



WATER HEATING
SMART PUMP, RESIDENTIAL
SWWH022-01

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MEASURE NAME

Smart Pump, Residential

STATEWIDE MEASURE ID

SWWH022-01

TECHNOLOGY SUMMARY

This measure pertains to a high-performance circulator (HPC) pump for single family and multifamily residential domestic hot water applications. A circulator pump is a specific type of pump used to circulate liquids in open or closed loop systems.

- **Open Loop.** In an open loop system, fresh water is introduced into the hot water recirculation system. Stainless steel or bronze bodied pumps are used in this application to negate the opportunity for rust due to fresh water (oxygen) being introduced into the system. Stainless steel or bronze bodied pumps have a higher initial cost compared to cast iron bodied pumps. In open loop systems, friction head and static head losses need to be overcome to deliver hot water.
- **Closed Loop.** In a closed loop system, no fresh water is introduced into the system, for hydronic heating or cooling for example. Cast-iron bodied pumps are used in closed-loop applications; they are the most cost-effective option due to no risk of rust because no fresh water (oxygen) will enter the system (compared to open loop systems). Friction head losses are the only losses that need to be overcome so inherently these pumps are smaller in horsepower (hp).

Note that closed loop systems are not applicable to this measure, because this measure is only applicable to domestic hot water recirculation.

A circulating pump is often used to circulate domestic hot water (DHW) so that a faucet will provide hot water instantly or in a short time after the user's "on demand" request. The latter "on-demand" system conserves more energy and water but is less popular in replacement applications because it is less convenient for the user and is much more expensive than a direct replacement as a *normal replacement* measure. With rising concerns over water conservation, DHW systems with circulator pumps are becoming more popular.

In a typical one-way plumbing system without a circulation pump, water is piped from the water heater through the pipes to the tap. Once the tap is shut OFF, the water remaining in the pipes will cool, producing the familiar "wait for hot water" effect the next time the tap is opened. A circulator pump constantly circulates a small amount of hot water through the pipes from the heater to the farthest fixture and back to the heater. This results in hot water continuously available at the faucets and in the hot water distribution pipes.

With on-demand DHW, no water is wasted because the user does not need to wait for the water temperature at the tap to reach the desired temperature; however, this option is less popular as hot water is not automatically dispensed from the faucet when requested by the user.

Pumps in the measure case are driven by an electrically commutated motor (ECM), have integrated variable frequency drives (VFD), and controlling logic which allows the pump to match the demand of the system. These features are summarized below:

- **Electrically commutated motor (ECM).** An ECM will reduce energy consumption by approximately 0% compared to a non-regulated, inefficient induction type of motor.

- **Variable Frequency Drive (VFD).** Many utilities, such as Pacific Gas & Electric and Southern California Edison recognize the energy savings potential that VFDs offer in pumping systems and have included the technology in their energy efficiency program portfolios. However, end-users often will only apply for these incentives for larger horsepower systems, typically greater than 25 hp, because of the small incentive amount or prohibitive cost. The HPC pump technology extends the energy saving opportunity of VFDs to the fractional horsepower realm, which has previously been overlooked.
- **Controlling Logic.** The inclusion of controlling logic offers additional energy savings by allowing the pump to only consume as much energy as is needed to perform the duty the system requires. A VFD enables the HPC pump to speed up and slow down according to needs of the system, resulting in higher energy savings. The Grundfos Alpha 15-55 controlling logic utilizes an operational mode called "AutoAdapt" where the pump will measure input current into the ECM driver to detect changes in the system pressure (i.e. hot water demand) and adjust flow rates accordingly. The logic allows the pump to operate along a system specific proportional pressure curve closely mirroring the specific system curve into which the pump is installed. This is done first by measuring time-weighted external inputs (current, flow across pump, pressure drop across pump) to identify current operating conditions and power draw in the system. These actual operating conditions are compared with built-in knowledge of optimized proportional pressure curves to determine the operating point and proportional pressure curve that uses the least amount of power while sustaining enough flow and head to operate effectively.¹ All without end user interaction.

Additionally, the “right-sizing” ability of an HPC pump offers a tremendous energy savings advantage over the market standard. This measure targets normal replacement applications for which a contractor will replace a pump at the end of its useful life. Typically, a contractor will replace the old pump with the current version of the new pump (considering the horsepower or wattage rating as the only sizing parameter). Moreover, if the old pump was oversized, the replacement will also likely be oversized. In a retrofit application the contractor does not have access to the information needed to properly size the “right-sized” circulator pump: the length and diameter of the pipe used in the piping system as well as the number of valves and fittings in the system are not accessible as the walls in which these pumps are installed are covered with sheetrock. To accurately “right-size” the pump, the contractor will need to remove sheetrock and/or enter the crawl space or attic which is not practical for contractors to do. As such, the “right-sizing” HPC pump presents the best opportunity for wide-spread market adoption.

A variety of manufacturers produce pumps that comply with the measure case specification. At the time of this measure analysis, approximately 519 wholesale distribution locations throughout California sell these pumps.

MEASURE CASE DESCRIPTION

This measure is defined as a high-performance circulator (HPC) pump which is a properly sized, high-efficiency ECM pump for domestic hot water (DHW) recirculation with variable speed controls to

¹ Kallesoe, C., N. Bidstrup, M. Bayer. 2013. *Adaptive Selection of Control-Curves for Domestic Circulators*.

accommodate demand. While not required, the HPC pump can accommodate external controls that limit operating hours.

BASE CASE DESCRIPTION

The base case is defined as standard circulator pump that is driven by a non-regulated, low-efficiency induction type motor, that does not utilize variable frequency drives (VFDs) and does not have the control capability to match demand. Standard pumps can accommodate external controls installed that can limit operating hours.

CODE REQUIREMENTS

This measure is not governed by either state or federal codes and standards. However, the California Building Energy Efficiency Standards (Title 24)² govern new construction requirements, as noted below.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None.	n/a
CA Building Energy Efficiency Standards – Title 24 (2016)	None.	n/a
Federal Standards	None.	n/a

Title 24, Section 150.1(c)8. For recirculation distribution systems serving individual dwelling units, only demand recirculation systems with manual control pumps (as specified in Title 24 reference appendix RA4.4.9) shall be used.

Title 24, Section 150.1(c)8b. Requires central-heating systems in multiple dwelling units to have a water heating recirculation loop that meets the requirements of sections 110.3(c)2 and 110.3(c)5 and is equipped with an automatic control system that controls the recirculation pump operation based on measurement of hot water demand and hot water return temperature.

Title 24, Section 150.2(b)1Gii. In reference to the prescriptive approach for additions and alterations to existing low-rise residential buildings, “[f]or recirculation systems, only demand recirculation systems with manual control pumps” shall be used unless a water heating system is installed that is shown to use no more energy than the prescribed methods. Additionally, if a larger replacement of the domestic hot water system is occurring that triggers Title 24, a manually controlled demand-based recirculation pump would be required. The replacement of a circulator pump is considered a “repair” and would not trigger Title 24.³

² California Energy Commission (CEC). 2015. *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2015-037-CMF.

³ This was confirmed by an EnergyCodeAce inquiry on February 20, 2017.

NORMALIZING UNIT

Each

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

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

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

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Normal replacement	UpDeemed	Res
Normal replacement	DnDeemDI	Res
Normal replacement	DnDeemed	Res
New construction	UpDeemed	Res
New construction	DnDeemDI	Res
New construction	DnDeemed	Res

Eligible Products

This measure is eligible for domestic hot water recirculation.

A brass or stainless circulator pump from any manufacturer that meets the following criteria is eligible:

- Utilizes an electrically-commutated motor (ECM)
- Has an integrated variable frequency drive (VFD)
- Has onboard pump controlling logic with self-optimizing programming to allow the pump to learn and operate at the best efficiency point on the pump curve.

These features must be utilized without any end user interaction.

Eligible Building Types and Vintages

The measure is applicable for any existing single family and multifamily residence of any vintage.

Eligible Climate Zones

This measure is applicable in any California climate zones.

PROGRAM EXCLUSIONS

This measure excludes hydronic heating applications.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Service & domestic hot water

ELECTRIC SAVINGS (kWh)

Fundamentally, the annual electric unit energy savings (UES) is calculated as the different between the annual unit energy consumption (UEC) of the measure case and base case pumps.

$$UES_{elec} = UEC_{base} - UEC_{measure}$$

The annual UEC of either the base or measure case pump is equal to the product of the power (kW) and the assumed operating hours. The key parameters of this calculation are specified and explained below.

$$UEC_{elec} = Power(kW) \times OpHours$$

UES Inputs

Parameter	Value	Source
Base Case Power (kW) (Grundfos UP 15-29 SU/LC)	0.0842	<i>Derived from:</i> Grundfos. 2017. "UP 15-29 SU/LC Circulator Pumps."
Measure Case Power (kW)	0.0267	<i>Derived from:</i> Pacific Gas and Electric (PG&E). 2017. "Appendix 6 – Alpha Measure Field Test Documents & Details." <i>Workpaper PGECOPUM107: High Performance Circulator (HPC) Pumps Revision #0</i> . May 29.
Operating Hours (hours/hr)	5,885	See below.

Power. The baseline and measure case power represent the running wattage derived from the power input of the assumed base case and measure case pumps.

Operating Hours. Three data sources were utilized to establish the operating hours for the base and measure case scenarios of this measure:⁴ 1) the California Lighting and Appliance Saturation Survey (CLASS), 2) the Alpha field survey, and 3) the U.S. Department of Energy (DOE) rulemaking EERE-2016-BT-STD-0004 for circulator pumps. The computation assumed the following:

- The operating hours of pumps installed with timers found in the Alpha field test were weighted to represent the overall timer category of the CLASS results.
- As aquastat operating hours are unknown, the DOE accepted value of 1,095 hours per year or three hours per day was adopted for the timer + aquastat and aquastat-only control categories from CLASS.

The weighted operating hours adopted for this measure analysis are specified in the following tables.

Installed Controls Weighting

Control Option						Source
No Controls	Timer w/ Hours	Timer w/o Hours	Timer + Aquastat	Aquastat only	On-Demand	
33.0%	39.0%	39.0%	11.0%	17.0%	0.0%	DNV GL. 2014. WO21: <i>Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012)</i> . Prepared for the California Public Utilities Commission, Energy Division. CALMAC Study ID: CPU0095.01.
31.0%	23.0%	15.0%	31.0%	0.0%	0.0%	Pacific Gas and Electric (PG&E). 2017. "Appendix 6 – Alpha Measure Field Test Documents & Details." <i>Workpaper PGECOPUM107: High Performance Circulator (HPC) Pumps Revision #0</i> . May 29.
50.0%	12.5%	12.5%	0.0%	20.0%	5.0%	U.S. Department of Energy (DOE), Appliance Standards and Rulemaking. Rulemaking EERE-2016-BT-STD-0004. (<i>Reference file unknown.</i>)

Installed Controls Weighted Operating Hours

Control Option	Weight	Operating Hours
No Controls	33.0%	8,760
Timer ^a	39.0%	6,891
Timer + Aquastat	11.0%	1,095
Aquastat-only	17.0%	1,095
Total w/ Alpha Field Results Timer Avg.	100.0%	5,885

a. In the Alpha field test, five pumps with timers were found; two were set to operate 24/7 while three had limited schedules.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Peak demand reduction is calculated as the different between the baseline and measure case running wattage, multiplied by the coincident demand factor (CDF), as shown below.

⁴ Based on the input from the Preliminary Review of the Energy Division of the California Public Utilities Commission (CPUC).

California Public Utilities Commission (CPUC), Energy Division. 2017. "Preliminary Workpaper Review for PGECOPUM107 R0 High Performance Circulate (HPC) Pumps." May 1.

$$DemandReduction(kW) = (kW_{base} - kW_{measure}) \times CDF$$

See the Electric Savings section for an explanation of the baseline and measure case wattage and operating hours. The CDF represents the portion of hours the pump is in operation, or the operating hours divided by 8,760.

Peak Demand Reduction Inputs

Parameter	Value	Source
Base Case Power (kW)	0.0842	<i>Derived from:</i> Grunfos. 2017. "UP 15-29 SU/LC Circulator Pumps."
Measure Case Power ^a (kW)	0.0267	<i>Derived from:</i> Pacific Gas and Electric (PG&E). 2017. "Appendix 6 – Alpha Measure Field Test Documents & Details." <i>Workpaper PGECOPUM107: High Performance Circulator (HPC) Pumps Revision #0</i> . May 29.
Operating Hours (hours/yr)	5,885	See Energy Savings.
Coincident Demand Factor	0.67	<i>Derived from:</i> Grunfos. 2017. "UP 15-29 SU/LC Circulator Pumps."

a. Field survey results were conducted over an average of seven days; the calculated running wattage was 12.1 after full optimization.

GAS SAVINGS (Therms)

Gas savings were not calculated for this measure; the gas consumption for the measure case is assumed to equal the gas consumption of the base case. There is a possibility that with temperature control, and/or a lower flow rate that gas usage may be reduced, but this has not been calculated and is not being claimed.

LIFE CYCLE

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

As per Resolution E-4807, the California Public Utilities Commission (CPUC) defined the EUL of an add-on equipment measure as the minimum of the EUL of the measure itself and the RUL of the host equipment.⁵ The RUL of the host equipment is calculated as one-third of the EUL of a pump motor. The methodology to calculate the RUL of the host equipment conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends "one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values." This approach provides a reasonable RUL estimate without the requiring any a prior knowledge about the age of the equipment being replaced.⁶

⁵ California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

⁶ KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

The EUL and RUL specified for the high-performance circulator (HPC) pump are specified below.⁷ Insofar as this is a normal replacement measure, the RUL is not applicable.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs) – HPC pump	15.0	California Public Utilities Commission (CPUC). 2014. “DEER2014-EUL-table-update_2014-02-05.xlsx.”
RUL (yrs)	n/a	-

BASE CASE MATERIAL COST (\$/UNIT)

The base case defined for this measure is the UP 15-29 SU/LC, which is the most commonly sold pump through the wholesale channel. Grundfos, the market leader, has sold nearly 2.5 times more 15-29 models in California than its smaller model, the Alpha 15-10. Contractors size conservatively, because replacing a pump under warranty is expensive. Similarly, when contractors replace a burned-out pump, they will specify at least an equivalent size.

The base case material cost was derived as the average of prices obtained in 2017 from contractors and distributors that operate in the Pacific Gas and Electric service area, provided below.

Base Case Material Cost Inputs

Contractor / location	Wholesaler	Date	Base Case (UP15-29, 0.08 hp)
Contractor #1, San Mateo	Wholesaler #1	28-Mar-17	
Contractor #2, Milpitas	Wholesaler #2	29-Mar-17	\$208.00
Contractor #2, Milpitas	Wholesaler #1	28-Mar-17	\$285.43
Contractor #3, Turlock	Wholesaler #3, Stockton	4-Apr-17	\$235.00
Contractor #4, San Rafael	Wholesaler #1, San Rafael	5-Apr-17	\$235.00
Contractor #5, Sonoma	Wholesaler #3, Sacramento	5-Apr-17	
Preferred cash customer	Wholesaler #3, Rocklin	7-Apr-17	\$291.00
Average			\$250.89

MEASURE CASE MATERIAL COST (\$/UNIT)

The measure case material cost was derived as the average of prices obtained in 2017 from contractors and distributors that operated in the Pacific Gas and Electric service area, provided below.

⁷ The Efficiency Vermont HPCP program adopted an EUL of 20 years for the measure case brushless permanent magnet circulator (BLPM) pump, and 15 years for the base case AC induction motor circulator pump. See:

Efficiency Vermont. 2015. *Technical Reference User Manual (TRM). Measure Savings Algorithms and Cost Assumptions*. Page 28.

Measure Case Cost Inputs

Contractor / location	Wholesaler	Date	Measure Case Unit Cost (Alpha 15-55, 0.06 hp)
Contractor #1, San Mateo	Wholesaler #1	28-Mar-17	\$369.00
Contractor #2, Milpitas	Wholesaler #2	29-Mar-17	\$312.50
Contractor #2, Milpitas	Wholesaler #1	28-Mar-17	\$378.75
Contractor #3, Turlock	Wholesaler #3, Stockton	4-Apr-17	
Contractor #4, San Rafael	Wholesaler #1, San Rafael	5-Apr-17	\$312.50
Contractor #5, Sonoma	Wholesaler #3, Sacramento	5-Apr-17	\$289.94
Preferred cash customer	Wholesaler #3, Rocklin	7-Apr-17	\$386.00
Average			\$341.45

Cast iron pumps are significantly less expensive than the stainless steel or bronze counterparts. For this reason, the measure case pump, which is of the non-ferrous variety, would not be installed in an application that is not DHW. A cursory review of base and measure case pump prices revealed that the base case stainless steel pump is more expensive than its measure case cast iron counterpart. This measure that even with a rebate equal to the full incremental measure cost (IMC), the cast iron Alpha 15-55 pump is less expensive than a non-ferrous Alpha 15-55.

BASE CASE LABOR COST (\$/UNIT)

Because the variable frequency drive (VFD) and controls for the measure case pump are built into the pump and the flange-to-flange dimension is often the same; the result is no additional installation cost as compared to the base case technology. Thus, the base case labor cost is assumed to equal the measure case labor cost.

MEASURE CASE LABOR COST (\$/UNIT)

The estimated installation cost of a HPC pump was obtained directly from the pump manufacturer, Grundfos.⁸ The variable frequency drive (VFD) and controls are built into the pump and the flange-to-flange dimension is often the same; this implies that there are no additional installation costs compared to the installation cost of the base case technology.

NET-TO-GROSS (NTG)

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

⁸ The source for this data/information is no longer available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG –residential default (IOUs)	0.550	Itron, Inc. 2011. <i>DEER Database 2011 Update Documentation</i> . Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.
NTG – non-DEER calculated NTG (POUs)	0.875	Pacific Gas and Electric (PG&E). 2017. “Reference #6 – CPUC Questions Submitted December 1, 2016.” <i>Workpaper PGECOPUM107: High Performance Circulator (HPC) Pumps Revision #0</i> . May 29.

The non-DEER calculated NTG was derived from two different sources of sales data. First, Grundfos market knowledge and market sales information for 2014 and 2015 was utilized to break down sales for open loop circulators in the 26-120 W nameplate range and to identify the annual growth rate for the HPC pump market. This analysis revealed a natural growth rate of sales of these products of 46.6% over these two years. This annual growth rate was used to determine the expected natural HPC pump sales in future years, which effectively represent HPC pump sales that occur without program intervention (i.e., the free ridership potential).

Second, the sales impact of a similar HPCP upstream model from Efficiency Vermont was analyzed and revealed the annual growth rate from the year prior to program implementation grew by 1,167% to the annual sales of the first year of post-program implementation. This success continued to the second year of the program with a 28% increase of annual sales of HPC pumps. This percentage increase can be applied to the California market to determine the total sales from implementing a HPC pump measure for the two years after program implementation. By including the natural market annual growth rate, overall sales after program implementation can be disaggregated into those from free riders and those who relied upon the program to influence their decision.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

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

Gross Savings Installation Adjustment Rates

Parameter	GSIA	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

This rate is appropriate, given that homeowners do not stockpile circulator pumps nor does the homeowner select the pump that will be used in their application. The pump selection is made by a plumbing contractor that visit the wholesaler at least two to three times per week to have pumps readily available to service the market. Plumbing contractors typically stock of one or two pumps on their service truck for speed of selection and installation. The Alpha serves the market well in this capacity as with its “right-sizing” ability, it is a unitary pumping solution for the majority of installation opportunities. This eliminates the “over-sizing” problem that exists in the marketplace while allowing contractors to maintain their standard practices.

NON-ENERGY BENEFITS

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

DEER DIFFERENCES ANALYSIS

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

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	No
DEER Operating Hours	No
DEER eQUEST Prototypes	There are no measures that directly contain this technology because it encompasses multiple technologies into one unit. Measures in DEER 2005 that <i>tangentially</i> relate to this measure are: D03-046 – Variable Flow Chilled Water Loop D03-047 – VSD Chilled Water Loop Pump D03-048 – Variable Flow Hot Water Loop D03-049 – VSD Hot Water Loop Pump D03-089 – Effic. Motors – Chilled Water Loop Pumps D03-090 – Effic. Motors – Hot Water Loop Pumps D03-095 – Circulator Pump Timeclock Retrofit system with electric storage water heater
DEER Version	n/a
Reason for Deviation from DEER	n/a
DEER Measure IDs Used	No
NTG	Source: DEER2016. The NTG of 0.55 is associated with NTG ID: <i>Res-Default>2yrs</i> Source: The NTG value of 0.875 was calculated from market data and EV program data.
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER. The value of 15 years is associated with EUL ID: <i>Motors-pump</i>

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	03/31/2018	Jennifer Holmes, Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: Workpaper PGECOPUM107, revision 0 (May 29, 2017) Consensus reached among Cal TF members.
	02/28/2019	Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.
	03/15/2021	Soe K Hla PG&E	Adopted all remaining measures for PG&E