Work Paper CODE
High Performance Circulator (HPC) Pumps
Revision # 1.0

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High Performance Circulator Pump Workpaper: California Technical Forum, 2016

HPC Pumps

Variable speed domestic hot water circulator pumps with brushless permanent magnet motor (BLPM) or electrically commutated motor (ECM) and controls

09/09/2016

At-a-Glance Summary

	HPC Pumps
Measure description[1]	Properly sized, high-efficiency ECM pump for domestic hot water recirculation with variable speed capabilities and controls to match demand.
Program delivery method	Primary: Upstream (Direct to wholesale distribution) Secondary: Midstream (Contractor), Downstream (End-user)
Measure application type	ROB (replace on burnout)
Base case description	Source: Market standard/ knowledge Market standard circulators consist of a pump driven by non-regulated, low-efficiency induction type motors, do not utilize variable frequency drives (VFD), and do not have the control capability to match demand.
Energy and demand impact common units	Per unit based on typical running power (watts taken from nameplate or calculated data)
Peak Demand Reduction (kW/unit)	**Peak Demand Reduction (kW/unit):** 1. Base Case: Grundfos UP 15-29 SU/LC – 84.2 Watts (Running Watts, most popular pump sold into CA market) 2. Measure Case: Grundfos Alpha 15-55 – 12.1 Watts (Optimized Running Watts) 3. **Savings: 84.2 Watts – 12.1 Watts = 72.1 Watts (0.072 kW/unit)** *See Reference section for running wattage calculations*
Energy savings (Base case – Measure) (kWh/unit)	**Energy Savings (kWh/unit):** 1. Assumed: 6,427[2] Running Hours/ Year 2. Base Case: 0.084 kW 3. Measure Case: 0.012 kW 4. **Savings: 0.072 kW/unit x 6,427 Running Hours/ Yr = 463 kWh Savings/ Year/ unit**

[1] Although this technology can be used in hydronic heating applications the scope of this workpaper is focused only on the hot water recirculation application. Only brass or stainless pumps will be eligible, effectively limiting this to domestic hot water recirculation.
[2] The Department of Energy (DOE) is currently undergoing a negotiated rulemaking for circulator pumps and the topic of annual operating hours is under discussion. The result of that discussion is a weighted average of pumps that are running with no controller, with timers employed, aquastats employed and on-demand. See reference section for chart breakdown.

Gas savings (Base case – Measure) (therms/unit)	None. Since the high efficiency replacement pump will run the same number of hours as the base case, heat loss from the plumbing system is assumed to be the same, resulting in no change in gas usage. 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.
Full measure cost[3] ($/unit)	Grundfos Alpha 15-55: $336 Material Cost Labor Cost: $300 Installation Cost Full Measure Cost: **$636/Pump**
Incremental measure cost3 ($/unit)	Measure Equipment Cost: $336 Baseline Equipment Cost: $231 Incremental Measure Cost: **$105/Pump** ***VFD and controls are built into pump and flange to flange dimension is often the same the result is no additional installation cost as compared to the baseline technology***
Effective useful life[4] (years)	15 Years per DEER EUL for ECM circulator pumps for the commercial sector. However, Efficiency Vermont has carried an effective useful life figure of 20 years. See link in footnote 4.
Net-to-gross ratio(s)	All-Default<=2yrsSource: 0.70 However, based on CA market knowledge as outlined in section 1.1, Grundfos would suggest using a net-to-gross figure of 0.93. For a breakout of the net-to-gross figures in the CA market, see subsection 3 in the references section. Also, it should be noted that both Efficiency Vermont and Energize Connecticut carried a net-to-gross figure of 0.95.
Important comments	1/28/2016 High-Efficiency Pumping Systems Abstract was presented at the California Technical Forum meeting in San Francisco. We received unanimous support for moving forward with the workpaper. In addition, there are measures and existing programs (Efficiency Vermont[5], Energize Connecticut[6], Focus on Energy[7] to name a few) that have adopted this technology and currently offer rebates for HPC Pumps. While utilizing the same technology, these programs all focus on hydronic heating as that is their primary use in colder parts of the United States. In California, domestic hot water (DHW) is the primary use.

[3] *Source* – Grundos Contactor Cost - Costs are estimated based on market knowledge and it is assumed that the labor costs for the measure and base case are equal thus the IMC labor cost is $0.

[4] *Source* – Efficiency Vermont: Technical Reference User Manual (TRM) 3/16/2015: TRM User Manual No. 2014-87, Brushless Permanent Magnet (BLPM) Circulator Pump, pg: 530

[5] https://www.efficiencyvermont.com/rebates/list/high-performance-circulator-pumps

[6] http://www.energizect.com/your-home/solutions-list/High-Efficiency-Furnace-Natural-Gas-Boiler-Rebates

[7] https://focusonenergy.com/sites/default/files/2016_HVAC_Plumbing_Incentive_Catalog.pdf, page 38. “Variable Speed Pump with Electronically Commutated Motor (ECM).”

Document Revision History

Revision #	Revision Date	Section-by-Section Description of Revisions	Author (Name, PA)

Commission Staff Review and Comment History

Revision #	Date Submitted to Commission Staff	Date Comments Received	Commission Staff Comments

Table of Contents

Section 1. General Measure & Baseline Data

1.1 Product Measures

General Description

High Performance Circulator (HPC) Pumps for residential domestic hot water applications.

QUALIFYING PUMPS Brass or stainless circulator pumps using electrically commutated motors (ECM) with integrated variable frequency drives (VFDs) with onboard pump controlling logic with self-optimizing programing allowing for the pump to learn and operate at the best efficiency point on the pump curve. These features are utilized without any end user interaction and save energy throughout the 15 year useful life of the pumping system.

General Information

A circulator pump is a specific type of pump used to circulate liquids in open or closed loop systems. The focus of this workpaper is on residential domestic hot water (DHW) applications which are considered open loop systems.

Open loop: Hot water recirculation where fresh water is introduced into the system. Stainless steel or bronze bodied pumps are used in this application in order 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 as compared to cast iron bodied pumps. In these open loop systems friction head, and static head need to be overcome in order to deliver hot water.

Closed loop (for reference only, as this measure is applicable only to domestic hot water recirculation): Hydronic heating or cooling where no fresh water is introduced into the system. Cast iron bodied pumps are used in these applications as they are the most cost-effective option due to no risk of rust because no fresh water (oxygen) is entering 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).

Targeted Application in California: Hot Water Recirculation

Circulating pumps are often used to circulate domestic hot water (DHW) so that faucets will provide hot water instantly or in a short time after a user's “on demand” request. The latter “on-demand” system conserves more energy & water, but is less popular in replacement applications as it is less convenient for the user. Is also much more expensive than direct replacement as a replacement on burnout measure. With rising concerns over water conservation DHW systems employing circulator pumps are becoming more popular.

In typical one-way plumbing without a circulation pump, water is simply piped from the water heater through the pipes to the tap. Once the tap is shut off, the water remaining in the pipes cools, producing the familiar wait for hot water effect the next time the tap is opened. A circulator pump, which, with the exception of the “on-demand” system, 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 the water at the faucets and in the hot water distribution pipes always being hot. With on-demand domestic hot water, no water is wasted waiting for the water temperature to increase but, as previously mentioned, this option is less popular as hot water is not automatically dispensed from the faucet when called for by the user.

The “wet rotor” sealed units used in home applications often have the motor rotor, pump impeller, and support bearings combined and sealed within the water circuit. This offers longer life and avoids one of the principal challenges faced by the larger, two-part pumps: maintaining a water-tight seal at the point where the pump drive shaft enters the pump body.

Pumps that have a steady stream of oxygenated, potable water flowing through them, i.e. open loop systems, must be made of materials such as bronze & stainless steel that resist corrosion.

2015 Estimated Residential ROB Market Landscape in California:
Plumbing (HWR): 51,400 (93.2% of CA market – Targeted application for workpaper)
Hydronic (HVAC): 3,770 (6.8% of CA market)
TOTAL CA 2015 Market: 55,170 Qty of pumps transacted
TOTAL CA 2015 kWh Consumption: 22,650,307

"Small" Market Segment: Up to 25 Watts (12, 744 pumps transacted – 22.9% of CA plumbing market)

- 1,339,401 kWh Consumed in 2015
- Market Standard Pumps: 8,318 (70.6% of market segment)
  - 1,410,244 kWh consumed
- Efficient Option: 3,464 (29.4% of market segment)
  - 42,987 kWh consumed

"Large" Market Segment: 26 – 120 Watts (39,618 pumps transacted – 77.1% of CA market)

- 21,310,906 kWh Consumed in 2015
- Market Standard Pumps: 39,341 (99.3% of market segment)
  - 21,289,339 kWh consumed
- Efficient Option: 277 (0.7% of market segment)
  - 21,567 kWh consumed

kWh Savings Potential by Market Conversion Rate:

- 25%: 4,855,787 (21% kWh savings as compared to current market)
- 50%: 9,711,565 (43% kWh savings as compared to current market)
- 75%: 14,567,349 (64% kWh savings as compared to current market)
- 100%: 19,423,131 (86% kWh savings as compared to current market)

See subsection 3 in References section for calculation methodology

Technical Description

The Alpha 15-55[8] is the energy efficiency measure that we are proposing as the measure case because it is the most common applicable residential HPC Pump option. A variety of manufacturers also make pumps that fit within the measure case description. In addition, we have identified roughly 519 wholesale distribution locations throughout the state of CA where these pumps are sold. Pumps in the measure case are all 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.

- ECM: Saves ~50% energy as compared to a non-regulated, inefficient induction type of motor.
- VFD: Many utilities such as Pacific Gas & Electric and Southern California Edison recognize the energy savings potential that VFDs offer in pumping systems by offering an incentive via prescriptive (express solutions) programs. However, many times end-users will only apply for these incentives for larger horsepower (HP) systems, typically greater than 25 HP, because of the small incentive amount or cost. HPC Pump technology extends the energy saving opportunity of VFDs to the fractional HP 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 need to perform the duty the system

[8] Alpha 15-55 Product Specification

requires. HPC Pumps have the ability to (through the VFD) actively 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 shaft tension 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. All without end user interaction.

1.2 Product Parameter Data

1.2.1 DEER Data

The table below is meant to give a quick summary of any applicable DEER measures and the reason this work paper uses a method which deviates from DEER.

Table 1.2.1.1. DEER Difference Summary

DEER	Used in Workpaper Approach?
Modified DEER methodology	No
Scaled DEER measure	No
DEER base case used	No
DEER measure case used	No
DEER building types Used	No
DEER operating hours used	No
Reason for Deviation from DEER	There are no measures that directly contain this technology because it encompasses multiple technologies into one unit. There are past 2005 DEERs that tangentially relate to the technology such as DEER ID's: • **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
mmndDEER Version	N/A
DEER ID and Measure Name (Sample)	N/A

Table 1.2.1.2. DEER Net-to-Gross Ratios

From DEER Tables					
NTGR_ID	Description	Sector	Building Type	NTG	Program Delivery
DEER EUL ID:_All-Default<=2yrs_)	New Entry	Res	Home	0.7	ROB

From Existing Program Tables[9]					
Program Name	Description	Sector	Building Type	NTG	Program Delivery
Efficiency Vermont	HPC Upstream	Res/Comm	Home/Office	0.95	ROB
Energize Connecticut	HPC Upstream	Res/Comm	Home	0.95	ROB

Effective Useful Life / Remaining Useful Life

List the EUL or RUL according to DEER.

Table 1.2.1.3. DEER EUL Values/Methodology

READi EUL ID	Market	End Use	Measure	EUL (Years)	RUL (Years)
Motors-pump	Residential	Circulation	High Performance Circulator Pump	15	5

In-Service Rate / First Year Installation Rate:

It is assumed that the installation rate for all ROB products is close to 100%. Homeowners do not stockpile circulator pumps nor does the homeowner select the pump that will be used in their application. Plumbing contractors may keep a stock of one or two pumps on their service truck. The pump selection is made by the plumbing contractor who would visit the wholesaler at least two to three times per week to have pumps readily available to service the market. The Alpha serves the market well in this capacity as with its “right-sizing” ability, it is the single pump solution to the vast majority of installation opportunities. This eliminates the “over-sizing” problem that exists in the marketplace.

Table 1.2.1.4. Installation Rate

From DEER Tables					
GSIA_ID	Description	Sector	Building Type	GSIA Value	Program Delivery
Motors-pump	HPC Pump	Res	Home	1	ROB

[9] While these programs are principally directed towards hydronic heating applications, the current market share of HPC’s is similarly low as what is found for domestic hot water circulators.

READi Technology Fields

To support the development of the ED ex ante tables, select fields from the ex-ante database will be identified in the workpaper. For a full set of values associated with the measures in the workpaper refer the Excel calculation template. (In the event that the READi IDs do not support the technology in this workpaper simply indicate “Non-DEER” and propose a value.)

Table 1.2.1.5. READi Tech IDs

READi Field Name	Values included in this workpaper
Measue Case UseCategory	SHW
Measure Case UseSubCats	Distribute
Measure Case TechGroups	LiquidCirc
Measure Case TechTypes	FlowTempCtrl
Base Case TechGroups	LiquidCirc
Base Case TechTypes	FlowTempCtrl

1.2.2 Codes & Standards Requirements Base Case and Measure Information

Title 20: No Title 20 requirements exist for this product.

Title 24: No Title 24 requirements for ROB. But some NC requirements are in place:

- Section 150.1(c)8 – For recirculation distribution systems serving individual dwelling units, only demand recirculation systems with manual control pumps (as specified in T24 reference appendix RA4.4.9) shall be used.

- Section 150.1(c)8b – requiring 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.

Federal Standards: No Federal Standards at this time exist for in-line pumps smaller than 5 hp that are defined as circulator pumps. However, the Department of Energy (DOE) has begun formal negotiations on this product category with the intention of establishing energy efficiency standards, which will likely become effective in 5 years from the date of adoption.

One Quick Market Stance Note: The “right-sizing” ability of an HPCP is a tremendous energy savings advantage over the market standard. This workpaper targets the retrofit (ROB) applications where a contractor replaces a pump that has reached the end of its useful life. The mindset of that contractor is to replace the old pump with the current version of the new pump (taking into account the HP or wattage rating as the only sizing parameter). And if that pump is oversized to start it is “re-oversized” at replacement. This begs the question, “shouldn’t a contractor know how to accurately size the proper circulation pump?” The short answer is yes they should but knowing that these installations take place in a retrofit application the contractor does not have access to the information needed to properly size the “right-sized” circulator pump. The contractor will need to know the length and diameter of the pipe used in the piping system as well as the number of valves and fittings in the system and this is not possible as the walls in which these pumps are installed are covered with sheetrock. In order to accurately properly “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. The “right-sizing” HPCP presents the best opportunity for wide-spread market adoption.

1.2.3 Relevant EM&V Studies

1. Efficiency Vermont HPCP Rebate Program
https://www.efficiencyvermont.com/rebates/list/high-performance-circulator-pumps (last accessed 6/10/2016). As this program takes place in the northeast where HVAC applications are more prevalent than in California, this specific program focuses on circulator pumps for hydronic heating compared to DHW as is being proposed in this workpaper. However, the success from offering a rebate to incentivize the purchases of HPC Pumps is very apparent with this program, as outlined in Table 1.2.3.1.

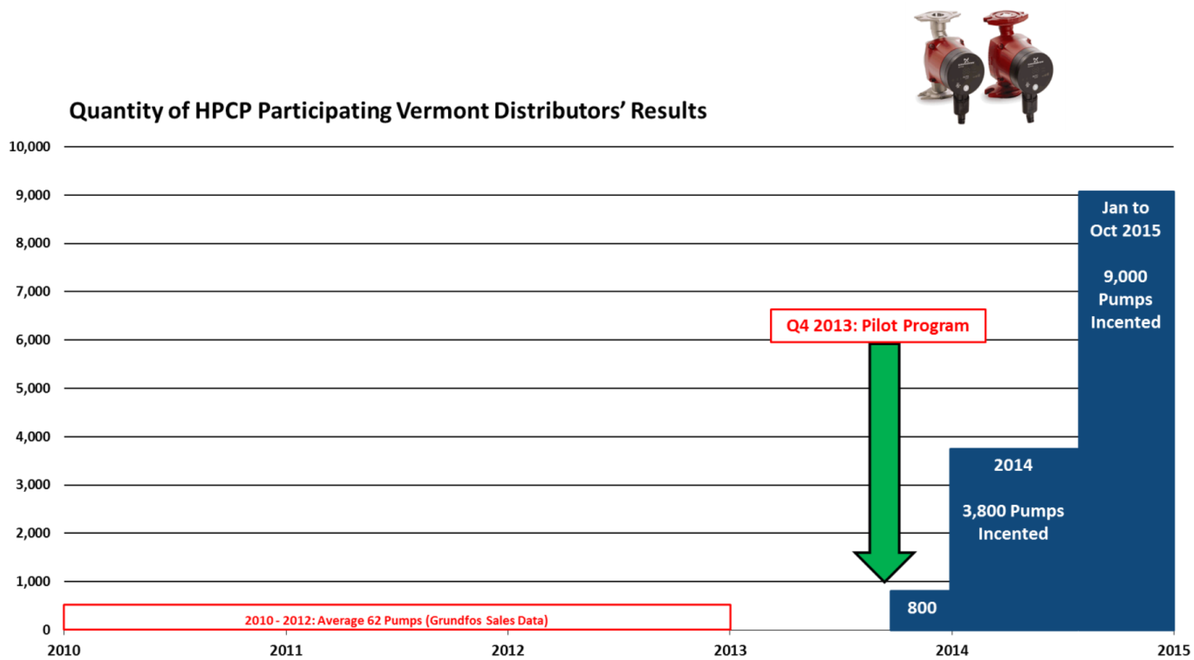


Table 1.2.3.1. Outlining sales data from the Efficiency Vermont HPC Pump rebate program.

1.2.4 Relevant Workpaper Dispositions

No relevant workpaper dispositions that relate to HPC Pump that we are aware of.

1.2.5 Other Sources for non-DEER Methods

- EPRI Report ("Assessment of New Energy Efficient Circulator Pump Technology", Product ID: 1020132, Published: Nov 15, 2010)
- Department of Energy Final Rule on Pump Efficiency, "Pumps ECS Final Rule"
- EPRI Report ("Assessment of New Motor Technologies and their Applications", Product ID: 3002001762, Published: Dec, 2013)
- Alpha Product Guide

Section 2. Calculation Methods

2.1 Program Implementation Analysis

Table 2.1.1. Baseline by Measure Application Type

Measure Application Type	Baseline	Baseline Technology	Duration
ROB	First	pump driven by non-regulated, low-efficiency induction type motors, do not utilize variable frequency drives (VFD), and do not have the control capability to match demand	EUL 15

2.2 Electric Energy Savings Estimation Methodologies

Table 2.2.1. First Baseline

Energy and demand impact common units	Per unit based on running wattage (taken from calculations based on submittal data)
Energy savings (Base case – Measure) (kWh/unit)	**Energy Savings (kWh/unit):** 1. Assumed: 6,427 Running Hours/ Year 2. Base Case: 0.084 kW 3. Measure Case: 0.012 kW 4. Savings: 0.072 kW/unit x 6,427 Running Hours/ Yr = 463 kWh Savings/ Year

2.3 Demand Reduction Estimation Methodologies

Table 2.2.3. First Baseline

Peak Demand Reduction (kW/unit)	**Peak Demand Reduction (kW/unit):** 1. Base Case: Grundfos UP 15-29 SU/LC – 87 Watts (Nameplate), **84.2 Watts (Running Watts** –see submittal data in REFERENCES section), most popular Grundfos pump sold into CA market 2. Measure Case: Grundfos Alpha 15-55 – 5 Watts minimum -45 Watts maximum (Nameplate), **12.1 Watts (Optimized Running Watts** – based on 2.45 GPM [1/2" return line at 4' per second velocity] @ 5.5' TDH [based on AutoAdapt proportional pressure curve]) 3. **Savings: 84.2 Watts – 12.1 Watts = 72.1 Watts (0.072 kW/unit)**

PLEASE NOTE: 6,427 running hours/ year is assumed in this workpaper and is the weighted average of pumps running with a combination of "on-demand", timer controlled, aquastatically controlled and no controls. With a strong knowledge of the CA market, Grundfos feels that the vast majority of pumps that would be targeted for replacement in this workpaper have an annual runtime of 8,760/ year. This is why we are carrying the Peak Demand Reduction based on the typical running and optimized running wattage.

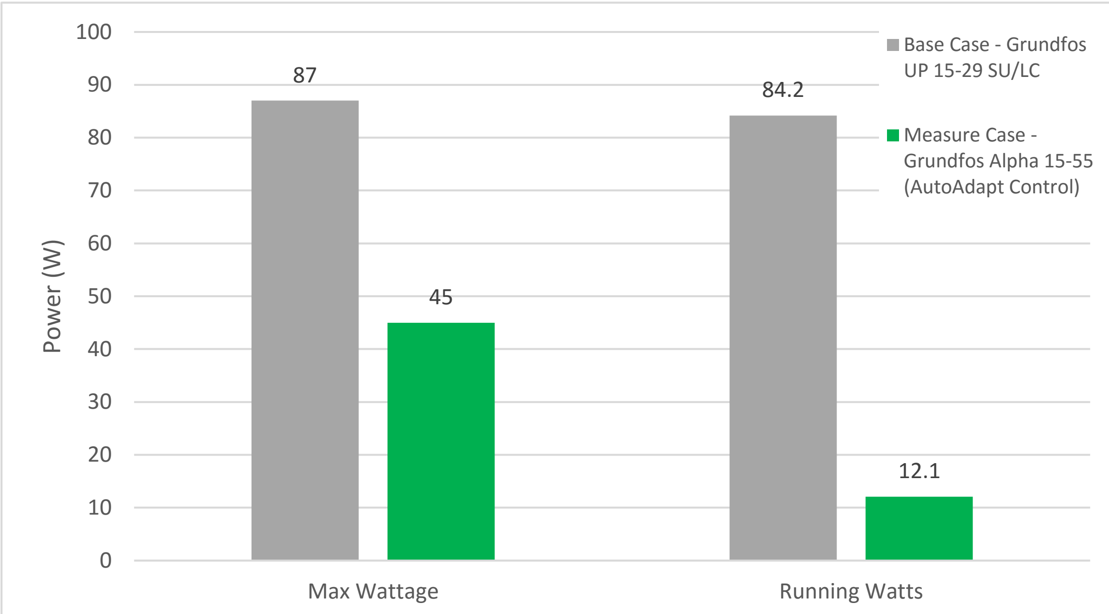


Figure 2.3.2. Illustrating the savings potential from the base case to measure case when in and out of AUTOADAPT controlling mode. The base case does not utilize any type of VFD or controlling logic, this is typical in the market place. The figure above shows the electrical savings potential due to the combination of the ECM, integrated VFD and controlling logic as the pump self-optimizes during its operation. See reference section for details on calculations from max watts to running watts.

2.4 Gas Energy Savings Estimation Methodologies

Not calculated, as measure case is assumed to be the same as the base case with respect to gas usage. Load Shapes

Target sector was used because the building type is residential homes, and the measure technology will be replacing a fixed speed pump that operates 24/7/365 and has a flat load shape.

Table 3.1. Building Types and Load Shapes

Building Type	E3 Alternate Building Type	Load Shape
Residential Home	NON_RES	Flat @ 6,427 hours

Section 3. Base Case, Measure, and Installation Costs

Table 4.1. Measure cost summary by application type

Measure Application Type	Base Case Equipment Cost	Measure Equipment Cost	Installation Cost ($/Unit)	Incremental Measure Cost	Full Measure Cost	Full Base Cost

	($/unit)	($/unit)		($/unit)	(1st Baseline period)[10] ($/unit)	(2nd baseline period)[11] ($/unit)
ROB	$231	$336	$300*	$105	$636	NA

* The installation cost is the same for the base case and the measured case.

3.1 Base Case(s) Costs

Costs have been taken directly from Grundfos sales channels and data, costs shown reflect pumps that will be installed in hot water recirculation (HWR) applications in CA. Pumps installed in HWR should be either bronze or stainless steel bodied. Pumps that are installed into HVAC applications should be cast iron bodied. Cast iron bodied pumps cost less, but are outside the scope of this workpaper. Because we are a manufacturer of the product identified in this workpaper we have intimate knowledge of the sales process and pricing levels. Costs can deviate based on sales area - and comparable pumps from a variety of manufacturers are going to be priced within 5 – 10% of our estimated figures. See qualifying product list[12] from the Efficiency Vermont program where the incentive (similar to our IMC) will pay out the same for a variety of HPC Pumps from different manufacturers in the same class.

3.2 Measure Case Costs

Costs have been taken directly from Grundfos sales channels and data. Because we are a manufacturer of the product identified in this workpaper we have intimate knowledge of the sales process and pricing levels. Costs can deviate based on sales area - and comparable pumps from a variety of manufacturers are going to be priced within 5 – 10% of our estimated figures. See qualifying product list[12] from the Efficiency Vermont program where the incentive (similar to our IMC) will pay out the same for a variety of HPCP pumps from different manufacturers in the same class.

3.3 Installation/Labor Costs

The scope of this workpaper is constrained to hot water recirculation applications. There may be a difference in labor costs for HVAC applications, but here we assume the installed and labor costs are the same for the base and the measure case. The estimate for installation and labor is approximately $300/unit, however, this number will vary by contractor.

3.4 Incremental & Full Measure Costs

Table 3.4.1. Incremental measure cost calculations

[10] Full measure cost = measure equipment cost + installation cost, for first baseline period
[11] Full base cost = 2nd baseline equipment cost + installation cost, for the second baseline period
[12] https://www.efficiencyvermont.com/Media/Default/docs/rebates/qpls/efficiency-vermont-high-performance-circulator-pumps-qualifying-products.pdf

Measure Application Type	Equation ($/unit)	Results ($/unit)
ROB	**Incremental Measure Cost** = (Measure Equipment Cost + Measure Labor Cost) – (Base Case Equipment Cost + Base Case Labor Cost)	**($336+$300) - ($231+$300) = $105**

Appendices

Appendix 1 – Cal TF Workpaper Template

Cal TF Workpaper Template.xlsx

Appendix 2 - Measure Application Type Definitions

The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls*, defines the measure application type terms as follows:

Measure Application Type

Code	Description	Comment
ER	Early retirement	Measure applied while existing equipment still viable, or retrofit of existing equipment
EAR	Retrofit Add-on	Retrofit to existing equipment without replacement
ROB	Replace on Burnout	Measure applied when existing equipment fails or maintenance requires replacement
NC	New Construction	Measure applied during construction design phase as an alternative to a code-compliant standard design

Baseline Technologies for UES and Cost calculations[13]

Measure Application Type	Baseline	Baseline Technology	Measure Cost Calculation	Duration
ER	First	Existing technology	Measure equipment cost + labor cost	RUL = 1/3*EUL[14]
	Second	Code or standard	(-1)*(Code/standard equipment cost + labor cost)	EUL - RUL
REA	First	Existing technology	Measure equipment cost + labor cost	EUL
	Second	N/A	N/A	N/A
ROB	First	Code or standard	(Measure equipment cost + labor cost) – (Code/standard cost + labor cost)	Full EUL
	Second	N/A	N/A	N/A
NC	First	Code or standard	(Measure equipment cost + labor cost) – (Code/standard cost + labor cost)	Full EUL
	Second	N/A	N/A	N/A

[13] According to the Energy Efficiency Policy Manual v.5 at page 32, the measure cost for an early-retirement case is "the full cost incurred to install the new high-efficiency measure or project, reduced by the net present value of the full cost that would have been incurred to install the standard efficiency second baseline equipment at the end of the [RUL] period". Page 33 elaborates that "the period between the RUL and EUL defines the second baseline calculation period…the measure cost for this period is the full cost of equipment, including installation, for the second baseline equipment measure".

[14] The Energy Efficiency Policy Manual v.5 at page 33 states "the remaining useful life (RUL)…[is established by DEER] as one-third of the expected useful life (EUL) for the equipment type".

Appendix 3 – Measure Cost Overview

Measure Cost rev9.docx

Appendix 4 – CPUC Quality Metrics

CPUC workpaper development actions to ensure quality are listed below, adapted from ex ante implementation scoring metrics described in Attachment 7 of Decision (D).13-09-023. The corresponding scoring metrics are shown below.

Metric	Workpaper Development Action to Ensure Quality
2	Address all aspects of the Uniform Workpaper Template[15]
3a[16]	Include appropriate program implementation background
3b	Include analysis of how implementation approach influences development of ex ante values
3c	Include all applicable supporting materials
3d	Include an adequate[17] description of assumptions or calculation methods
4	Pursue up-front collaboration on high impact measures with Commission staff prior to formal submission for review
7	Include analysis of recent and relevant existing data and projects that are applicable to workpaper technologies for parameter development that reflects professional care, expertise, and experience
9	Appropriately incorporate DEER assumptions, methods, and values for new or modified existing measures using professional care and expertise
10	Incorporate cumulative experience into workpaper through inclusion of an analysis of previous activities, reviews, and direction. (ED expects IOUs to immediately incorporate disposition guidance into workpapers to be submitted for formal review)

[15] The Uniform Workpaper Template is not posted on the DEER website as of 4/21/14, and is currently in Microsoft Access Database format.
[16] Metric 3 is not split among a – d in Attachment 7, however metric 3 was separated into four subcategories in this document for the purposes of identifying individual workpaper development actions to address quality.
[17] "Adequate" is defined in Attachment 7 such that derivations of underlying assumptions of workpaper are easy to understand by the CPUC reviewer.

Appendix 5 – DEER Resources Flow Chart

Draft DEER
Resources Flow Cha

References

Table of Contents

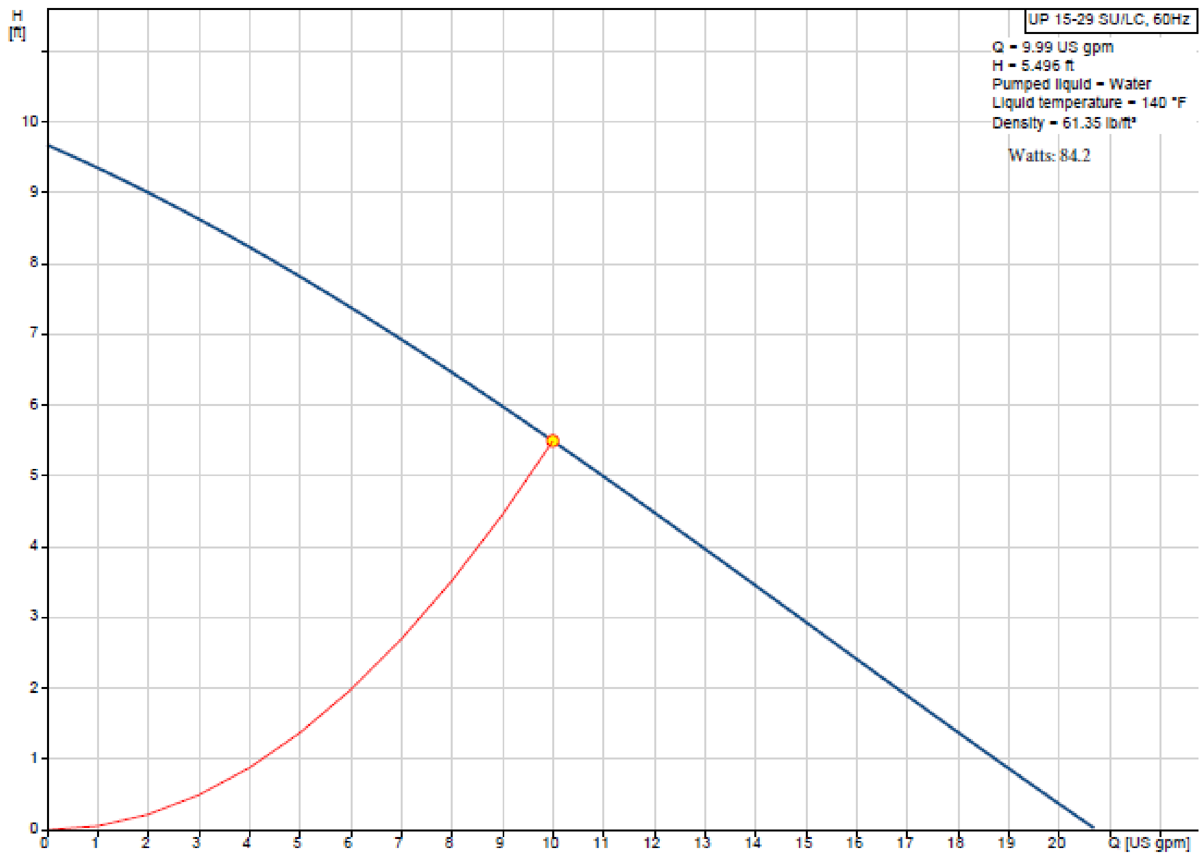
1. BASE CASE PUMP SUBMITTAL DATA

Product photo could vary from the actual product

UP 15-29 SU/LC

Circulator pumps

Conditions of Service		Pump Data		Motor Data	
Flow:	9.99 US gpm	Maximum operating pressure:	145 psi	Max. power input:	87 W
Head:	5.496 ft	Liquid temperature range:	35.6 .. 230 °F	Rated power - P2:	0.121 HP
Efficiency:		Maximum ambient temperature:	104 °F	Rated voltage:	115 V
Liquid:	Water	Approvals:	UL, CSA	Main frequency:	60 Hz
Temperature:	140 °F	Type of connection:	S.S. Union	Insulation class:	F
NPSH required:	ft	Flange standard:	USA Threaded	Motor protection:	CONTACT
Viscosity:		Pipe connection:	1 1/4" NPSM	Thermal protection:	internal
Specific Gravity:	0.985	Product number:	59896776		

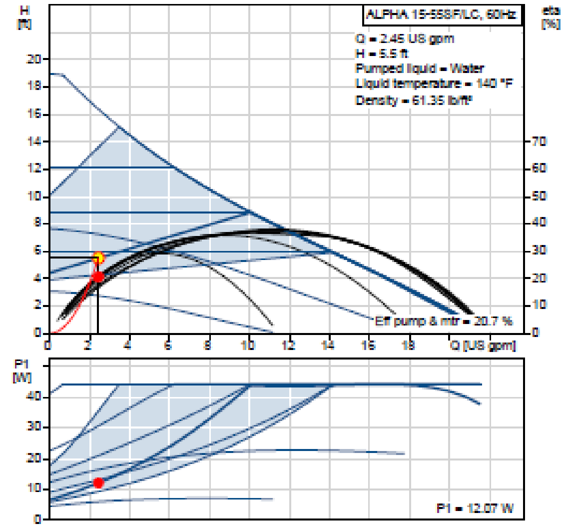


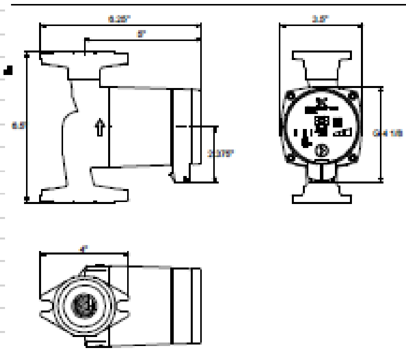
2. MEASURE CASE PUMP SUBMITTAL DATA

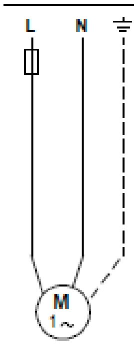
Company name: Grundfos Pumps
Created by:
Phone:

Date: 7/7/2016

Description	Value
General information:	
Product name:	ALPHA 15-55SF/LC
Product No.:	59896834
EAN:	5700312930129
Price:	On request
Technical:	
Actual calculated flow:	2.45 US gpm
Resulting head of the pump:	5.5 ft
Head max:	18.05 ft
TF class:	110
Approvals on nameplate:	ETL, FCC
Materials:	
Pump housing:	Stainless steel
	DIN W.-Nr. 14308
	ASTM CF8
Impeller:	Composite, PES
Installation:	
Range of ambient temperature:	32 .. 104 °F
Maximum operating pressure:	145 psi
Pipe connection:	G 1 1/2
Pressure stage:	PN 10
Port-to-port length:	6 1/2 in
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	35.6 .. 230 °F
Liquid temp:	140 °F
Density:	61.35 lb/ft³
Electrical data:	
Power input - P1:	5 .. 45 W
Main frequency:	60 Hz
Rated voltage:	1 x 115 V
Maximum current consumption:	0.1 .. 0.65 A
Enclosure class (IEC 34-5):	IP42
Insulation class (IEC 85):	F
Motor protection:	NONE
Thermal protec:	ELEC
Controls:	
Pos term box:	6H
Others:	
Net weight:	5.95 lb
Gross weight:	6.17 lb
Shipping volume:	87.6 ft³
Sales region:	USA







2.A. Efficient Option Component Breakdown

<u>Grundfos Alpha 15-55 SF/LC</u>

Pump Wet End: Stainless Steel for OPEN (plumbing) applications, Cast Iron for CLOSED (HVAC) applications, 6-1/2" flange-to-flange (standard)

Integrated VFD: VFD built directly into the pump, allows for self-optimization ability

Self-Optimizing: Algorithm dictates pumps performance and right-sizes for the specific application into which it is installed

Control Modes: Single button allows changing to seven different control modes. AUTOAdapt is default setting. Active mode is lit.

Control Modes: The Grundfos Alpha offers seven different control modes: AUTOAdapt (self-optimizing, default setting), three fixed speeds (HI, MED, LOW) and three constant pressure (HI, MED, LOW). The Alpha is defaulted to operate in AUTOAdapt at start up and is the optimal control mode to optimize energy consumption. In the event of a power outage, the Alpha will restart in the control mode that was last utilized. The display on the Alpha alternates between a flow indication (in GPM) and current wattage consumption. The display will alternate between these two figures every four seconds.

UNITARY SOLUTION: The Grundfos Alpha is a unitary solution. This means that it is a "plug and pump solution". Out of the box, the Alpha has the wet end pump, integrated VFD and self –optimizing ability. There is no need for external equipment in order to gain energy savings. Installation takes no additional time, expense or complication as compared to the current market standard.

3. California Circulator Wholesale Market Landscape Analysis

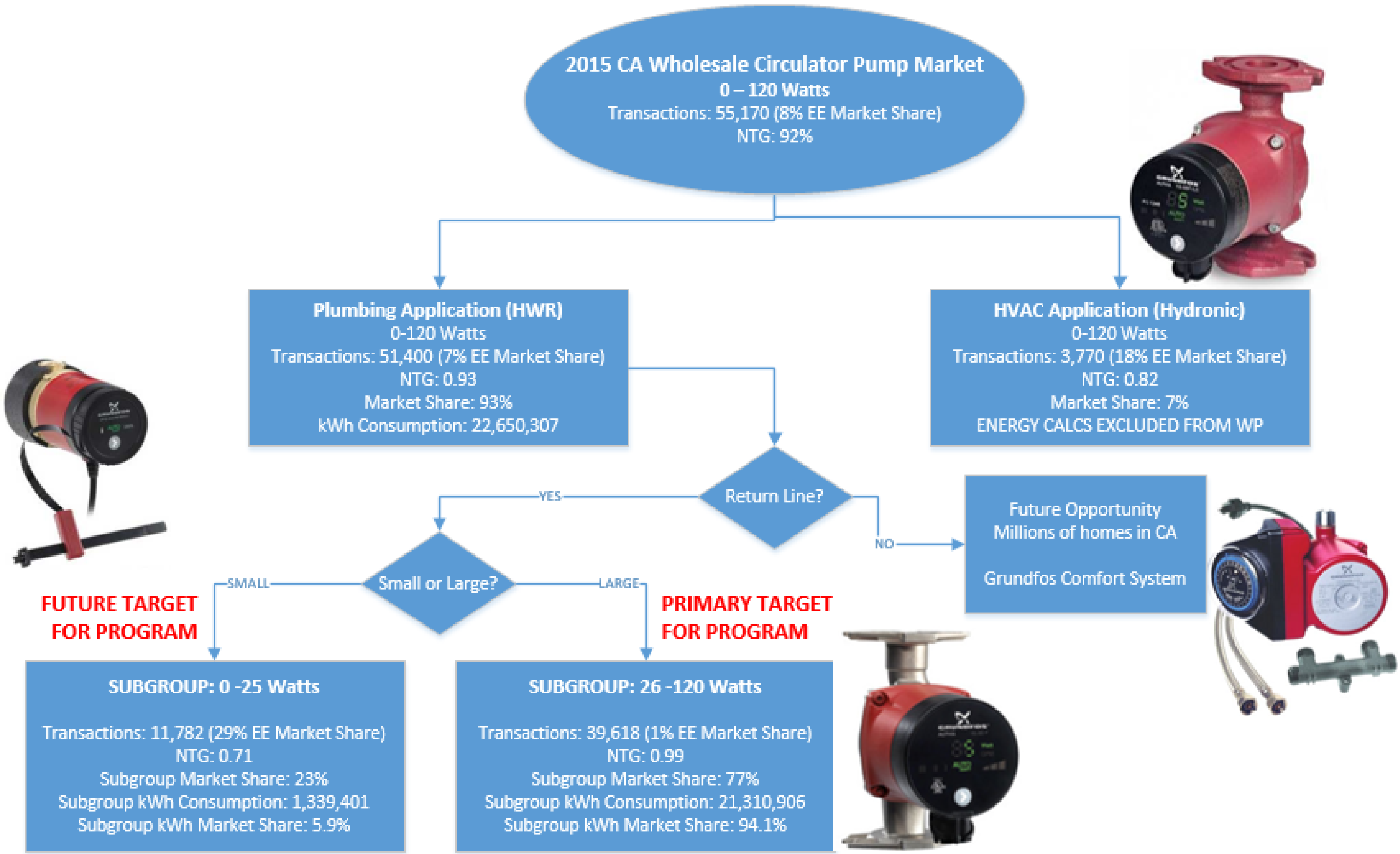
CA Wholesale Circulator Market (Up to 120 Watts)

Plumbing (HWR):	51,400	93.2%	***Focus of Workpaper - Energy Calcs Based On This Market Application***
Hydronic (HVAC):	3,770	6.8%	***Market Application is EXCLUDED From Energy Calculations***
TOTAL:	55,170	Qty Pumps Transacted/ Yr	

MARKET SEGMENT - UP TO 25 WATTS - PLUMBING MARKET				**MARKET SEGMENT OF 26 - 120 WATTS - PLUMBING MARKET**			
% of CA Market:	22.9%			% of CA Market:	77.1%		
Market Qty:	11,782			Market Qty:	39,618		
Market Standard (Up To 25 Watts)		**Efficient Option (Up To 25 Watts)**		**Market Standard (26 - 120 Watts)**		**Efficient Option (26 - 120 Watts)**	
Market Segment:	70.6%	Market Segment:	29.4%	Market Segment:	99.3%	Market Segment:	0.7%
UP 15-10 B5/TLC (P/N: 59896215)		Comfort PM Auto		UP 15-29 SU/LC (P/N: 59896776)		Alpha 15-55 SF/LC (P/N: 59896834)	
Max Watts:	25	UP 10-16 A PM BU/ LC (P/N: 98420224)		Max Watts:	87		
% Max Watts:	97%	Max Watts:	8.5	% Max Watts:	97%		
Running Watts:	24.25	kW:	0.009	Running Watts:	84.2	Running Watts:	12.1
kW:	0.024	Running Hours/ Day:	4	kW:	0.084	kW:	0.012
Running Hours/ Yr:	6427	Running Hours/ Yr:	1460	Running Hours/ Yr:	6427	Running Hours/ Yr:	6427
kWh/ Yr/ Pump:	156	kWh/ Yr/ Pump:	12.4	kWh/ Yr/ Pump:	541	kWh/ Yr/ Pump:	78
		kWh Savings/ Pump:	143			kWh Savings/ Pump:	463
Existing Market (Qty):	8,318	Existing Market (Qty):	3,464	Existing Market (Qty):	39,341	Existing Market (Qty):	277
Existing Market kWh/ Yr:	1,296,414	Existing Market kWh/ Yr:	42,987	Existing Market kWh/ Yr:	21,289,339	Existing Market kWh/ Yr:	21,567
Existing CA Market kWh:	1,339,401			Existing CA Market kWh:	21,310,906		
Total Existing CA Market kWh:	**22,650,307**						
Transformed Market Potential						**Market Conversion Rate:**	**100%**
Market Standard (Up To 25 Watts)		**Efficient Option (Up To 25 Watts)**		**Market Standard (26 - 120 Watts)**		**Efficient Option (26 - 120 Watts)**	
Qty Pumps Transacted:	0	Qty Pumps Transacted:	11,782	Qty Pumps Transacted:	0	Qty Pumps Transacted:	39,618
kWh:	0	kWh:	146,215	kWh:	0	kWh:	3,080,961
Transformed CA Market kWh:	146,215			Transformed CA Market kWh:	3,080,961		
Total Transformed CA Market kWh:	**3,227,176**						
kWh Savings:	**19,423,132**			**Savings %:**	**86%**		

kWh Savings by Market Conversion Rate

25%: 4,855,783 (21% Savings)	75%: 14,567,349 (64% Savings)
50%: 9,711,566 (43% Savings)	100%: 19,423,132 (86% Savings)



Plumbing Applications - Up to 25 Watts

1,339,401 :Existing kWh Consumption

Mrkt Conv	kWh Savings Pot'l	% Savings
25%	298,296	22%
50%	596,593	45%
75%	894,890	67%
100%	1,193,186	89%

Plumbing Applications - 26 - 120 Watts

21,310,906 :Existing kWh Consumption

Mrkt Conv	kWh Savings Pot'l	% Savings
25%	4,557,491	21%
50%	9,114,972	43%
75%	13,672,459	64%
100%	18,229,945	86%

Plumbing Applications -TOTAL

22,650,307 :Existing kWh Consumption

Mrkt Conv	kWh Savings Pot'l	% Savings
25%	4,855,787	21%
50%	9,711,565	43%
75%	14,567,349	64%
100%	19,423,131	86%

4. How is running wattage calculated?

Calculating running wattage for this class of fractional HP circulating pumps can be difficult as power and efficiency curves are often NOT published. This is especially the case for the market standard (inefficient) option. However, for the efficient option (measure case) Grundfos DOES publish the power and efficiency curves.

Market Standard:
For the purposes of the work paper, we included unpublished information on the wattage at the best efficiency point (BEP). Max wattage from nameplate is 87 Watts.

Operation	GPM	TDH	Watts
Dead Head (Max Head)	0.0	9.7	80.4
BEP	10.0	5.0	84.2
Run Out (Max Flow)	19.4	0.7	85.8

In the hot water recirculation application, the selected pumps flow is sized based on maximum water consumption ("worst case scenario" – all taps open) and total dynamic head is calculated based on length and diameter of pipe, valves and fittings. In reality the pumps operation would be at very low flows the vast majority of its operating hours, this would result in an over production of head as the market standard pumps operating performance is set on its fixed speed pump curve. The result is that the actual power consumption may be a bit less than the estimate provided in this work paper, but Grundfos is assuming that the market standard is operating at its best efficiency point. The difference between actual wattage consumption and calculated running watts would be minimal (within 5%) but could be verified potentially through the measurement and verification process.

Efficient Option:
We know that the Alpha will be running in AUTOAdapt control mode, which is a proportional pressure control scheme. This means that as flow decreases, head will also decrease. Knowing this we can estimate the (1) flow rate in GPM, (2) the head produced based on the proportional pressure operation and lastly (3) the running wattage.

1. Assumed ½" return line on hot water return line to heat source, water traveling at 4 ft./ second velocity, **GPM would be 2.45**.
2. Based on the operation of AutoAdapt, we can firmly estimate the proportional pressure curve on which the Alpha will operate. The total dynamic head **(TDH) will be 5.5'**.
3. Because power and efficiency curves ARE published, we know that the Alpha consumes **12.1 Watts of power at 2.45 GPM @ 5.5' TDH**.

In reality, the pump may run at a lower flow as the pump continues to operate in and learn the system into which it is installed. So the "steady state" duty point and consumption may be less than what is estimated in this work paper. The minimal wattage consumption for the Alpha is 5 Watts so the "steady state" power consumption could be between 5 Watts and 12.1 Watts.

5. Dept. of Energy Circulator Work Group Circulator Pump Running Hours

Control Type	Sector	Fraction of Consumers	HPY	Notes
No Control	Residential	50%	8760	Constant Operation
	Commercial			
Timer	Residential	25%	7300	50%@ 24/7 and 50%@ 16hrs/day
	Commercial		6570	50%@ 24/7 and 50%@ 12hrs/day
Aquastat	Residential	20%	1095	3 hrs per day
	Commercial			
On Demand	Residential	5%	61	10 minutes per day*
	Commercial		122	20 minutes per day*

*Assuming that circulators operate for 30 sec for each demand "push"

- Assumed that operating hours do not vary by region and applied a ±20% variation to the estimated HPY.
- Weighted average HPY: **Residential: 6,427; Commercial: 6,248**

Running hours/ year of 6,427 is assumed in this work paper. Note that this is a weighted average of pumps that have no control, timer, aquastat and On-Demand operation type.