test procedure used to measure motor efficiency does not best reflect variable speed motor efficiency. Therefore, the CASE team is working to develop recommendations to this test procedure to better account for variable speed motors and will be reaching out to CEC with suggestions in the following months.

11.1.2 Align Title 20 with APSP 15

While the form of APSP 15 is not the same as Title 20, it is desirable to make these two standards as compatible as possible. We propose specific language revisions to make Title 20 more compatible with APSP 15.

11.1.3 Changes to Test and List Pump Performance

We recommend changes to the way pump performance is tested, reported, and listed so as to allow better comparisons between products at typical operating conditions on CEC System Curves A, B, and C. These will also better align Title 20 with APSP 15.

11.1.4 Improve Pump Label

We propose clarifications to the current pool pump and motor labeling requirements to ensure better compliance.

11.1.5 Performance Standard for Residential Filtration Pumps >1THP

Change prescriptive pump requirements for residential filtration pumps over 1 THP from being dual, multi or variable speed to having an Energy Factor of 3.8 or greater on CEC Curve A.

11.1.6 Ensure Measured Pump Capacity is not Greater than Reported Pump Capacity

Ensure that the measured capacity of OEM pool pump motors is not greater than the reported HP, SF and motor capacity (THP) values.

11.1.7 Reporting of Motor Efficiency

We propose clarifying requirements regarding the reporting of tested pool pump and motor efficiency. We also propose separating the reporting requirements for pumps from those for replacement motors, due to their different characteristics.

We request that the CEC include reported replacement pump motor data in the online appliance database.

11.1.8 Changes to Pool Pump Controller Language

Pool pump controllers are subject to a design regulation specifying the capability to operate pumps on at least two speeds and return to the normal filtration speed within no more than one normal period (24 hours) when set to high speed for cleaning or maintenance. With the advent of variable-speed drives and controllers, the present language no longer clearly conveys the intent of the existing standards. Also, variable-speed pump controllers often come with factory preset speeds and times.

We recommend that existing standards be reworded and clarified with respect to variable-speed pump operation. We further recommend that power consumption data be reported and listed for pool pump controllers. This includes reporting the power that a controller uses while the motor is in standby mode as well as the power factor of the controller.

11.1.9 LED Pool Lights

Since the adoption of the original pool pump standards, high performance LED pool underwater lights have become available. While there are test procedures for LED lamps, manufacturers are not currently required to specify the performance of LED lamps for new integral and replacement pool lights.

Testing, reporting, and listing of the performance of these lamps will facilitate adoption and consumer awareness of this high performing technology. We recommend parameters to be included for testing and listing. Listing these parameters in the CEC's Appliance Database will also help utility programs that might wish to encourage this efficient technology.

At the time of submittal of this report, the specific IES test procedures are yet to be cited, but the CASE Team will be following up with specific recommendations.

11.1.10 Labeling for Portable Electric Spas

Portable electric spas are currently regulated by Title 20, including testing, reporting, listing, and minimum standby power standards. We recommend that portable electric spas be required to carry a label which is visible to consumers shopping for portable electric spas on showroom floors. It will inform consumers of the standby power consumption, maximum allowable standby power consumption, estimated standby cost/ year and its relative energy performance as compared to what's required by California current standby power standards for portable electric spas. This label would be applied as a sticker on the spa shell so as to be visible to the consumer and would be required to remain adhered to the spa until it is sold. See Section 9.4.4 for proposed label designs.

11.2 Proposed Changes to the Title 20 Code Language

Proposed additions to the code language are <u>underlined</u>, and deletions are ~~struck out~~. Ellipses (…) are used to indicate spaces or "skips" between code language.

1601(g) Section 1601. Scope.

Gas pool heaters, oil pool heaters, electric resistance pool heaters, heat pump pool heaters, residential pool <u>filtration</u> pump and motor combinations, <u>pool pump motors</u>, <u>replacement pool pump motors,</u> ~~and~~ portable electric spas<u>, pool pump controls, and LED pool lights</u>.

1602(g) Section 1602. Definitions. Pool Heaters, Portable Electric Spas, Residential Pool Pump and Motor Combinations, ~~Replacement Residential~~ Pool Pump Motors, <u>Pool Pump Controls, and LED Pool Lights.</u>

…

<u>"Pool pump control" means a mechanical, electrical, or electronic device, which may be integral to the pump or remotely located, that enables pump operation at one or more speeds and at selectable times during the day.</u>

<u>"LED pool light" means an integral underwater lighting fixture using LEDs (light emitting diodes); or, a replacement lamp or lamp assembly including a driver, using LEDs.</u>

<u>"Pool pump motor" means a single-phase motor with a Total Horse Power rating of</u> ~~greater 0.5 HP and~~ <u>less than</u> ~~or equal to 4~~<u>5.0 HP that is used as a replacement pool pump motor or as part of any pool pump and motor combination.</u>

"Replacement residential pool pump motor" means a replacement <u>single-phase</u> motor <u>with a Total Horse Power rating of</u> ~~greater 0.5 HP and less than or equal to 4~~<u>less than 5.0 HP</u> 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<u>, operate cleaning equipment, or operate other pool features in residential pools.</u>

"Replacement pool pump motor" means a dedicated purpose pool pump replacement single-phase motor with a Total Horse Power rating ~~of greater 0.5 HP and~~ less than ~~or equal to 4~~5.0 HP intended to be coupled to an existing pool pump that is used to circulate and filter pool water in order to maintain clarity and sanitation, operate cleaning equipment, or operate other pool and spa features.

"Residential pool pump" means an impeller attached to a motor that is used to circulate and filter pool water in order to maintain clarity and sanitation, operate cleaning equipment, or operate other pool features in residential pools.

"Residential pool pump and motor combination" means a residential pool pump motor coupled to a residential pool pump and sold as an integral unit..

"Residential pool pump motor" means a single-phase motor with a Total Horse Power rating of less than 5.0 HP that is used as a replacement residential pool pump motor or as part of a residential pool pump and motor combination.

…

"Single Phase Motor" means a motor supplied by single phase power or a motor supplied with an integral drive served by single phase power.

…

1604 (g) Section 1604. Test Methods for Specific Appliances. Pool Heaters, Portable Electric Spas, Residential Pool Pump and Motor Combinations, ~~and Replacement Residential~~ Pool Pump Motors, Pool Pump Controls, and LED Pool Lights.

…

(3) Test Method for ~~Residentia~~l Pool Pump and Motors

The test method for ~~residential~~ pool pumps and motors is as follows:

(A) Reported motor efficiency shall be verifiable by test method IEEE 114-~~2001~~ 2010 ~~(corrected).~~

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

(C) Tests shall be conducted using unmodified, manufactured, and fully assembled pump, including strainer basket when applicable.

(D) Three system curves shall be calculated:

Curve A: $H = 0.0167 \times F^2$

Curve B: $H = 0.050 \times F^2$

Curve C: $H = 0.0082 \times F^2$

Where:

H is the total system head in feet of water.

F is the flow rate in gallons per minute (gpm).

(E) For each curve (A, B, ~~or~~ and 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 (RPM)

2. Motor efficiency (percent %)

~~2~~3. Flow (gallons per minute)

~~3~~4. Power and apparent power (watts and volt amps)

~~4~~5. Energy Factor (gallons per watt hour)

Where the Energy Factor (EF) is calculated as:

EF = Flow (gpm) * 60 / Power (watts)

(i) For single-speed pumps and two- 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. Intersect data shall be reported for each speed and system curve.

(ii) For two-, multi-, or variable-speed pumps, test and report performance at the intersect point of the pump performance curve with each system curve. Intersect data shall be reported for the original factory setting, highest operational, half, lowest operational, and the best efficiency speeds.

(4) Test Method for Pool Pump Controls

The test method for pool pump controllers is as follows:

1. Place the unit in Standby Mode.

2. Wait five minutes to allow the unit to stabilize.

3. Measure and report the energy consumption and power factor over the course of one hour.

4. Report the average energy use into power by dividing by 1 hour.

5. Report the Power Factor.

(5) Test Method for Measured Capacity of OEM Integral Pool Pumps and Motors

The test method for testing the measured versus reported capacity of OEM integral pool pumps and motors is as follows:

1. For each CEC curve (A, B, and C), the pump head shall be adjusted until the flow and head lie on the curve.

2. Test report the performance at the intersection point of the pump curve and each system curve at the highest operational speed.

3. Record the speed and electrical input power.

4. Attach the pump motor to a dynamometer and increase resistive torque until the same speed and power are realized as recorded in Step 3.

5. Measure the torque in Foot-Pounds

6. Convert Foot-Pounds to brake horsepower by dividing by 5252.

7. Record measured capacity (brake horsepower) at tested/highest operational speed.

(6) Test Method for LED Pool Lights

The CASE Team has yet to cite specific test procedure at the time of submittal of this CASE Report.

…

1605.1(g) Section 1605. Energy Performance, Energy Design, Water Performance, and Water Design Standards: In General. Section 1605.1. Federal and State Standards for Federally-Regulated Appliances. Pool Heaters, Portable Electric Spas, Residential Pool Pump and Motor Combinations, ~~and Replacement Residential~~ Pool Pump Motors, Pool Pump Controls, and LED Pool Lights.

…

(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) Section 1605.2 State Standards for Federally-Regulated Appliances. (g) Pool Heaters, Portable Electric Spas, Residential Pool Pump and Motor Combinations, and ~~Replacement Residential~~ Pool Pump Motors.

…

(1) See Sections 1605.1(g) and 1605.3(g) for energy efficiency standards and energy design standards for pool heaters.

(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 State Standards for Non-Federally-Regulated Appliances.

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

…

(5) **Residential Pool Pump and Motor Combinations, and Replacement Residential Pool Pump Motors.**

(A) **Motor Efficiency**. Pool pump motors manufactured on or after ~~January 1, 2006 may not be split-phase or capacitor start – induction run type.~~ [Compliance Date] must have a rated and tested efficiency as follows:

1. Single speed motors must have a rated efficiency of no less than 70%.
2. Two-speed motors must have a rated efficiency of no less than 70% at high speed, and no less than 55% at low speed.
3. Variable speed and multi speed motors must have a rated efficiency of no less than 80% at high speed, and no less than 70% at half speed.

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

1. **Residential Pool Pump and Motor Combinations**. Residential pool pump and motor~~s~~ combinations with a capacity of 1 HP or more which are manufactured on or after January 1, ~~2008~~2015, which are designed for residential pool filtration, shall have an Energy Factor of at least 3.8 on CEC Curve A at its most efficient operating point. ~~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~~. Section 1605.3(g)(5)(B)1. applies to models manufactured ~~prior to~~ after January 1, ~~2010~~ 2015.
2. **Residential Pool Pump Motors**. Residential pool pump motors with a pool pump motor capacity of 1 HP or greater which are manufactured on or after January 1, 2010, which are designed for residential pool filtration, 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 1605.3(g)(5)(B)2 applies to models manufactured on or after January 1, 2010.

3. **Pump Controls.**

   a. Pool pump motor controls manufactured on or after January 1, 2008 that are sold for use with a two- or ~~more~~ multi-speed pump shall have the capability of operating the pool pump at least at two speeds. The control's default circulation speed setting shall be no more than one-half of the motor's maximum rotation rate. Any high speed override capability for maintenance mode shall be for a temporary period not to exceed one 24-hour cycle without resetting to default settings.

   b. Pool pump motor controls manufactured on or after [Compliance Date] that are sold for use with a variable speed pump shall have the capability of operating the pool pump across the pump's entire operational speed range. The control's default circulation speed setting shall be no more than one-half of the motor's maximum rotation rate. Controller shall have the capability to independently program high speed duration and default speed duration, with remaining hours to be spent in "standby" mode in which controls/timers remain ON, but the motor is idle. Any high speed override capability for maintenance mode shall be for a temporary period not to exceed one 24-hour cycle without resetting to default settings.

(C) **Measured vs. Reported Capacity of OEM Integral Pool Pumps and Motors**

1. The measured capacity of pool pump motors (horsepower or kilowatt equivalent) may not be more than the reported motor capacity (THP) when the pump and motor are sold as an integral unit on an OEM basis, when operated on CEC Curves A, B, or C".

…

Section 1606. Filing by Manufacturers; Listing of Appliances in Database.

Table X Continued - Data Submittal Requirements

	Appliance	Required Information	Permissible Answers
G	Residential Pool Pump and Motor Combinations ~~and Replacement Residential Pool Pump Motors~~	Pump Motor Construction	Permanent Split Capacitor, Capacitor Start-Capacitor Run, ECM, Capacitor Start-Induction Run, Split-Phase, Permanent Magnet Synchronous Motor, 3-phase
		Pump Motor Design	Single-speed, dual-speed, multi-speed, variable-speed
		Frame	
		Original Factory Set Speed (in RPM)	
		Highest Operational Speed (if applicable, in RPM)	
		Half Speed (if applicable, in RPM)	
		Lowest Operational Speed (if applicable, in RPM)	
		Best Efficiency Speed (if applicable, 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
		Pump and Motor combination includes integral controller	Yes, no
		This information Pool Pump Motor Capacity	

		must be reported for each tested speed, as applicable.	Motor Service Factor	
			Motor Efficiency (%)	
			Nameplate Horsepower	
			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)	
	Pool Pump Motors	Motor Construction		Permanent Split Capacitor, Capacitor Start-Capacitor Run, ECM, Capacitor Start-Induction Run, Split-Phase, Permanent Magnet Synchronous Motor, 3-phase
		Motor Design		Single-speed, dual-speed, multi-speed, variable-speed
		Frame		
		Original Factory Set Speed (in RPM)		
		Highest Operational Speed (in RPM)		
		Half Speed (if applicable, in RPM)		
		Lowest Operational Speed (if applicable, in RPM)		

		Best Efficiency Speed (if applicable, 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
		This information must be reported for each speed listed above, as applicable.	Pool Pump Motor Capacity	
			Motor Service Factor	
			Motor Efficiency (%)	
			Nameplate Horsepower	
	Pool Pump Controllers	Standby Power Demand in Watts		
		Power Factor in %		
		Controller has ability to control each of the following motor designs.	Dual Speed Motor	Yes, no
			Multi-Speed Motor	Yes, no
			Variable Speed Motor	Yes, no
	Pool LED Lamps	Power Demand in Watts		
		True Power Factor (PF)		
		Total Harmonic Distortion (THD)		
		Total Lumen Output		
		Vertical Luminance Distribution from normal to minus 90 degrees, in 15-degree increments		
		Beam Lumens in the field specified above (normal to minus 90 degrees), in 15-degree increments		
		Correlated Color Temperature (in degrees K)		
		Lamp Lumen Depreciation (%)		
	Portable Electric	*Voltage		

	Spas	Volume (gallons)	
		Rated Capacity (number of people)	
		Normalized Standby Power (watts)	
		Spa Enclosure is Fully Insulated	Yes, no

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

1 = Voluntary for federally-regulated appliances

2 = Voluntary for state-regulated appliances

…

Section 1607. Marking of Appliances.

…

(d) Energy Performance Information.

…

(10) ~~Residential~~ Pool Pumps.

(A) Each ~~residential~~ pool pump head shall be marked, permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than ¼" high, the ~~nameplate~~ total capacity (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 ¼" high, the ~~pool pump motor~~ nameplate capacity (HP) of the motor.

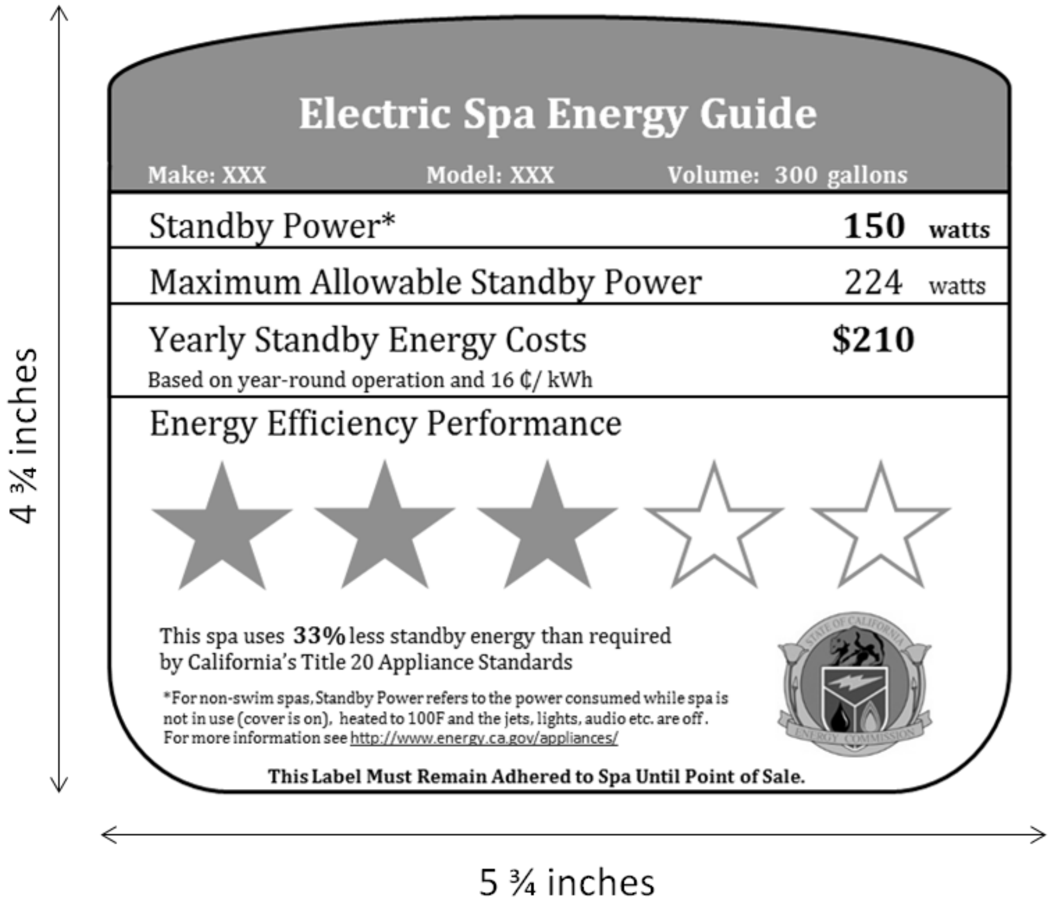
(C) Two-, multi-, or variable-speed ~~residential~~ pool pumps certified under Section 1606 of this Article on or after January 1, 2010 shall be marked, permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than ¼", "This pump includes a T20 compliant controller, or this pump must be installed with a T20 compliant controller

(D) Each pool pump motor, OEM or replacement, greater than 1 THP with an Energy Factor <3.8 on CEC Curve A shall be marked, permanently and legibly on an accessible and conspicuous place on the unit, in characters no less than ¼", "This product may not be installed in residential filtration applications in CA".

…

(12) Portable Electric Spas.

(A) The manufacturer shall include a removable sticker label on the shell of the spa no lower than 6 inches from the top of the spa. The label must be no smaller than 4 ¾ inches tall by 5 ¾ inches wide and be printed on a white background. The information needed to create this label is: Make, Model, Volume and Normalized Standby power. A tool to create this label is available on the Appliance Efficiency page on the CEC website.



Electric Spa Energy Guide
Make: XXX
Model: XXX
Volume: 300 gallons
Standby Power*
150 watts
Maximum Allowable Standby Power
224 watts
Yearly Standby Energy Costs
$210
Based on year-round operation and 16 ¢/ kWh
Energy Efficiency Performance
This spa uses 33% less standby energy than required by California's Title 20 Appliance Standards
*For non-swim spas, Standby Power refers to the power consumed while spa is not in use (cover is on), heated to 100F and the jets, lights, audio etc. are off. For more information see http://www.energy.ca.gov/appliances/
This Label Must Remain Adhered to Spa Until Point of Sale.
4 ¾ inches
5 ¾ inches

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Appendix A: Figures and Tables

Table A.1 Average Pool Pump Nameplate Size, Installed by CA IOU Service Area

IOU Service Area	*Number of Pump Motors*	*Horsepower of Pump Motor*	
		Average	*Standard Deviation*
PG&E	100	1.170	0.425
SCE	118	1.500	0.466
SDG&E	81	1.225	0.464

Source: ADM 2002, 3-1.

Table A.2 Percentage Distribution of Filtration Pool Pump Nameplate Motor Sizes, Installed by CA IOU Service Area

	Utility Service Area		
	PG&E	*SCE*	*SDG&E*
Number of pool sites surveyed	100	118	81
Percent with ½ hp motors	5.0%	1.7%	1.2%
Percent with ¾ hp motors	20.0%	8.5%	30.9%
Percent with 1 hp motors	38.0%	22.0%	23.5%
Percent with 1.5 hp motors	25.0%	29.7%	27.2%
Percent with 2 hp motors	12.0%	38.1%	17.3%
Total	100.0%	100.0%	100.0%

Source: ADM 2002, 3-1.

Table A.3 kW Demand for Filtration Pump Motors, for IOU Service Area in CA

Table 3-3. kW demand for Filtration Pump Motors by Pump Motor Horsepower for Combined Service Areas

Pump Motor Horsepower	*Baseline Data*			*Post-Program Data*		
	Number of Motors Measured	*Average Measured kW Usage*	*Standard Deviation of kW Usage*	*Number of Motors Measured*	*Average Measured kW Usage*	*Standard Deviation of kW Usage*
½ hp motors	2	0.857	0.081	2	1.120	
¾ hp motors	32	1.106	0.205	17	1.249	0.123
1 hp motors	90	1.223	0.281	15	1.305	0.242
1 ½ hp motors	47	1.440	0.327	11	1.736	0.177
2 hp motors	47	1.728	0.349	2	1.785	0.573
All motors	218	1.359	0.371	47	1.398	0.292

Source: ADM 2002, 3-2.

Table A.4 Hours: Residential Pool Pumps and Motors

Sites Reported for	*Hours Operated per Baseline*		
	N	*Mean*	*Standard Deviation*
All sites	423	4.199	2.208
PG&E	131	4.115	2.009
SCE	165	4.525	2.599
SDG&E	127	3.862	1.763

Source: ADM 2002, Table 4-2.

Table A.5 Load Profile: Residential Pool Pumps and Motors

Table 4-6. Average Hourly kW Profiles for Baseline and Program Periods for Different Utility Service Areas

Hour of Day	PG&E		SCE		SDG&E	
	Baseline	Program	Baseline	Program	Baseline	Program
1	0.118	0.208	0.117	0.217	0.015	0.036
2	0.123	0.149	0.106	0.173	0.028	0.028
3	0.229	0.192	0.124	0.178	0.028	0.051
4	0.289	0.196	0.136	0.186	0.043	0.073
5	0.385	0.252	0.077	0.170	0.121	0.102
6	0.403	0.342	0.120	0.229	0.210	0.165
7	0.473	0.444	0.224	0.394	0.408	0.306
8	0.442	0.412	0.270	0.538	0.493	0.553
9	0.576	0.376	0.470	0.656	0.571	0.782
10	0.652	0.249	0.546	0.615	0.585	0.900
11	0.783	0.047	0.654	0.501	0.688	0.784
12	0.789	0.024	0.729	0.195	0.592	0.393
13	0.562	0.018	0.735	0.090	0.342	0.008
14	0.452	0.012	0.674	0.056	0.287	0.000
15	0.369	0.012	0.546	0.081	0.254	0.000
16	0.362	0.000	0.379	0.081	0.226	0.000
17	0.227	0.000	0.223	0.082	0.102	0.018
18	0.139	0.014	0.073	0.092	0.044	0.018
19	0.110	0.020	0.128	0.273	0.077	0.136
20	0.057	0.049	0.196	0.349	0.037	0.215
21	0.118	0.302	0.201	0.399	0.019	0.202
22	0.118	0.361	0.192	0.382	0.019	0.165
23	0.110	0.376	0.186	0.208	0.036	0.104
24	0.076	0.269	0.132	0.187	0.025	0.043

Source: ADM 2002, 4-6.

Table A.6 Pool Average kW, IOU Service Area

Table 5-1. Number of Pools Participating in Timer Component and Estimated Average kW per Pool by IOU Service Area

	Utility Service Area		
	PG&E	SCE	SDG&E
Number of pools participating in timer component	30,500	47,044	14,639
Average kW per pool pump	1.718	1.374	1.417

Source: ADM 2002, 5-1.

Table A.7 Demand for Pump Motors by Nameplate HP

Table 6-5. Comparison of kW Demand for Pump Motors of Different Nameplate Horsepower for Baseline and Program Sites for SCE and SDG&E

Motor Nameplate Horsepower	Baseline Sites			Program Sites		
	N	Average kW	Standard Deviation kW	N	Average kW	Standard Deviation kW
SCE						
¾ hp motors	9	1.011	0.240	4	1.255	0.142
1 hp motors	29	1.154	0.283	7	1.346	0.252
1.5 hp motors	18	1.379	0.356	7	1.780	0.066
2 hp motors	26	1.727	0.344	2	1.785	0.573
SDG&E						
¾ hp motors	11	1.185	0.151	13	1.247	0.124
1 hp motors	35	1.336	0.266	7	1.302	0.247
1.5 hp motors	9	1.461	0.335	1	2.000	

Source: ADM 2002, 6-7.

Table A.8 Distribution of Pool Pump Type, PG&E Service Area

Pool filtration pump characteristics	PG&E participating contractors/retailers (n=19)	PG&E general population contractors/retailers (n=27)	PG&E pool owners (n=300)
% of pools w/ working pool filtration pumps?*	99.7%	97.0%	98.3%
pool filtration pump types**			
% of single-speed	76%	76%	89%
% of two-speed	11%	10%	9%
% of variable-speed	12%	14%	3%
Total	100%	100%	100%

Source: KEMA 2009, 5-47.

Table A.9 Average Pool Pump Nameplate Size, Installed in PG&E Service Area

Horsepower of single-speed pool pumps*	PG&E participating contractors/retailers (n=18)	PG&E general population contractors/retailers (n=27)	PG&E pool owners (n=207)**
< 1 hp	25%	43%	21%
1-1.5 hp	59%	47%	48%
2-2.5 hp	18%	5%	26%
3 hp	1%	1%	6%
Total	103%	96%	100%

Source: KEMA 2009, 5-48.

Table A.10 Pool Pump Operating Hours

Table 5-8:
Length of Operating Period
for Residential Pool Pumps
As Estimated by PG&E Contractors/Retailers and Pool Owners

Pool pump operating periods	PG&E participating contractors/retailers (n=17,15,15)	PG&E general population contractors/retailers (n=26,18)	PG&E pool owners (n=268,20)
Average of typical single-speed pool pump operating periods (# hours)*	6.9	6.0	4.1
Average of typical multi-speed pool pump operating periods (# hours)*	9.3	6.6	3.4 at low speed 2.1 at high speed
Average % of time that multi-speed pool pumps operate at lowest speed**	83%	Question not asked	62%

Note: "We asked the contractors/retailers: "When you encounter single/multi-speed pool pumps in your service work, on average, about how many hours per day are they operating? ...". We asked the pool owners: "How many hours a day do you normally run your pool filtration pump? "* For the contractors' retailers as a follow-up to the question: "When you encounter multi-speed pool pumps in your service work, on average, about how many hours per day are they operating?" we asked: "About what percentage of this time is spent on the lowest speeds?" For the pool owners the percentage is the ratio of 3.4 hours to 5.5 hours indicated in the cell above.

Source: KEMA 2009, 5-50.

Table A.11 Pool Cleaning Systems Frequency, PG&E Service Territory

Table 5-10:
Distribution of Residential Automatic Pool Cleaning Systems
As Estimated by PG&E Contractors/Retailers and Pool Owners

Automatic Pool Cleaning Systems	PG&E participating contractors/ retailers (n=18)	PG&E general population contractors/ retailers (n=28)	PG&E pool owners (n=254)
% of pools w/ working pool filtration pumps?*	89%	91%	85%
reported frequency of automatic cleaning system types**			
presser side w/ booster pump	64%	56%	17%
suction side	27%	29%	14%
presser side w/o booster pump	9%	9%	4%
in-floor	3%	6%	8%
robotic	0%	0%	45%
other			18%
Total	103%	100%	106%

Note: For the contractor/retailer responses, the "totals" are the sums of average proportions and inconsistent responses (e.g., missing data or surveyor did not check that total % of responses = 100%) may cause these totals to not equal 100%.The pool owner survey results exceed 100% because the respondents were allowed to give multiple responses.
*We asked the contractors/retailers: "About what % of the residential pools that you service have working automatic pool cleaning systems?" We asked the pool owners: "Do you have an automatic pool cleaner?"
**We asked the contractors/retailers: "Of the residential pools that you service that have working automatic pool cleaning systems, about what % of these systems fall into the following categories? …". We asked the pool owners: "What type(s) of pool cleaner do you have?" **

Source: KEMA 2009, 5-56.

Table A.12 Pool Cleaning Systems Operating Hours

Table 5-11:
Length of Operating Period
for Residential Automatic Pool Cleaning Systems
As Estimated by PG&E Contractors/Retailers

Automatic Pool Cleaning Systems	PG&E participating contractors/ retailers	PG&E general population contractors/ retailers
average daily operating hours		
presser side w/ booster pump (n=18, 25)	3.0	2.1
suction side (n=14, 26)	5.5	5.7
presser side w/o booster pump (n=10, 8)	5.3	5.3
in-floor (n=3, 6)	4.2	5.2

Note: The contractors/retailers were only asked for average daily operating hours if the type of automatic pool cleaning system was one that they had encountered somewhat frequently. This is why the sample sizes decrease with the decreasing frequency of the cleaning systems (see previous table). Only one contractor/retailer provided an estimate for the average operating times of robotic cleaners (2 hours). For the presser side cleaners without booster pumps, four of the general population contractors/retailers said that these systems operate whenever the pool filtration pump is operating.

Source: KEMA 2009, 5-57.

Appendix B: Cost Analysis Assumptions

The electricity rates used in the analysis of this CASE Report were derived from projected future prices for residential, commercial and industrial sectors in the CEC's "Mid-case" projection of the 2012 Demand Forecast (2012), which used a 3% discount rate and provide prices in 2010 dollars. The sales weighted average of the 5 largest utilities in California was converted to 2013 dollars using an inflation adjustment of 1.07 (DOL 2013). A sector weighted average electricity rate was then calculated using 2% commercial, 98% residential, 0% industrial (P.K. Data 2012) See the rates by year below in Table B.1.

Table B.1 Statewide Weighted Average Electricity Rates 2015 - 2040 (PG&E, SCE, SDG&E, LADWP and SMUD - 5 largest Utilities) in 2013 cents/kWh

Year	Residential	Commercial	Industrial	Sector Weighted Average
2015	16.82	14.67	11.31	16.61
2016	17.02	14.84	11.43	16.81
2017	17.24	15.02	11.56	17.02
2018	17.47	15.22	11.70	17.25
2019	17.71	15.42	11.84	17.49
2020	18.00	15.67	12.01	17.77
2021	18.34	15.98	12.23	18.12
2022	18.70	16.29	12.45	18.47
2023	19.06	16.61	12.67	18.82
2024	19.43	16.93	12.90	19.19
2025	19.81	17.27	13.13	19.56
2026	20.19	17.60	13.37	19.94
2027	20.59	17.95	13.61	20.33
2028	20.98	18.30	13.86	20.72
2029	21.39	18.66	14.12	21.13
2030	21.81	19.03	14.38	21.54
2031	22.23	19.40	14.64	21.96
2032	22.66	19.78	14.92	22.38
2033	23.10	20.17	15.19	22.82
2034	23.55	20.57	15.48	23.26
2035	24.01	20.97	15.77	23.71
2036	24.48	21.38	16.06	24.18
2037	24.96	21.80	16.37	24.65
2038	25.44	22.23	16.68	25.13
2039	25.94	22.67	16.99	25.62
2040	26.44	23.12	17.32	26.12

Appendix C: Criteria Pollutant Emissions and Monetization

C.1 Criteria Pollutant Emissions Calculation

To calculate the statewide emissions rate for California, the incremental emissions between CARB's high load and low load power generation forecasts for 2020 were divided by the incremental generation between CARB's high load and low load power generation forecast for 2020. Incremental emissions were calculated based on the delta between California emissions in the high and low generation forecasts divided by the delta of total electricity generated in those two scenarios. This emission rate per MWh is intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario instead of the high load scenario. While emission rates may change somewhat over time, 2020 was considered a representative year for this measure.

C.2 Criteria Pollutant Emissions Monetization

Avoided ambient ozone precursor and fine particulate air pollution benefits were monetized based on avoided control costs rather than damage costs due to the availability of emission control cost-effectiveness thresholds, as well as challenges in quantifying a specific value for damages per ton of pollutants.

Two sources of data for cost-effectiveness thresholds were evaluated. The first is Carl Moyer cost-effectiveness thresholds for ozone precursors and fine particulates (CARB 2011a, CARB 2013a and 2013b). The Carl Moyer program has provided incentives for voluntary reductions in criteria pollutant reductions from a variety of mobile combustion sources as well as stationary agricultural pumps that meet specified cost-effectiveness cut-offs.

The second is the San Joaquin Valley UAPCD Best-Available Control Technology ("BACT") cost-effectiveness thresholds study. Pollution reduction technologies that are not yet demonstrated in practice (in which case they are required without a cost-effectiveness evaluation) can be required at new power plants and other sources if technologically feasible and within cost-effectiveness thresholds. San Joaquin Valley UAPCD conducted a state-wide study as the basis for updating their BACT thresholds in 2008.

This CASE report relies primarily on the Carl Moyer thresholds due to their state-wide nature and applicability to combustion sources[2]. In addition, the Carl Moyer fine particulate values for fine particulate apply to combustion sources with specific health impacts, while BACT thresholds include both combustion sources and dust. The Carl Moyer values are somewhat more conservative for ozone precursors than San Joaquin Valley UAPCD BACT thresholds, and significantly higher for fine particulate[3].The Carl Moyer program does not address sulfur oxides, however, thus the San Joaquin BACT thresholds were used for this pollutant.

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[2] Further evaluation of the qualitative impacts of combustion fine particulate emissions from power generation and transportation sources may be beneficial.

[3] We note that both the Carl Moyer and San Joaquin Valley UAPCD BACT cost-effectiveness thresholds for fine particulates fall within the wide range of fine particulate ERC trading prices in California in 2011 and 2012.

Price reports for California Emission Reduction Credit (ERCs, i.e. air pollution credits purchased to offset regulated emission increases) for 2011 and 2012 were also compared to the values selected in this CASE report. For each pollutant there is a wide range of ERC values per ton that are both higher and lower than the values per ton used in this CASE report [CARB 2011b and 2012]. Due to wide variability and low trading volumes, ERC values were evaluated for comparative purposes only.

Appendix D: Greenhouse Gas Valuation Discussion

The climate impacts of pollution from fossil fuel combustion and other human activities, including the greenhouse gas effect, present a major risk to global economies, public health and the environment. While there are uncertainties of the exact magnitude given the interconnectedness of ecological systems, at least three methods exist for estimating the societal costs of greenhouse gases: 1) the Damage Cost Approach 2) the Abatement Cost Approach and 3) the Regulated Carbon Market Approach. See below for more details regarding each approach.

D.1 Damage Cost Approach

In 2007, the U.S. Court of Appeals for the Ninth Circuit ruled that the National Highway Transportation Traffic Safety Administration (NHTSA) was required to assign a dollar value to benefits from abated carbon dioxide emissions. The court stated that while there are a wide range of estimates of monetary values, the price of carbon dioxide abatement is indisputably non-zero. In 2009, to meet the necessity of a consistent value for use by government agencies, the Obama Administration established the Interagency Working Group on the Social Cost of Carbon to establish official estimates (Johnson and Hope).

The Interagency Working Group primarily uses estimates of avoided damages from climate change which are valued at a price per ton of carbon dioxide, a method known as the damage cost approach.

D.1.1 Interagency Working Group Estimates

The Interagency Working Group SCC estimates, based on the damage cost approach, were calculated using three climate economic models called integrated assessment models which include the Dynamic Integrated Climate Economy (DICE), Policy Analysis of the Greenhouse Effect (PAGE), and Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) models. These models incorporate projections of future emissions translated into atmospheric concentration levels which are then translated into temperature changes and human welfare and ecosystem impacts with inherent economic values. As part of the Federal rulemaking process, DOE publishes estimated monetary benefits using Interagency Working Group SCC values for each Trial Standard Level considered in their analyses, calculated as a net present value of benefits received by society from emission reductions and avoided damages over the lifetime of the product. The recent U.S. DOE Final Rulemaking for microwave ovens contains a Social Cost of Carbon section that presents the Interagency Working Group's most recent SCC values over a range of discount rates (DOE 2013) as shown in Table D.1. The two $ metric ton of values used in this CASE report were taken from the two highlighted columns, and converted to 2013 dollars.

Table D.1 Social Cost of CO_2 2010 – 2050 (in 2007 dollars per metric ton of CO_2) (source: Interagency Working Group on Social Cost of Carbon, United States Government, 2013)

Discount Rate	5.0%	3.0%	2.5%	3.0%
Year	Avg	Avg	Avg	95th
2010	11	33	52	90
2015	12	38	58	109
2020	12	43	65	129
2025	14	48	70	144
2030	16	52	76	159
2035	19	57	81	176
2040	21	62	87	192
2045	24	66	92	206
2050	27	71	98	221

The Interagency Working Group decision to implement a global estimate of the SCC rather than a domestic value reflects the reality of environmental damages which are expected to occur worldwide. Excluding global damages is inconsistent with U.S. regulatory policy aimed at incorporating international issues related to resource use, humanitarian interests, and national security. As such, a regional SCC value specific to the Western United States or California specifically should be at similarly inclusive of global damages. Various studies state that certain values may be understated due to the asymmetrical risk of catastrophic damage if climate change impacts are above median predictions, and some estimates indicate that the upper end of possible damage costs could be substantially higher than indicated by the IWG (Ackerman and Stanton 2012, Horii and Williams 2013).

D.2 Abatement Cost Approach

Abating carbon dioxide emissions can impose costs associated with more efficient technologies and processes, and policy-makers could also compare strategies using a different by estimating the annualized costs of reducing one ton of carbon dioxide net of savings and co-benefits. The cost of abatement approach could reflect established greenhouse gas reduction policies and establish values for carbon dioxide reductions relative to electricity de-carbonization and other measures. (While recognizing the potential usefulness of this method, this report utilizes the IWG SCC approach and we note that the value lies within the range of abatement costs discussed further below.)

The cost abatement approach utilizes market information regarding emission abatement technologies and processes and presents a wide-range of values for the price per ton of carbon dioxide. The California Air Resources Board data of the cost-effectiveness of energy efficiency measures and emission regulations would provide one source of potential data for an analysis under this method. To meet the AB 32 target, ARB has established the “Cost of a Bundle of Strategies Approach” which includes a range of cost-effective strategies and regulations (CARB 2008b). The results of this approach within the framework of the Climate Action Team Macroeconomic Analysis are provided for California, Arizona, New Mexico, the United States, and a global total identified in that same report, as shown in Table D.2 below.

Table D.2 Cost-effectiveness Range for the CAT Macroeconomic Analysis

Exhibit 3: Cost-effectiveness Range for the CAT Macroeconomic Analysis, Selected States, United States, Global -

State	Cost-effectiveness Range $/ ton CO_2eq	Tons Reduced $MMtCO_2e/yr$	Percent of BAU
California 2020 (CAT[1], CEC[2])	- 528 to 615	132	22
Arizona[3] 2020	- 90 to 65	69	47
New Mexico[4] 2020	- 120 to105	35	34
United States (2030)[5]	-93 to 91	3,000	31
Global Total (2030)	-225 to 91	26,000	45

Source:
1. Climate Action Team Updated Macroeconomic Analysis of Climate Strategies, Presented in the March 2006 Climate Action Team Report, September 2007.
2. California Energy Commission, *Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California*, July 2005, ICF ($/MTC$0_2$eq).
3. Arizona Climate Change Advisory Group, *Climate Change Action Plan*, August 2006, ($/MTC$0_2$eq).
4. New Mexico Climate Change Advisory Group, Final Report, December 2006.
5. McKinsey & Company, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* December 2007.
6. The McKinsey Quarterly, McKinsey & Company, *A Cost Curve for Greenhouse Gas Reduction*, Fall 2007.

Source: CARB 2008b

Energy and Environmental Economics (E3) study defines the cost abatement approach more specifically as electricity de-carbonization and is based on annual emissions targets consistent with existing California climate policy. Long-term costs are determined by large-scale factors such as electricity grid stability, technological advancements, and alternative fuel prices. Near-term costs per ton of avoided carbon could be$200/ton in the near-term (Horii and Williams 2013), thus as noted earlier the value used in this report may be conservative.

D.3 Regulated Carbon Market Approach

Emissions allowance markets provide a third potential method for valuing carbon dioxide. Examples include the European Union Emissions Trading System and the California AB32 cap and trade system as described below. Allowances serve as permits authorizing emisisons and are traded through the cap-and-trade market between actors whose economic demands dictate the sale or purchase of permits. In theory, allowance prices could serve as a proxy for the cost of abatement. However, this report does not rely on the prices of cap-and-trade allowances due to the vulnerability of the allowance market to external fluctuations, and the influence of regulatory decisions affecting scarcity or over-allocation unrelated to damages or abatement costs.

D.3.1 European Union Emissions Trading System

The European Union Emissions Trading System (EU ETS) covers more than 11,000 power stations, industrial plants, and airlines in 31 countries. However, the market is constantly affected by over-supply following the 2008 global recession and has seen prices drop to dramatic lows in early 2013, resulting in the practice of "back-loading" (delaying issuances of permits) by the European parliament. At the end of June 2013, prices of permits dropped to $5.41/ton, a price which is well below damage cost estimates and sub-optimal for encouraging innovative carbon dioxide emission abatement strategies.

D.3.2 California Cap & Trade

In comparison, California cap-and-trade allowance prices were reported to be at least $14/ton in May of 2013, with over 14.5 million total allowances sold for 2013 (CARB 2013b). However, cap-and-trade markets are likely to cover only subsets of emitting sectors of the industry covered by AB 32. In addition, the market prices of allowances are determined only partly by costs incurred by society or industry actors and largely by the stringency of the cap determined by regulatory agencies and uncontrollable market forces, as seen by the failure of the EU ETS to set a consistent and effective signal to curb carbon dioxide emissions.