Efficiency Maine Trust
Heat Pump Water Heater Initiatives
Impact Evaluation

Program Years 2015-2017

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Prepared For

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Executive Summary

This report covers the impact evaluation and cost-benefit analysis of heat pump water heaters (HPWHs) incentivized through Efficiency Maine Trust's (EMT's) Consumer Products Program (CPP) and the Low-Income Direct Install (LIDI) Initiative. The evaluation period covers projects completed between July 1, 2014 and June 30, 2017.

The Consumer Products Program provides homeowners with mail-in rebates for the purchase of high-efficiency appliances and incentivizes LED bulbs. Appliances installed through the program include air purifiers, clothes washers, dehumidifiers, and heat pump water heaters.

Through the Low-Income Direct Install Initiative, heat pump water heaters are installed in low-incomes homes with pre-existing electric resistance water heaters. LEDs and low-flow showerheads, bathroom aerators, and kitchen aerators are offered to homeowners who do not already have them installed as a package with the heat pump water heater. The initiative covers 100% of the project cost for low-income Maine residents who are eligible to participate.

This evaluation covers heat pump water heaters installed through the two programs. The analysis used several combinations of methods chosen to balance cost and accuracy.

Evaluation Overview

The objectives of this impact evaluation were to develop estimates for the gross energy savings, peak demand reduction, and realization rates for heat pump water heaters installed between July 2014 and June 2017 (FY2015 - FY2017). Additional outcomes of the study included calculating free ridership (FR) for the CPP and benefit-cost ratios (BCR) for both programs. Spillover (SO) was not estimated as there was no clear, causal pathway between the program and potential sources of SO. FR and SO were not evaluated for the LIDI Initiative, as free ridership is commonly assumed to be 0% for this type of program.[1]

Heat pump water heater savings were evaluated using on-site measurement and verification. Short-term *in situ* metering was conducted on a sample of 58 CPP and 58 LIDI homes to estimate heat pump water heater gross savings. Metering deployments were conducted in six phases throughout the year, from October 2017 to September 2018. Each home was metered for four weeks in the existing operational mode to assess the HPWH efficiency and two weeks in electric resistance mode to determine the hot water energy consumption. Metering throughout the year provided the opportunity to investigate seasonal effects on heat pump water heater performance. Energy savings were estimated according to the level of hot water load, which is a driving factor affecting the savings.

Detailed customer surveys were conducted to inform the estimation of gross savings. The impact evaluation team also developed in-service rate (ISR) estimates for LEDs and low-flow devices for LIDI homes that completed on-site metering.

[1] In addition, West Hill Energy and Computing conducted the impact evaluation of a low-income residential program in New York State and found the free ridership was 3% mostly associated with small, low cost measures such as CFLs.

The evaluation activities and outcomes are presented in Table ES-1 below.

TABLE ES-1: SUMMARY OF EVALUATION ACTIVITIES

Evaluation Activity	Program Attribution	Baseline Assumptions	Energy and Demand Savings	TRM Adjustments	Realization Rate
On-Site Measurement		√	√	√	√
Customer Surveys	√	√		√	√
Manufacturer Data		√		√	

Net savings were estimated using the self-report method and incorporated responses to program influence questions. Both the self-report and program -influenced questions were tied to the program's causal mechanisms.

Evaluation Results

A summary of the gross and net savings, by program, are summarized in Table ES-2 below.

TABLE ES-2: SUMMARY OF EVALUATED SAVINGS PER HOME BY PROGRAM

Program	Average *Ex Ante* Savings per Site	Evaluated Gross Savings per Site	Realization Rate	Evaluated Program NTGR	Evaluated Net Savings[1]
Consumer Products Program (CPP)	1,797 kWh/year	1,949 kWh/year	108%	69%	1,345 +/- 146 kWh
	0.338 Winter peak kW[2]	0.307 kW	79%	69%	0.212 kW
	0.181 Summer peak kW[3]	0.212 kW	117%	69%	0.146 kW
Low Income Direct Install (LIDI) Program	2,008 kWh/year	1,634 kWh/year	81%	100%[4]	1,634 +/- 77 kWh
	0.427 Winter peak kW[2]	0.257 kW	60%	100%[4]	0.257 kW
	0.199 Summer peak kW[3]	0.178 kW	89%	100%[4]	0.178 kW

[1] Confidence intervals were calculated at the 80% confidence level.
[2] Winter peak period is December and January from 5 to 7 PM per EMT TRM.
[3] Summer peak period is June through August from 1 to 5 PM per EMT TRM.
[4] Assumed 0% FR for low income program.

For the CPP, the FR was estimated by using both self-report and program influence based on the participant surveys. The results from the two methods were extremely close, as summarized in Table ES-3.

Table ES-3: Summary of NTGR For Consumer Products Program

Measure	Self-Report NTGR[1]	Program influence NTGR[1]	Final NTGR[2]
Heat Pump Water Heaters	70%	69%	69% +/- 7%

[1] NTGR = 1 – FR (Free rider rate).
[2] Final NTGR is the average of the self-report and program influence NTGR's.

The benefit-cost analysis showed that all measures offered through the CPP and LIDI programs are cost-effective. The calculations from the base case primary benefit-cost test (PBCT) and program administrator cost test (PACT) for each measure show that all measure-level PBCT ratios are greater than 1. The results for CPP are presented in Table ES-4 below.

Table ES-4: CPP Base Case PBCT and PACT

Measure	PBCT	PACT
Heat Pump Water Heater	1.23	1.52
Program	1.06	1.27

The PBCT results for LIDI are presented in Table ES-5 below. For LIDI, the PBCT and PACT produced the same results because all inputs are the same.[2]

Table ES-5: LIDI Base Case PBCT and PACT

Measure	PBCT/PACT
Heat Pump Water Heater Direct Install	1.09
LED Low Income Standard Bulb Long Life	1.49
Low Flow Bathroom Aerator Direct Install	1.90
Low Flow Kitchen Aerator Direct Install	4.67
Low Flow Shower Head Direct Install	3.01
Program	1.03

[2] The difference between the PBCT and PACT is that the PACT includes only the costs to the program administrator, whereas the PBCT also includes the participant costs. In LIDI, the program administrator covers all of the costs of the installation at no cost to the participant. Consequently, the results of the PBCT and PACT are the same for LIDI.

Key Findings and Observations

In general, heat pump water heaters (HPWHs) are effective and use substantially less electricity than stand-alone electric water heaters, as shown in Table ES-2 above. The following three terms are used in the description of the analysis:

- **Hot water energy consumption** is the total input energy (kWh) to the water heater required to heat the water, including efficiency losses. The hot water energy consumption is multiplied by the efficiency of water heater to obtain the hot water load.
- **Hot water load** is the output energy (kWh) from the water heater to provide the required amount of hot water; the hot water load is divided by the efficiency of the water heater to calculate the hot water energy consumption.
- **Hot water demand** is the amount of hot water (gallons) required by the household

The key findings and observations from the evaluation are discussed below.

Technical and Survey Findings

On average, about half of the HPWHs were used in hybrid mode and half in heat pump mode. While the metered average Coefficient of Performance (COP) was higher than was found in other field studies, the hot water load was lower. These two effects (one upward and one downward) offset the savings for CPP and resulted in lower savings for LIDI. Some of the technical findings are summarized in Table ES-6.

TABLE ES-6: TECHNICAL FINDINGS FROM THE HPWH METERING AND SURVEY

Topic	Findings	Comments
Hybrid v Heat Pump Mode	Homes with lower hot water demand: savings are similar in hybrid and heat pump modes	Electric elements in hybrid mode are less likely to turn on when loads are lower.
	Homes with higher hot water demand: savings are higher in heat pump mode	Recovery time is longer in heat pump mode and residents are more likely to switch to hybrid.
COP	Evaluated average COP in this study was higher than found in other, metering-based studies.	2.80 for CPP and 2.85 for LIDI, as compared to 2.46 (CT study) and 1.85 (Winters study).
Average Hot Water Energy Consumption in electric resistance mode	Hot water energy consumption in electric resistance mode was found to be lower in this evaluation than other metering-based studies.	7.1 kWh/day for CPP and 5.9 kWh/day for LIDI, as compared to 8.4 (CT) and 9.1 (Winter).
HPWH Location	Most HPWHs (78%) are installed in basements that are not intentionally heated. [1]	There were no thermostats in the basement, although the heating system was often located in the basement.
Interactive Effects	HPWHs do not appear to be increasing the space heating requirements of the home.	Analysis of heating system use for 13 homes showed no extra use in heat pump mode as compared to electric resistance mode.
	Impacts on air-conditioning could not be determined.[2]	Although 34 homes were metered during the summer, there were only 6 homes with air-conditioning in areas that could be affected by the HPWH, which was not a sufficient sample size to estimate interactive impacts
	HPWHs are reported to be reducing dehumidifier use in a small percent of homes.[3]	About 3% of survey respondents reported removing the dehumidifier, 9% reported reducing use by 1 month a year or more and 6% by 3 months or more.

[1]78% is an average percentage for both CPP and LIDI based on 116 site visits. About 81% of the 58 LIDI HPWHs were installed in unheated basements. About 16% were installed in heated basements and the remaining 3% in closets in living space. About 74% of the 58 CPP heat pump water heaters were installed in unheated basements. About 21% were installed in heated basements and the remaining 5% were installed in unheated utility rooms and an unheated cellar.
[2] Direct measurements were insufficient to estimate the impact due to the small number of homes with central air conditioners in use during the metering period.
[3] Direct measurements were insufficient to estimate the reduction due to the small number of homes with dehumidifiers in use during the metering period.

Ninety-three percent (93%) of survey respondents reported being very satisfied, or somewhat satisfied, with the HPWH. Seven percent (7%) reported the HPWH did not provide sufficient hot water and 10% reported dissatisfaction with the noise level.

TRM Prospective Adjustments

Heat pump water heater COPs have increased over the years resulting in more savings when compared against an electric resistance water heater. This evaluation covered program years 2015 to 2017 and the HPWHs installed during that time period. Recognizing the evaluated savings reflect one particular period of time, we recommend the savings be calculated as given in Equation ES-1. Adjustment factors and initial inputs into the equations are provided below.

Equation ES-7: TRM Savings Calculation

$$kWh_{savings} = kWh_{hw} \times \left(\frac{1}{EF_{BASE}} - \frac{1}{(COP_{rated} \times EAF)}\right)$$

Winter and summer peak savings can then be calculated by applying the ratio of peak to kWh savings.

Table ES-7: Inputs into the TRM Savings Calculation

Input	Description	Recommended Value	Source
CPP kWh_{hw}	kWh annual hot water load	2,821 kWh	RECS 2015, adjusted for occupancy
LIDI kWh_{hw}	kWh annual hot water load	2,364 kWh	RECS 2015, adjusted for occupancy and lower use in low income homes
EF_{BASE}	Energy Factor of the baseline water heater	94.5%	Maine 2017 TRM[1]
COP_{rated}	Rated COP of the HPWH	Actual Value	Manufacturer cut sheets
EAF	Efficiency Adjustment Factor, ratio of actual COP from field metering to rated COP	CPP: 88% LIDI: 83%	Metering
WP Factor	Winter peak savings/kWh savings	0.000157	Metering
SP Factor	Summer peak savings/kWh savings	0.000109	Metering

[1] This value is also consistent with the baseline efficiency used in the analysis of HPWHs in the CT study.

This approach provides flexibility to adjust savings, as the average efficiency of the unit increases and/or estimates of hot water load are updated.

1 Introduction

This report covers the impact evaluation and cost benefit analysis conducted for two of Efficiency Maine's heat pump water heater programs: Consumer Products Program (CPP) and Low-Income Direct Install Initiative (LIDI). The evaluation period covers projects completed between July 1, 2014 and June 30, 2017.

The Consumer Products Program provides mail-in rebates for the purchase of high-efficiency equipment and incentivizes LED bulbs. Appliances installed through this program include air purifiers, clothes washers, dehumidifiers, and heat pump water heaters. The program started providing instant rebates at the distributor level in early 2017. The Low-Income Direct Install Initiative installs water heaters in low-income homes previously served with electric resistance water heaters. The initiative covers 100% of the project costs for eligible low-income Maine residents.

1.1 Evaluation Objectives

The impact evaluation objectives were to estimate gross energy savings, peak demand reduction, and realization rates for heat pump water heaters installed between July 2014 and June 2017 (FY2015 - FY2017). The outcomes for this study include the following:

- Develop gross program energy (kWh) and summer and winter demand (kW) savings
- Calculate realization rates
- Recommend changes to the Technical Reference Manual (TRM), as needed
- Estimate the net-to-gross ratio (NTGR) for the evaluated measures
- Conduct a benefit/cost analysis using the evaluated savings

The impact evaluation team also developed in-service rate (ISR) estimates for LEDs, low-flow showerheads, and aerators for LIDI homes that completed heat pump water heater on-site metering. The next section provides further detail on the evaluation approach.

1.2 Evaluation Approach

On-site measurement and verification were the primary method used to estimate heat pump water heater electric savings. Table 1-1 summarizes evaluation activities for this study.

TABLE 1-1: SUMMARY OF EVALUATION ACTIVITIES

Evaluation Activity	Program Attribution	Baseline Assumptions	Energy and Demand Savings	TRM Adjustments	Realization Rate
On-Site Measurement		√	√	√	√
Customer Surveys	√	√		√	√
Manufacturer Data		√		√	

1.3 Organization of the Report

Table 1-2 provides a short description of each chapter in the report.

TABLE 1-2: REPORT ORGANIZATION BY CHAPTER

Chapter	Title	Description
	Executive Summary	Brief description of methods and results
1	Introduction	Overview of the evaluation
2	Program Description	Brief description of the CPP and LIDI initiatives and *ex ante* savings
3	Gross Savings Methods	Methods used to estimate heat pump water heater electric savings
4	Gross Savings Results	Gross savings results by program
5	Net-to-Gross Analysis	Methods and results for the NTG analysis for the CPP program
6	Participant Survey Results	Key results from the detailed customer survey
7	Benefit-Cost Analysis	Methods and results for the benefit cost analysis
8	Review of TRM Methods and Inputs	Summary of recommendations for changes to the TRM
9	Findings and Observations	Overview of the evaluation findings
10	References	List of key documents used in the preparation of this report
A	Appendix A: Sampling Approach	Sampling approach used to select homes for metering and surveys
B	Appendix B: Customer Survey Instruments	Customer survey used to recruit for on-sites and a detailed survey to collect additional information on HPWH operation and NTG
C	Appendix C: Customer Survey Findings	Results from the detailed customer survey
D	Appendix D: Heat Pump Water Heater Site Visit Protocols and Forms	Protocols and data collection forms used to conduct on-site measurement and verification
E	Appendix E: Gross Saving Methods	Additional details on methods used to estimate gross savings
F	Appendix F: Benefit Cost Analysis Details	Additional details on the benefit cost analysis methods and sensitivity analyses results

2 Program Description

This section provides a description of the two-heat pump water heater programs and a summary of the *ex ante*[3] electric savings during the evaluation period.

2.1 Consumer Products Program (CPP)

The Consumer Products Program provides mail-in rebates for the purchase of high-efficiency appliances and incentivizes LED bulbs. The appliance portion of the program includes air purifiers, clothes washers, dehumidifiers, heat pump water heaters, and other household appliances. The program started providing instant rebates at the distributor level in early 2017.

Advertising activities designed to reach out to customers are planned on a quarterly basis, such as point-of-purchase materials and presentations, in-store scrolling videos, brochures and advertising through online media channels, including Pandora Radio, Twitter, Facebook, YouTube, and Google ads.

2.2 Low Income Direct Install (LIDI) Program

Low Income Direct Install initiative is a program that offers heat pump water heaters in low-income homes previously served with electric resistance water heaters. LEDs and low-flow showerheads, bathroom aerators, and kitchen aerators are offered to homeowners who do not already have them installed, as a package with the heat pump water heater. Table 2-1 below provides a summary of the *ex ante* counts during the evaluation period (FY15-FY17).

TABLE 2-1: SUMMARY OF *EX ANTE* COUNTS MEASURE

Measure	Number of Homes	Program Count
Heat pump water heaters	1,270	1,270
LED light bulbs	447	5,961
CFLs	710	7,100
Low-flow showerheads	562	634
Low-flow kitchen aerators	494	506
Low-flow bathroom aerators	293	395

[3] *Ex ante* refers to gross savings recorded in the Efficiency Maine's database (effRT) at the time the measure was installed using the savings assumptions and formulas defined in the TRM.

The LIDI initiative covers 100% of the project cost for low-income Maine residents who are eligible to participate. Participants are recruited through channels such as Community Action Agencies and tribal organizations.

2.3 Program Savings

The table below provides a summary of the MWh, summer, and winter kW *ex ante* savings by year for FY15-FY17.

TABLE 2-2: *EX ANTE* SAVINGS BY YEAR

	Consumer Products Program				Low-Income Direct Install Initiative			
Fiscal Year	Units Installed	MWh Saved	Winter kW Reduction	Summer kW Reduction	Units Installed	MWh Saved	Winter kW Reduction	Summer kW Reduction
2015	2,325	3,922	870	407	635	1,233	274	128
2016	2,656	4,481	993	465	75	146	32	15
2017	4,238	8,228	1735	811	560	1,171	236	110
Totals	9,219	16,631	3,597	1,683	1,270	2,550	542	253

3 Gross Savings Methods

Short-term *in situ* metering was conducted on a sample of 58 CPP and 58 LIDI homes to estimate heat pump water heater (HPWH) gross savings. The key elements of the evaluation design are as follows:

- Metering deployments were conducted in six phases throughout the year, from October 2017 to September 2018 to allow for investigating seasonal effects on HPWH performance
- Each home was metered for four weeks in the existing operational mode to assess the HPWH efficiency
- After four weeks, homeowners were requested to switch their water heaters to electric resistance mode for two weeks to determine the hot water energy consumption in electric resistance mode
- Savings were estimated according to the level of hot water energy consumption in electric resistance mode, which is a driving factor affecting the savings
- Detailed customer surveys were conducted to inform the estimation of gross savings

Each of these components contributed to the calculation of the energy savings as described in the remainder of this section.

The sampling strategy is described briefly, below, and additional detail is provided in Appendix A. The following sections cover the methods used to analyze the detailed customer survey, estimate gross savings, and investigate interactive effects. Appendix E contains supplemental information about the analysis of the gross savings and interactive effects.

3.1 Definition of Terms

The following terms are used throughout the report:

- **Hot water energy consumption** is the total input energy (kWh) to the water heater required to heat the water, including efficiency losses. The hot water energy consumption is multiplied by the efficiency of water heater to obtain the hot water load.
- **Hot water load** is the output energy (kWh) from the water heater to provide the required amount of hot water; the hot water load is divided by the efficiency of the water heater to calculate the hot water energy consumption.
- **Hot water demand** is the amount of hot water (gallons) required by the household.

3.2 Sampling

Cluster sampling was used to reduce evaluation costs associated with traveling over long distances.[4] The sample size was designed to meet a confidence/precision target of 80/10, with 50 homes selected from the CPP and 50 from the LIDI program. Extra homes were metered to account for dropouts, unusable data, and scheduling issues.

Participants were solicited for the metering through a web-based screener survey. E-mail blasts and advance letters were sent to 1,119 CPP and 390 LIDI participants. Of the total sample frame, 280 completed the screener survey and 116 sites were metered. All participants who completed the metering and a detailed survey received a $75 check incentive. Of the 116 homes that were metered, 99 homes returned usable data.

All LIDI homes in the selected towns were solicited for the on-site metering. CPP homes within each town were randomly selected. Sampling weights were applied to calculate the gross savings. The analysis was conducted with and without sampling weights and the results fell within 5% for CPP and 1% for LIDI.

Sampling weights were also calculated for the CPP NTG analysis by dividing the survey respondents into two groups: those with metering and those who only responded to the survey. The results were within 1% for both the self-report FR and the program influence score, so the final analysis was conducted without the sampling weights to simplify the process.

More details on the sampling approach are provided in Appendix A and survey instruments are provided in Appendix B.

3.3 Detailed Customer Survey

For both LIDI and CPP, a detailed customer survey was conducted, including all participants in the metering. An additional 50 customers who purchased HPWHs through the CPP were also surveyed. The purpose of the survey was to investigate heat pump water heater operation, identify types of water heaters being replaced, and water heaters customers considered before purchasing a heat pump water heater. The survey also focused on NTG and program influence. Other topics covered included motivations, level of satisfaction with the equipment, sources of rebate awareness, participant demographics, and home characteristics.

3.4 Estimating Gross Savings

There are two primary factors that contribute to the HPWH savings, as measured in the field: magnitude of hot water demand and the efficiency of the HPWH. These factors are discussed in Table 3-1. The relationship between these two inputs is complex, as the higher the hot water demand, the more likely the HPWH is set to hybrid mode, which has a lower efficiency.

[4] The towns included in the metering sample are Auburn, Gorham, Winthrop, Augusta and Bangor.

TABLE 3-1: PRIMARY FACTORS CONTRIBUTING TO HPWH SAVINGS

Drivers of HPWH Savings	Main Contributors
Magnitude of hot water demand	Household size, lifestyle, economic status
Efficiency of the HPWH (COP)[1]	Mode of operation[2]

[1] The COP is the ratio of the output to input energy.
[2] While there are numerous other contributors, such as the location of the water heater, the make and model, and temperatures of the inlet and outlet temperatures, the mode of operation is the main variable that most directly affects the savings.

The savings were calculated as shown in Equation 3-1.

EQUATION 3-1: KWH SAVINGS CALCULATION

$$kWh_{savings} = kWh_{hw} \times \left(\frac{1}{EF_{BASE}} - \frac{1}{COP_{metered}}\right)$$

where

$kWh_{savings}$ is the HPWH savings

kWh_{hw} is the annual hot water load

EF_{base} is the Energy Factor of the baseline (electric resistance) water heater

$COP_{metered}$ is the coefficient of performance of the HPWH as determined from the metering

For the purposes of applying the evaluation results to future program changes, an efficiency adjustment factor (EAF) was calculated by comparing the manufacturer's rating to the metered COP.

3.4.1 Hot Water Load

The metering involved direct measurement of the kW of the HPWH and temperatures of the inlet water, outlet water, and ambient air around the HPWH. The metered data in electric resistance mode was used to determine the hot water load, as the efficiency of the HPWH in electric resistance mode is known.

Occupancy is sometimes used as a proxy for the magnitude of the hot water load. For example, the Residential Energy Consumption Survey (RECS) conducted by the US Energy Information Administration[5] provides hot water energy consumption by number of occupants in the home.

[5] Residential Energy Consumption Survey, "https://www.eia.gov/consumption/residential"

In this evaluation, the metering data did not show a strong correlation between occupancy and hot water load.[6] *Post hoc* stratification was conducted on the magnitude of the hot water consumption in electric resistance mode rather than occupancy.[7] The hot water energy consumption in electric resistance mode was adjusted to account for differences in average hot water load between the metered homes and the RECS data, as discussed in Section 3.3.4.[8]

3.4.2 Efficiency of the HPWH

The efficiency of a HPWH is reported as the Coefficient of Performance (COP), the ratio of the output to input energy. The COP was calculated to compare the efficiency of the metered HPWH units to the reported manufacturers' specifications and to reflect the actual operation of the HPWHs by stratum.

The COP was calculated using the efficiency of the HPWH in electric resistance mode and efficient mode. This calculation assumes that the daily hot water load was the same between the two periods. The COP was estimated by mode (heat pump and hybrid) and by the magnitude of the hot water load.[9]

3.4.3 Baseline Definition

The TRM assumes the baseline unit is an electric resistance water heater. For the LIDI, homes only received a HPWH if they were using an electric resistance water heater. For the CPP, the responses to the customer detailed survey indicate that 85% of participants fell into one of the following two categories:

1. Considered purchasing an electric resistance water heater
2. Did not consider any alternatives to the HPWH

Based on this information, the evaluated savings were calculated using the electric resistance water heater as the baseline.

3.4.4 Calculating the Gross Savings

The energy savings, the average daily hot water load and the COP were calculated by stratum and used as inputs into Equation 3-1. To calculate the peak demand savings, the kW/kWh ratio was calculated during the ISO peak hours.[10] Survey data was used to apply these savings to the population. The evaluated savings were calculated and scaled up to the population using the

[6] The Pearson correlation coefficient was 0.49, indicating a weak correlation. This finding is most likely due to a combination of the limited sample size and high variability in hot water load.

[7] The sample was evenly divided into three groups according to the average kWh/day in electric resistance mode.

[8] The RECS hot water energy consumption was multiplied by the efficiency of the baseline water heater to calculate the RECS hot water load to make a direct comparison.

[9] The efficient mode was noted at the time the meters were installed. Study participants were asked to switch the HPWH to electric resistance mode and provide a photo of the HPWH control for verification.

[10] Per the Efficiency Maine Retail / Residential Technical Reference Manual, version 2017.1, ISO hours are non-holiday weekdays between 5-7 PM for the winter peak, and 1-5 PM for the summer peak.

steps outlined in Table 3-2 below. Sampling weights were applied to estimate gross evaluated savings.

TABLE 3-2: CALCULATING THE EVALUATED SAVINGS

Analysis Step	Description
Calculate hot water energy consumption per day in electric resistance mode for each home	The average hot water energy consumption per day in electric resistance mode was calculated from meter data for each home in units of kWh/day.
Define strata by hot water energy consumption in electric resistance mode for each program	The HPWHs were sorted by the magnitude of the hot water energy consumption in electric resistance mode and divided into three equal groups according to the magnitude of the hot water energy consumption.
Calculate average hot water load (kwh/day)	The average hot water load was calculated for each stratum by multiplying the average efficiency in electric resistance mode by the hot water energy consumption in electric resistance mode.
Calculate the average COP by mode and stratum	The average COP was calculated for each usage stratum, and for both hybrid and heat pump modes. The percent of HPWHs in hybrid and heat pump modes were applied to calculate a weighted average by stratum.
Calculate annual savings by stratum and combine by program	The weighted average savings were calculated for each stratum and summed for the program.
Calculate peak kW savings	The peak kW savings were calculated by applying a kW/kWh ratio based on the estimated savings from the metered data.

As a final step, the metered hot water load was compared to the average hot water load in the Northeast, as estimated by RECS[11]. The RECS data provides hot water energy consumption. To make a direct comparison between the metered data and the RECS data, both values were adjusted by the efficiency of the water heaters to obtain the hot water load. The HPWH efficiency in electric resistance mode was 98%, taken from the manufacturers' specifications. For the baseline efficiency, the TRM value of 94.5% was applied to the RECS data. This analysis indicated the metered homes, adjusted for occupancy, used less than the RECS average. As RECS is based on a much larger sample size and there is no reason to expect HPWH users would have lower hot water load, the savings were adjusted to the RECS level for CPP.

The metering of LIDI homes showed substantially lower use than the CPP homes, suggesting LIDI homes are likely to use less than the average for all residential homes. The LIDI savings were adjusted based on the assumption that Maine LIDI and CPP homes have a proportional relationship to average hot water load, i.e., the percent increase from the metering to the RECS hot water load, as calculated for the CPP homes, also applies to LIDI homes.

[11] RECS 2015 (Residential Energy Consumption Survey). https://www.eia.gov/consumption/residential/data/2015/. Data for New England was used. The Residential Energy Consumption Survey (RECS) is a periodic study conducted by the U.S. Energy Information Administration (EIA) which collects data on energy-related characteristics and usage patterns on a national representative sample of housing units.

There were 22 homes out of the 51 LIDI homes in the final analysis that had low flow devices installed. A comparison of the baseline usage for homes with low flow devices versus homes without low flow devices showed that there is no clear relationship between LIDI low hot water load and low flow devices.

3.5 Interactive Effects

The West Hill Energy team investigated whether HPWHs increase demand on the heating system, since they remove heat from the area they are in and use it to heat water. A corollary is that the HPWH could reduce air-conditioning use, as it may provide cooling to the space.

As part of this study, we metered the kW draw of the heating system in 28 households during the heating season. Air-conditioning was also metered, but there were too few homes with sufficient metering to draw conclusions.[12] The procedure for the analysis of the heating system interactive effects is outlined in Table 3-3 below.

TABLE 3-3: HEATING SYSTEM INTERACTIVE EFFECTS ANALYSIS PROCEDURE

Analysis Step	Description
Establish heating system on/off thresholds	Each heating system draws a slightly different kW value when turned on. Each home was analyzed by breaking the heating kW over the entire period into 10% percentiles to establish the kW when the heating system was on/off.
Add weather data and create temperature bins	Each household was mapped to the hourly weather data of the nearest NOAA weather data station in Maine and temperature bins were defined at 5°F degree intervals.
Assess whether data is sufficient	Outside air temperature bins were removed if they had no comparison mode (electric only data / heat pump only data), if the outside temperature was higher than 50°F[1], or if they had fewer than 20 hours of data.
Summarize results	The weighted average of the percent on time in each of the modes was calculated and aggregated.

[1] When the outside air temperature was above 50F, the heating system runtime did not correlate well with the weather data, indicating other factors may be influencing the runtime.

Households were removed from the analysis if they had odd consumption patterns (e.g. utilized wood heat for a few weeks, then switched back to oil), if they had only warm weather data (the average outside air temperature bin for the house is greater than 40°F), or if they had fewer than 3 temperature bins.[13] A total of 13 homes were included in the final analysis. Due to the small sample size, the results are suggestive rather than definitive.

[12] While 34 homes were metered during the summer, only 6 homes had air conditioners located in an area likely to be affected by the HPWH.

[13] The cut off of 40°F was used as heating systems run infrequently above 40°F, making it difficult to compare the heating system use between baseline and efficient case metering. The metering period for these homes had no hours below 40°F when the heating system would be expected to run more frequently.

4 Gross Savings Results

This section covers the results from the gross savings analysis. The following sections cover the hot water energy consumption in electric resistance mode, adjustments to the hot water energy consumption in electric resistance mode, the evaluated savings, interactive effects, and comparison to other studies.

4.1 Metered Savings

The metered savings before the RECS adjustments are shown below in Table 4-1 and Table 4-2.[14] The savings were stratified by hot water energy consumption in electric resistance mode.

TABLE 4-1: METERED KWH SAVINGS AND COP BY STRATUM FOR CPP

Hot Water Energy Consumption Stratum[1]	Number of HPWHs	Average HW Energy Consumption[1] (kWh/day)	Average COP	kWh Savings per Year
1	16	4.3	2.56	1,038
2	17	6.6	2.82	1,628
3	16	10.4	2.72	2,555
Average per HPWH[2]	49a	7.1	2.65	1,703

[1] Stratum were defined by the average kWh per day in electric resistance mode. The sample was sorted by kWh/day and divided into three equal groups.

[2] Weighted average based on percentage of hot water energy consumption in electric resistance mode in each stratum.

a HPWHs were metered in 49 homes; one home was metered in both hybrid and heat pump mode (at different times), giving a total of 50 HPWH metering cycles.

TABLE 4-2: METERED KWH SAVINGS AND COP BY STRATUM FOR LIDI

Hot Water Energy Consumption Stratum[1]	Number of HPWHs	Average HW Energy Consumption[1] (kWh/day)	Average COP	kWh Savings per Year
1	17	2.6	2.61	638
2	17	5.4	2.95	1,359
3	17	9.7	2.71	2,280
Average per HPWH[2]	51	5.9	2.70	1,428

[1] Stratum were defined by the average kWh per day in electric resistance mode. The sample was sorted by kWh/day and divided into three equal groups.

[14] In this section, the results are not adjusted for the sampling weights, as the purpose is to present the results of the metering rather than the overall program impacts.

[2]Weighted average based on percentage of hot water energy consumption in electric resistance mode in each stratum

Figure 4-1 shows the COPs by mode and hot water demand[15] level for both LIDI and CPP homes combined. In hybrid mode, the COP is fairly consistent across all usage groups. For the low-use homes, the COP in hybrid mode and heat pump mode are quite close. In heat pump mode, the COP is substantially higher in moderate- and high-use homes as compared to low-use homes.

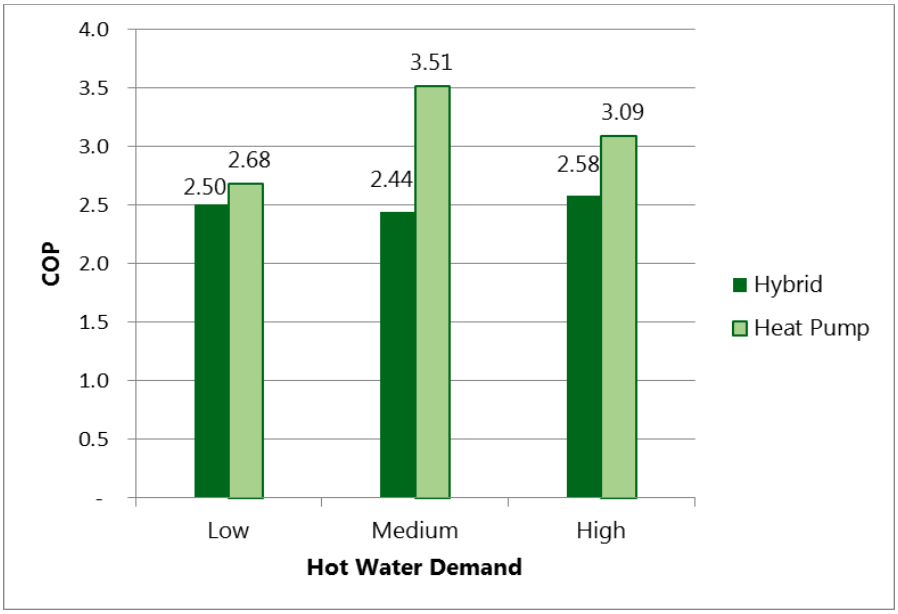

FIGURE 4-1: AVERAGE COP BY MODE AND HOT WATER DEMAND

This finding is consistent with the operation of the HPWHs. In hybrid mode, the electric resistance elements will turn on when the demand for hot water is high. As this situation is more likely to occur in homes requiring a higher volume of hot water, the COP is lower. In heat pump mode, the electric resistance element does not turn on and, consequently, the recovery time is longer. The end result is that the COP in heat pump mode is similar for the homes with medium- to high-consumption. [16]

The other key input into the savings calculations is the use of the hybrid and heat pump modes. The percent of homes using hybrid mode are shown in Figure 4-2.[17] Across all hot water demand levels, fewer LIDI participants opted to use hybrid mode, explaining the higher COP in LIDI homes.

[15]West Hill Energy stratified savings based on the hot water energy consumption in electric resistance mode. The hot water energy consumption in electric resistance mode is directly proportional to the hot water demand.

[16] In heat pump mode, the difference in COPs between the medium- and high-use homes is not statistically significant at the 90% confidence level.

[17] Six homes used high demand mode, which operated similarly to hybrid mode and were included in the hybrid category.

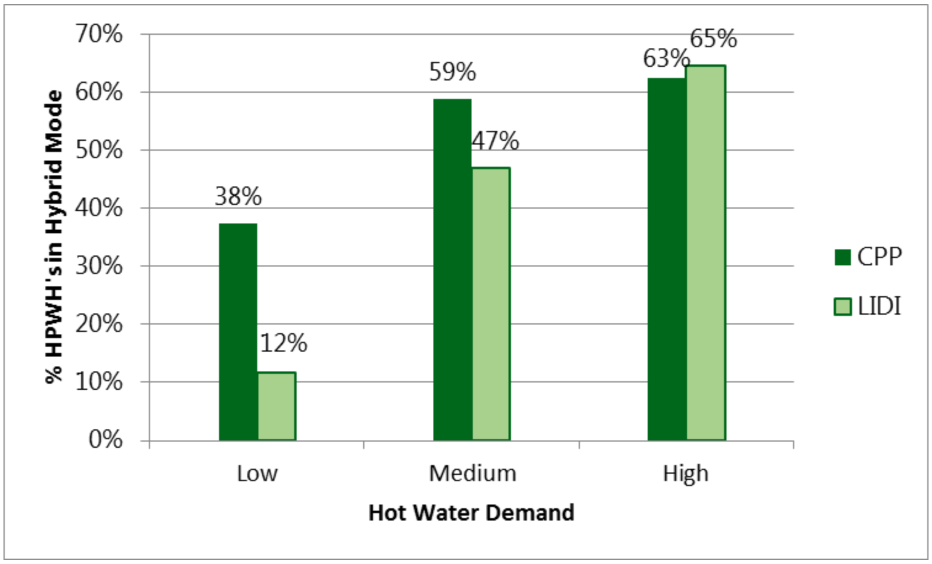

FIGURE 4-2: PERCENT OF HPWHS IN HYBRID MODE BY PROGRAM AND HOT WATER DEMAND

4.2 Hot Water Load

The average hot water load in the sample was compared to the RECS survey results for the Northeast, as shown in Table 4-3. This analysis indicates the metering samples (both CPP and LIDI) have a lower hot water load than the RECS estimates for the population in the Northeast. The RECS average use is about 21% higher than the CPP average use. As the RECS survey is based on a substantially higher sample size and is more likely to reflect the hot water load for the residential sector, the CPP HPWH savings were adjusted upward by 14%.

The average LIDI hot water load is substantially lower than the CPP hot water load, suggesting low income households have a lower hot water load than the population as a whole. There were 22 homes out of the 51 LIDI homes in the final analysis that had low flow devices installed. A comparison of the baseline usage for homes with low flow devices versus homes without low flow devices adjusted for occupancy showed that there is no clear relationship between LIDI low hot water load and low flow devices. We assumed the relationship between the metered sample and the population is the same for CPP and LIDI and adjusted the LIDI HPWH savings upward by the same percentage (14%) as the CPP.

Table 4-3: Comparison of Hot Water Load to the RECS Survey

Hot Water Energy Consumption Stratum[1]	RECS Equivalent Hot Water Load (kWh/Day)[2]	CPP Average Hot Water Load (kWh/day)[3]	LIDI Average Hot Water Load (kWh/day)[3]
1	6.2	4.3	2.6
2	6.9	6.4	5.3
3	9.1	10.2	9.5
Average per Household	7.2	6.8	5.7

[1] The HPWHs were sorted by the magnitude of the hot water energy consumption in electric resistance mode and divided into three equal groups according to the magnitude of the hot water energy consumption in electric resistance mode. This resulted in three equal groups stratified by hot water demand.
[2] The RECS survey gives the kWh use of the water heater by number of occupants. The RECS numbers were adjusted to account for the distribution of occupancy among the homes in each of the hot water energy consumption in electric resistance mode stratum and for the water heater efficiency to the calculate hot water load.
[3] Sampling weights were applied. The hot water loads were calculated from the hot water energy consumption in electric resistance by multiplying by the efficiency of the HPWHs in electric resistance mode.

4.3 Evaluated Savings

The final, evaluated results of the analysis for heat pump water heaters are shown in Table 4-4 for CPP and Table 4-5 for LIDI. The evaluation study was designed to meet 80/10 for the kWh savings but not for the winter and summer kW savings. The relative precision at the 80% confidence interval for the energy savings (kWh) is 4% for CPP and 5% for LIDI. The relative precision is 14% for winter peak and 13% for summer peak at the 80% confidence interval.[18] The sample size was based on previous experience with metering HPWHs and was designed to meet the 80/10 confidence/precision target for the energy savings. The variability for winter and summer peak kW is higher.[19]

Table 4-4: Gross Savings and RRs For CPP

	kWh Savings[1]	Winter Peak kW Savings[1]	Summer Peak kW Savings[1]
Evaluated Savings	1,949 +/- 83	0.307 +/- 0.043	0.212+/- 0.028
Ex Ante	1,797	0.388	0.181
Realization Rate	108% +/- 4%	79% +/- 14%	117%+/- 13%

[1] Precision for kWh and peak kW savings is reported at the 80% confidence level, as it consistent with the ISO-NE Forward Capacity Market guidelines

[18] Precision for kWh and peak kW savings is reported at the 80% confidence level, as it consistent with the ISO-NE Forward Capacity Market guidelines.

[19] The evaluation design and sample size were based on meeting the 80/10 confidence/precision target for energy savings. Due to variability in water heater energy consumption coincident with the ISO NE defined peaks, a much larger sample size would have been required to meet 80/10 for peak savings estimates. Given the small contribution of heat pump water heaters to the overall portfolio demand reductions bid into ISO NE, the trust opted to maintain a smaller sample size thus resulting in less relative precision.

TABLE 4-5: GROSS SAVINGS AND RRS FOR LIDI

	kWh Savings[1]	Winter Peak kW Savings[1]	Summer Peak kW Savings[1]
Evaluated	1,634 +/- 77	0.257+/- 0.036	0.178+/- 0.024
Ex Ante	2,008	0.427	0.199
Realization Rate	81% +/- 5%	60% +/- 14%	89% +/- 13%

[2] Precision for kWh and peak kW savings is reported at the 80% confidence level, as it consistent with the ISO-NE Forward Capacity Market guidelines

The RRs indicate the CPP estimates of savings are quite close to the evaluated savings. The LIDI savings are lower, primarily due to a lower hot water load in these homes.

4.4 Interactive Effects

There was sufficient data to compare the difference in water heater run-time between the electric resistance and efficient operation for 13 homes. The results of the analysis are shown in Table 4-6 below. This analysis shows the heating system ran 50% of the time when in electric mode and 48% when in the efficient mode.

TABLE 4-6: HEATING SYSTEM INTERACTIVE EFFECTS RESULTS

			Percent of the Time Heating System is On	
Number of HPWHs	Heated Basements	Unheated Basements[1]	Electric Mode	Efficient Mode
13	6	7	50%	48%

[1] An "unheated basement" was defined in the participant survey as a basement area without a thermostat, *i.e.*, not intentionally heated. It is common in New England for the heating plant to be located the basement, although many homes do not have thermostats in, or intentionally heat, the basement space.

While these results are inconclusive due to the low number of households included in the final data, they suggest the heating system is not running more when the HPWH is in the efficient mode than when it is in the electric mode. The same conclusion was reached for the Connecticut study using a different method.[20]

In this analysis, the 13 homes were (approximately) evenly divided between HPWHs in heated and unheated basements. Out of 58 LIDI participants with a completed site visit, 81% had their

[20] West Hill Energy & Computing, et al. 2018. "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation Final Report," prepared for the CT EEB Evaluation Administration Team. Section 4.4.3.

heat pump water heater installed in an unheated basement. About 16% were installed in heated basements and the remaining 3% in closets in living space. Of the 58 CPP participants who completed a site visit, 74% of the heat pump water heaters were installed in unheated basements. About 21% were installed in heated basements and the remaining 5% were installed in unheated utility rooms and an unheated cellar. On average (both CPP and LIDI), 78% of the heat pump water heaters were installed in unheated basements. Thus, it seems even less likely there would be an impact on heating use for the larger population of homes with HPWHs.

4.5 Comparison to Other HPWH Studies

Several other studies have looked into heat pump water heater savings. The results of these studies are shown in Table 4-7. The two studies at the top of the table have higher electric resistance hot water energy consumption than was found in this study, which increased the savings in those studies. The Steven Winter study has the least number of homes evaluated and this study has the highest hot water energy consumption out of the three. The EMT evaluated COP is the highest in these studies.

TABLE 4-7: COMPARISON TO OTHER FIELD STUDIES

Program	Number of HPWHs	HW Energy Consumption in Electric Resistance Mode (kWh/Day)	Savings (kWh/year)	Rated COP	Evaluated COP
CT[1]	36	8.4	1,818	2.68	2.46
Steven Winters[2]	11	9.1	1,687	2.35	1.85
EMT Evaluated CPP[3]	49	7.1	1,949	3.19	2.80
EMT Evaluated LIDI[3]	51	5.9	1,634	3.46	2.85

[1] West Hill Energy & Computing, et. al. 2018. "CT HVAC and Water Heater Process and Impact Evaluation and CT Heat Pump Water Heater Impact Evaluation Final Report," prepared for the CT EEB Evaluation Administration Team. https://www.energizect.com/sites/default/files/R1614-1613_ResHVAC_Report_Final_8.29.18.pdf
[2] Steven Winter Associates Inc., "Heat Pump Water Heaters, Evaluation of Field Installed Performance," June 26, 2012, Table 1 and 4. 50- and 60-Gallon Heat Pump Water Heaters. Rated and Evaluated COP are based on 10 homes included in table 4 of the report.
[3] Metered hot water energy consumption in electric resistance mode, prior to the RECS or hot water load adjustments.

4.6 LIDI LEDs and Low-Flow Devices In-Service Rate

As part of the LIDI program, Efficiency Maine also offers free low-flow devices and LED light bulbs to qualifying low income homeowners. LEDs and low-flow devices (showerheads, bathroom aerators, and kitchen aerators) are offered to homeowners who do not already have them installed, as a package with the heat pump water heater.

During site visits Phase 3 to Phase 6, the West Hill Energy Team performed a visual inspection to check if the LEDs and low-flow devices were installed. The goal of this exercise was to determine the in-service rate and update the TRM values. The ISR results need to be placed in context. The site visits were conducted to meter the HPWHs and using these site visits to estimate the ISR is essentially a sample of convenience. In addition, the sample size was small and the precision is poor. Consequently, caution should be used when applying these results to the program as a whole.

There were 50 LIDI homes that had site visits completed from Phase 3 through Phase 6. Of these 50 homes, 48% (24 homes) had LEDs and low-flow devices provided as part of the project. The final ISR results were based on 17 homes where full information was collected. Table 4-8 below provides a summary of the ISR results.

TABLE 4-8: SUMMARY OF ISR RESULTS BY MEASURE

Measure	Total Program Count	Total Verified On-Site[1]	ISR[2]	Relative Precision at 80% Confidence Level[3]
Heat pump water heaters	1,270	116	100%	0%
LED light bulbs	193	149	77% +/ 13%	17%
Low-flow showerheads	16	14	88% +/ 10%	12%
Low-flow kitchen aerators	13	11	85% +/ 11%	13%
Low-flow bathroom aerators	13	10	77% +/ 13%	17%

[1] Results are based on 17 homes from Phase 3 to Phase 6 site visits. There were no LIDI site visits in Phase 1. Phase 2 participants were not part of the ISR verification because the evaluation had not been established.
[2] The ISR and the 80% confidence interval
[3] Relative precision = error bound/ISR

According to the 2017 LIDI Electric Initiative Manual, showerheads and aerators are required to be installed by the contractor. LED light bulbs can be installed by the contractor or the homeowner. As shown in the table above, the largest discrepancy in the counts was with the LED light bulbs, which are not required to be installed by the contractor. Some homeowners reported the LEDs were in storage and they were planning to install them as the old ones burned out.

5 Net-to-Gross Analysis

Customer surveys were used to estimate Free Ridership (FR) for the CPP. The customer survey was fielded between January 2018 and October 2018 for participants who installed heat pump water heaters between 2014 and 2017.[21] Spillover (SO) was not estimated for the CPP, as there does not seem to be a clear, causal mechanism for generating SO with this program. However, the results should be understood to be missing the SO component. The net-to-gross ratio (NTGR) for the LIDI was assumed to be 100%, as is common for low-income programs.

Three approaches were applied to estimate the FR:

1. Self-report
2. Program influence
3. Combination of self-report and program influence

The self-report approach relies on estimates from contractors and distributors about the percent of sales, or stocking of efficient equipment with and without the rebates and direct questions to customers about what they would have done in the absence of a rebate. The program influence component uses pairwise questions comparing program activities to outside influences.

Both of these methods rely on the participant's perspective pertaining to their decision-making process. The self-report approach may tend to understate program attribution due to hindsight bias, i.e., as time passes, people tend to conclude that a previous decision was predictable and may be more likely to say they would have made the same choice in the absence of the program.[22] However, program influence questions may tend to overstate program attribution, as respondents are more likely to give the socially-desirable response.[23] Consequently, the recommended approach to estimating net savings utilizes the self-report method and incorporates program influence.

5.1 Methods

Free riders were estimated using self-reports, program influence, and a combination of the two. Each of these three approaches is described below.

5.1.1 Self-Report

There are two components of the self-report free rider estimate:

1. Likelihood of installation
2. Timing

[21] About 17% of the participants had HPWH installations in 2014 and 30% in 2015. About 23% of the installations were completed in 2016 and the remaining 30% in 2017.

[22] Kahnman, Daniel. 2001. *Thinking Fast and Slow*. Farrar, Strauss and Girard, New York City, NY, pp. 202 to 204.

[23] McRae, M. "'Sure you do. Uh-huh': Improving the Accuracy of Self-Reported Efficiency Actions." In Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings. Pacific Grove, CA: American Council for an Energy-Efficient Economy

The first survey question asked about whether the respondent was likely to install the measure if they had not participated in the program. If the respondent stated they probably, or definitely, would have installed the measure without the program, they were asked when they would have made the installation. Additional credit to the program is given if the installation would have occurred six or more months after the program installation.

5.1.2 Program Influence

Program influence is associated with the causal mechanisms of the program. As the CPP is a rebate program, the program theory is fairly simple and the primary, causal mechanism is reducing the first cost through the rebate. In addition, EMT has a list of registered contractors, which CPP participants may have used, although there was no requirement to do so.

All respondents were asked about the influence of the rebate on their decision to install the heat pump water heater. Survey respondents, who indicated they used the EMT contractor list, were asked about the influence of the EMT contractor on their decision-making process.

The program influence score for each barrier was estimated using matrix algebra, as is consistent with the Analytical Hierarchy Process method. The highest program influence score (rebate or EMT contractor) was used for each respondent.

5.1.3 Combining Self-Report and Program Influence

The two methods were combined as follows:

1. The program influence and self-report NTGR scores were calculated separately for each respondent
2. If the respondent completed the questions allowing estimation by both methods, the two scores were averaged.
3. If the respondent only completed questions for the self-report method, the self-report score was used and *vice versa*.
4. The combined score was averaged over all respondents.

As discussed in Section 5.1.1 above, self-report and program influence methods may have conflicting biases, with one resulting in a higher free rider rate and the other in a lower free rider rate. This approach addresses these potential biases by combining the results of the two methods on a house-by-house basis.

5.2 Results

The FR results from the two methods are shown in Table 5-1. The results from the self-report and program influence methods were almost identical (within 1%), although the NTGR estimates on a "per respondent" basis were divergent in some cases.

TABLE 5-1: FR RESULTS BY MEASURE GROUP AND METHODS

Metric	Self-Report (n=91)[1]	Program Influence (n=98)[1]	Combined SR & PI (n=105)[2]
Free Rider Rate	30%	31%	***31%***
NTGR	70%	69%	***69%***

[1] Sample size reflects the number of respondents with valid answers to key questions. Respondents with "Don't know" or other invalid answers were removed.

[2] Two of the 107 respondents did not complete either the self-report or program influence questions.

This analysis indicates the combined NTGR is 69%+/-7%. The evaluation team recommends using the combined approach based on both the self-report and program influence methods. In this case, the average results from the two methods are very close, but the combined approach allows us to increase the sample size to 105 out of the total of 107 survey respondents.

6 Participant Survey Results

Some of the key findings from the survey are summarized below. Additional details are provided in Appendix C.

6.1 Mode

Figure 6-1 provides a summary of water heater mode use, as reported by the CPP and LIDI survey respondents. About one third (34%) of CPP and three-quarters (77%) of LIDI respondents reported running their heat pump water heater in a single mode, typically either heat pump or hybrid mode.

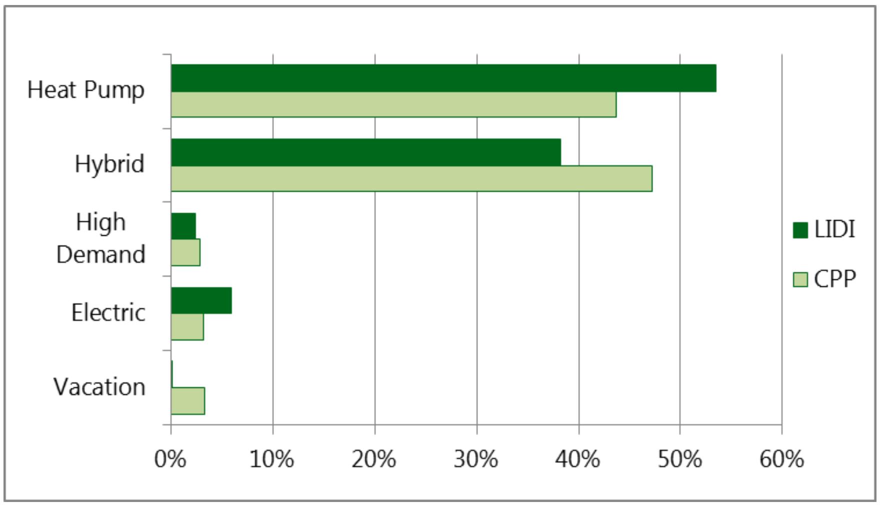

FIGURE 6-1: WATER HEATER MODES FOR LIDI (n=52) AND CPP (n=105) SURVEY RESPONDENTS[24]

6.2 Dehumidifier Use

A heat pump water heater acts as a dehumidifier, as it extracts heat from the area where it is located. The survey results showed that program participants are less likely to run the dehumidifier after installing a heat pump water heater for this reason. The survey question specified that the dehumidifier be located in the vicinity of the HPWH.

Key results from the dehumidifier survey questions are provided below:

- The percentage of respondents who reported having a dehumidifier was similar for CPP and LIDI respondents

[24] Respondents were asked this question only if the heat pump water heater was installed over one year prior to the survey.

- A small percentage (about 20%) of both CPP and LIDI respondents reported having a dehumidifier.
- About 60% of homes with dehumidifiers reported using them somewhat, or a lot less in the post-installation period
- Of the reported 20% of homes with dehumidifiers, about 15% reported removing the dehumidifier, 46% reported reducing use by 1 month a year or more, and 32% by 3 months or more

Overall, the survey indicates HPWHs reduce dehumidifier use, although only a relatively small percent of homes have dehumidifiers. A part of the metering plan was to meter homes with dehumidifiers; however, few homes had dehumidifiers, and in many cases, the dehumidifier was not in operation when the metering was conducted. Consequently, it was not possible to directly measure the reduction in dehumidifier use.

6.3 Customer Satisfaction

Respondents rated their satisfaction with the heat pump water heater purchased through the program, as well as with a variety of specific aspects of the equipment. Figure 6-2 shows overall equipment satisfaction for both CPP and LIDI participants.

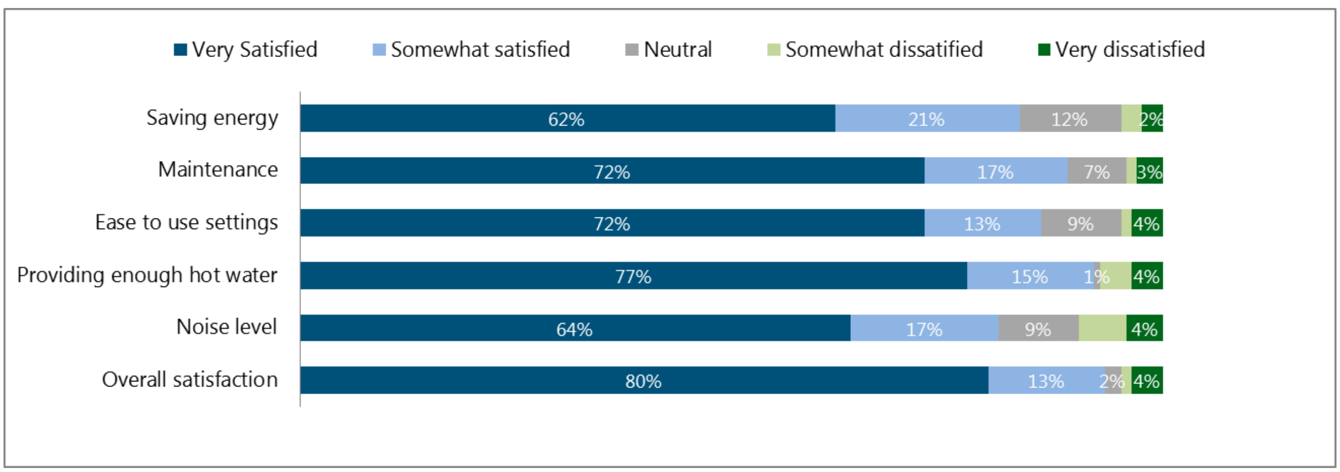

FIGURE 6-2: SATISFACTION WITH HPWHS (n=163)

Overall, the overwhelming majority (93%) of all respondents were, at least, somewhat satisfied with their equipment and four-fifths were very satisfied (80%). In an open-ended question, 12% of the respondents reported having issues with their heat pump water heater, such as leaks, cleaning the filter, not having enough hot water in heat pump mode, and technical issues with the display.

Survey respondents were asked if their contractor explained how to use the different heat pump water heater operational modes. About 75% of the CPP respondents reported their contractor explained how to use heat pump water heater operational modes. LIDI participants are required to use an Efficiency Maine contractor and 70% cited their contractor explained how to use the different modes.

6.4 Barriers to Installation

CPP respondents were asked to rank the barriers to installation of the HPWHs. About 38% of respondents reported they had no barriers and 3% stated the listed barriers did not include their concerns.[25] The results of this inquiry are shown in Figure 6-3.

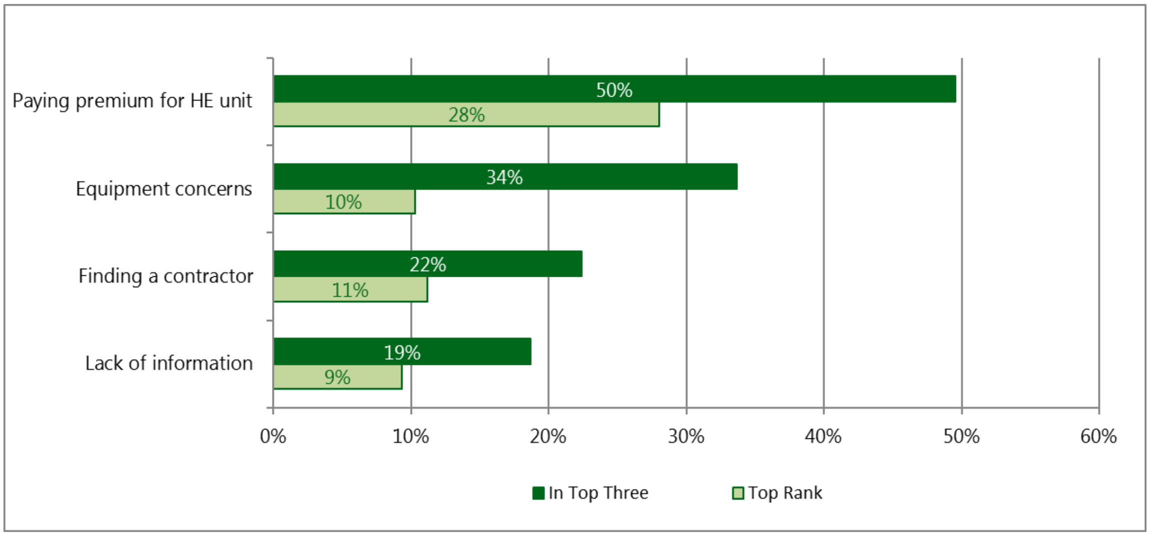

FIGURE 6-3: BARRIERS TO INSTALLATION OF HPWHS (n=107)[26]

Paying the premium was the most frequently chosen barrier within the top three identified by each respondent, followed by equipment concerns, finding a contractor, and lack of information. This analysis suggests all four barriers were experienced by a substantial portion of respondents.

[25] Respondents could enter other barriers that they faced in addition to the ones that were already listed in the survey. Two respondents cited being concerned about the installation process and one reported they were concerned if the heat pump water heater would lower their electric bill.

[26] Sixty-three respondents reported experiencing one or more of the listed barriers. The percentages were based on all 107 respondents.

7 Benefit-Cost Analysis

In Maine, the Primary Benefit-Cost Test (PBCT) and Program Administrator Cost Test (PACT) are defined as shown in Table 7-1.

TABLE 7-1: DEFINITIONS OF PBCT AND PACT TESTS

<table>
<tr><th>Benefit/Cost Test</th><th>Description</th><th>Benefits</th><th>Costs</th></tr>
<tr><td>Program Primary Benefit-Cost Test (PBCT)</td><td>Compares program administrator plus customer costs to utility resource savings. Reflects the perspective of all utility customers (participants and non-participants).</td><td rowspan="2">Avoided electric generation costs including energy and capacity costs
Avoided transmission and distribution costs
Avoided fossil fuel costs Other resource benefits, such as reduced water and sewer costs
Non-resource benefits Avoided costs of electric energy and unregulated fuels savings</td><td>Direct program costs
Incremental measure costs to purchase and install the efficiency measure over the baseline scenario
Ongoing customer costs
Costs to purchase and install the energy efficiency measure, to operate the program, extra fuel use due to measure installations</td></tr>
<tr><td>Program Administrator Cost Test (PACT)</td><td>Compares the program administrator costs to supply-side resource savings. Reflects the perspective of utility, government agency, or third party implementing the program</td><td>Only costs incurred by the program administrator (excludes participant costs)</td></tr>
</table>

The impact evaluation team examined key inputs to the PBCT and PACT, including realization rates (RRs), net-to-gross ratios (NTGRs), and spillover rates.

7.1 Methods

The research objective for the benefit-cost analysis was to estimate the cost-effectiveness of individual measures offered through the CPP and LIDI program during fiscal year 2017. The objectives and approach of the benefit-cost analysis are summarized below in Table 7-2 and described further in subsequent sections.

TABLE 7-2: SUMMARY OF APPROACH TO BCR ANALYSIS

Objective	Description
Calculate FY17 base case measure-level and program-level PBCT and PACT ratios using TPIII assumptions	Based on Triennial Plan III (TPIII) assumptions regarding 1) avoided costs, 2) whether savings are net or gross, 3) whether incentives to free riders are treated as a cost, 4) the start year, 5) the default discount rate
Calculate prospective measure-level and program-level PBCTs and PACs using Triennial Plan IV assumptions	Calculate the prospective measure-level and program-level PBCT and PACT using Triennial Plan IV (TPIV) assumptions regarding free ridership and carbon benefits avoided costs

7.1.1 Base Case Measure Level PBCT and PACT Ratios Using TPIII Assumptions

The base case measure-level and program-level PBCT and PACT ratios were calculated based on the following inputs:

- Measure cost, quantity installed, and incentive costs
- Program delivery costs for FY17
- The expected gross and net savings for kWh and kW, and water
- Energy period factors (EPF) for each measure promoted by CPP and LIDI

The TPIII parameters used to calculate the base case PBCT and PACT ratios are presented below in Table 7-3.

TABLE 7-3: TPIII M&A PARAMETERS FOR LIDI AND CPP BASE CASE

Parameter	Value
Avoided cost data set	LEI High
Net or Gross	Net
Include incentives to free riders as cost	Yes
Year 1	2017
Default discount rate	6.50%
RGGI discount rate	2.43%

Efficiency Maine uses provided the HESP Cost Effectiveness Analysis (HCEA) tool, which is an Excel-based implementation of the cost-benefit analysis tool calculations. *Ex ante* gross savings estimates in the HCEA for kWh and kW were updated to be consistent with the *ex ante* savings per unit assumed during the implementation of the FY17 program. The key base case inputs for each measure in the two programs are provided in Appendix F. These inputs were entered into the HCEA spreadsheet to calculate the program-level and measure-level PBCT and PACT ratios for FY17.

7.1.2 Prospective PBCT and PACT Ratios using TPIV Assumptions

At the time the benefit-cost analysis was performed for this evaluation, the methodology and assumptions (M&As) for use in cost effectiveness calculations for Triennial Plan IV (TPIV) had not yet been approved by the Maine Public Utilities Commission (PUC). Since the analysis was performed, the Trust has submitted and the Maine PUC has accepted a new set of M&As for TPIV that uses updated avoided costs and treats incentives paid to free-riders as a transfer (the cost to the program is exactly equal to the benefit realized by the participant). The prospective measure-level and program-level PBCT and PACT used the approved TPIV M&A parameters, rather than the TPIII parameters. The TPIV parameters are listed in Table 7-5. The TPIII inputs are included for comparison purposes.

TABLE 7-4: TPIV M&A PARAMETERS FOR PROSPECTIVE BASE CASE PBCT AND PACT

Parameter	TPIV	TPIII
Avoided cost data set	AESC 2018[1]	LEI High
Net or Gross	Gross	Net
Include incentives to free riders as cost	No	Yes
Year 1[2]	2018	2017
Default discount rate	2.8%	6.5%
RGGI discount rate	2.8%	2.43%

[1] Synapse Energy Economics, et. al., Avoided Energy Supply Components in New England: Costs Study Report, March 30, 2018.
[2] For AESC 2018, there are no values for 2017. As a result, the Year 1 value is set to 2018.

7.2 Results

This section presents the results of the benefit cost analysis. Appendix F includes additional details on the analysis inputs and results.

7.2.1 Measure-Level and Program-Level Benefit-Cost Ratios

The PBCT and PACT results were calculated for each program as provided in Table 7-5 and Table 7-7.

Consumer Products Program

The results for the CPP are presented in **Error! Reference source not found.** below.

TABLE 7-5: BASE CASE PBCT AND PACT FOR CPP

Measure	PBCT	PACT
Heat Pump Water Heater	1.23	1.52
Program	1.06	1.27

Using the Triennial Plan III M&A parameters, the PBCT, at both the measure-level and program-level, exceed 1.0. Using the Triennial Plan IV M&A parameters increases the PBCT from 1.06 to 1.79. Table 7-6 shows a comparison of the PBCT ratios based on different M&As.

Table 7-6: Select PBCT Comparisons Based on Different Scenarios for CPP

Scenario	M&A	FR Incentives as Costs	Carbon	Program PBCT
Base Case	TPIII	Included	None	1.06
Exclude FR Incentives	TPIII	Excluded	None	1.35
Add Carbon Pricing	TPIII	Included	Starting Price	1.20
Use TPIV M&A	TPIV	Excluded	None	1.90

Low Income Direct Install

As shown in Table 7-7, the PBCT and PACT produced the same results because in both cases the inputs were the same.

Table 7-7: Base Case PBCT and PACT for LIDI

Measure	PBCT/PACT[1]
Heat Pump Water Heater Direct Install	1.09
LED Low Income Standard Bulb Long Life	1.49
Low-Flow Bathroom Aerator Direct Install	1.90
Low-Flow Kitchen Aerator Direct Install	4.67
Low-Flow Shower Head Direct Install	3.01
Program	1.03

[1] The difference between the PBCT and PACT is that the PACT includes only the costs to the program administrator, whereas the PBCT also includes the participant costs. In LIDI, the program administrator covers all the costs of the installation at no cost to the participant. Consequently, the results of the PBCT and PACT are the same.

Table 7-8 shows a comparison of the PBCT ratios based on different M&As. As shown in the table, using the TPIV M&A parameters increases the PBCT ratio by 9%, from 1.03 to 1.12.

TABLE 7-8: SELECT PBCT COMPARISONS FROM THE SENSITIVITY ANALYSIS FOR LIDI

Scenario	M&A	FR Incentives as Costs	Carbon	Program PBCT
Base Case	TPIII	Included	None	1.03
Add Carbon Pricing	TPIII	Included	Starting Price	1.06
Use TPIV M&A	TPIV	Excluded	None	1.12

7.3 Conclusions

The key conclusions from this benefit-cost analysis are as follows:

- For both the CPP and LIDI, programs and measures are cost effective under the base case conditions, *i.e.*, the Base Case PBCT and PACT are greater than 1.
- Using prospective TPIV assumptions, the exclusion of rebates to free riders as a cost increases the CPP program-level PBCT ratio from 1.06 to 1.79. Under TPIII, the cost effectiveness test included rebates to free riders as a cost, which is double counting. Some regulators, evaluators, and economists at the state and national level have provided a strong rationale for not counting payments to free riders as a cost. The National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources (NSPM) includes incentives paid to free riders as a cost only if participant impacts are excluded in the cost-effectiveness test.
- The inclusion of carbon benefits in future PBCT and PACT calculations can produce small to moderate increases in the PBCT and PACT.
- For both programs, a combination of two or more variable changes can have a substantial impact on measure-level and program-level PBCT and PACT ratios, *e.g.*, a combination of excluding incentives to free riders as a cost and including carbon benefits.

California and New York currently include other benefits in the form of market effects and environmental benefits to the cost-effectiveness test. The NSPM also allows a broader range of benefits such as increased comfort, productivity, reduced health care costs and impacts on economic development and jobs. While not explored in this analysis, including additional non-energy benefits[27] (such as local economic development, reduced utility disconnects, and greater comfort and improved health for building occupants) will also increase the PBCT and PACT.

[27] State and Local Energy Efficiency Action Network. 2012. *Energy Efficiency Program Impact Evaluation Guide*. Prepared by Steven R. Schiller, Schiller Consulting, Inc., www.seeaction.energy.gov; Woolf, Tim, Chris Neme, Marty Kushler, Steven R. Schiller, and Tom Eckman. (2017). *National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources.* Prepared for the National Efficiency Screening Project.

8 Review of TRM Methods and Inputs

This section covers two topics: comparison of *ex ante* savings to the TRM and recommendations for adjustments to the TRM.

8.1 Comparison of *Ex Ante* and TRM Savings

The *ex ante* savings were compared against the TRM prescribed values for all evaluated program years to check for accuracy. The results of this analysis showed that the *ex ante* savings recorded in the effRT database matched the TRM savings for all evaluated program years.

8.2 Recommendations for Changes to the TRM

Savings from HPWHs are variable for a number of reasons and are expected to increase as the efficiency of the HPWHs improves. This evaluation covered fiscal years 2015 to 2017 and the HPWHs installed during that time period. Recognizing the evaluated savings reflect one particular period of time, we recommend that the savings be calculated as given in Equation 8-1. Adjustment factors and initial inputs into the equations are provided below.

EQUATION 8-1: TRM SAVINGS CALCULATION

$$kWh_{savings} = kWh_{hw} \times \left(\frac{1}{EF_{BASE}} - \frac{1}{(COP_{rated} \times EAF)}\right)$$

Winter and summer peak savings can then be calculated by applying the ratio of peak to kWh savings. The inputs are described in Table 8-1.

TABLE 8-1: INPUTS INTO THE TRM SAVINGS CALCULATION

Input	Description	Recommended Value	Source
CPP kWh_{hw}	kWh annual hot water load	2,821 kWh	RECS 2015, adjusted for occupancy
LIDI kWh_{hw}	kWh annual hot water load	2,364 kWh	RECS 2015, adjusted for occupancy and lower use in low income homes
EF_{BASE}	Energy Factor of the baseline water heater	94.5%	Maine 2017 TRM[1]
COP_{rated}	Rated COP of the HPWH	Actual Value	Manufacturer cut sheets
EAF	Efficiency Adjustment Factor, ratio of actual COP from field metering to rated COP[2]	CPP: 88% LIDI: 83%	Metering
WP Factor	*Winter peak savings/kWh savings*	0.000157	Metering
SP Factor	Summer peak savings/kWh savings	0.000109	Metering

[1] This value is also consistent with the baseline efficiency used in the analysis of HPWHs in the CT study.
[2] The rated COP is based on standard rating conditions in a laboratory and typically use fixed inlet temperatures, outlet temperatures, ambient inlet conditions, and hot water requirements. The EAF adjusts these rated COP values to the COPs from the metered data, which reflect how the heat pump water heaters actually perform in homes.

This approach provides flexibility to adjust savings as unit efficiency increases and/or estimates of the hot water demand/load are updated.

8.3 Comparison of HPWHs, LED and Low-Flow devices ISR to the TRM

The ISRs for LEDs and low-flow devices for the LIDI program were compared against TRM 2017 prescribed values. The comparison is depicted in Table 8-2 below. The *ex ante* ISR for the LEDs was based on a long-term ISR from an NMR study.[28] For low-flow devices, EMT assumed all provided purchased units are installed and this assumption is consistent with the MA 2013-2015 TRM. During on-site verification, all heat pump water heaters were confirmed to be installed and in use, resulting in an ISR of 100%.

[28] NMR Group, Efficiency Maine Retail Lighting Program Overall Evaluation Report, April 16, 2015, p. 14

TABLE 8-2: SUMMARY OF *EX ANTE* COUNTS MEASURE

Measure	TRM 2017 Long-term ISRs	Verified ISR's[1]	Relative Precision at 80% Confidence Level[2]
Heat pump water heaters	100%	100%	0%
LED light bulbs[1]	99%	77% +/-13%	17%
Low-flow showerheads	100%	88%+/-10%	12%
Low-flow kitchen aerators	100%	85%+/-11%	13%
Low-flow bathroom aerators	100%	77%+/-13%	17%

[1] The TRM ISR is a long-term estimation and the verified ISR is based on LEDs that the evaluation team found to be installed on site
[2]The ISR and the 80% confidence interval
[3] Relative precision = error bound/ISR

As shown in the table above, fewer LEDs and low-flow devices were installed than reported by the program. The main reason behind homeowners not installing the low-flow devices was that they did not fit properly. Site visits to investigate LED ISRs were completed between February 2018 and October 2018 and all homes had LED installations completed in 2017. For low flow devices, installations had been completed in 2015 and 2017. Some participants reported putting LED bulbs in storage and replacing old bulbs as they burned out. The TRM reports a long-term LEDs ISR considering bulbs in storage will be installed eventually. The verified ISR results were based on the number of LEDs installed on site and excluded bulbs that were in storage.

The results from this analysis need to be placed into context. The site visits were conducted to meter the HPWHs and, using these site visits to estimate the ISR, is essentially a sample of convenience. In addition, the sample size is small and the precision is poor. Consequently, caution should be used when applying these results to the program as a whole.

9 Findings and Observations

In general, the HPWHs are effective and use substantially less electricity than stand-alone, electric water heaters. The overall evaluation results are summarized in Table 9-1.

TABLE 9-1: SUMMARY OF EVALUATED SAVINGS

Program	Number of HPWHs	Evaluated kWh Savings	RR	NTGR	Net kWh Savings
CPP	49	1,949	108% +/- 4%	69% +/- 7%	1,345 +/- 146
LIDI	51	1,634	81% +/- 5%	100%	1,634 +/- 77

While the metered average COP was higher than was found in other field studies, the hot water load was lower. These two effects (one upward and one downward) offset the savings for CPP and resulted in lower savings for LIDI. On average, about half of the HPWHs were used in hybrid mode and half in heat pump mode. Some of the technical findings are summarized in Table 9-2.

TABLE 9-2: TECHNICAL FINDINGS FROM THE HPWH METERING AND SURVEY

Topic	Findings	Comments
Hybrid v Heat Pump Mode	Homes with lower hot water demand: savings are similar in hybrid and heat pump modes	Electric elements in hybrid mode are less likely to turn on when loads are lower.
	Homes with higher hot water demand: savings are higher in heat pump mode	Recovery time is longer in heat pump mode and residents are more likely to switch to hybrid.
COP	Evaluated average COP in this study was higher than found in other, metering-based studies.	2.80 for CPP and 2.85 for LIDI, as compared to 2.46 (CT study) and 1.85 (Winters study).
Average hot water energy consumption in electric resistance mode	Hot water energy consumption in electric resistance mode was found to be lower in this evaluation than other metering-based studies.	7.1 kWh/day for CPP and 5.9 for LIDI, as compared to 8.4 (CT) and 9.1 (Winters).
HPWH Location	Most HPWHs (78%)[1] are installed in basements that are not intentionally heated.	There were no thermostats in the basement, although the heating system was often located in the basement.
Interactive Effects	HPWHs do not appear to be increasing the space heating requirements of the home.	Analysis of heating system use for 13 homes showed no extra use in heat pump mode as compared to electric resistance mode.
	Impacts on air-conditioning could not be determined.[2]	Although 34 homes were metered during the summer, there were only 6 homes with air-conditioning in areas that could be affected by the HPWH.
	HPWHs are reported to be reducing dehumidifier use in a small percent of homes.[3]	About 3% of survey respondents reported removing the dehumidifier, 9% reported reducing use by 1 month a year or more and 6% by 3 months or more.

[1]78% is an average percentage for both CPP and LIDI based on 116 site visits. About 81% of the 58 LIDI HPWHs were installed in unheated basements. About 16% were installed in heated basements and the remaining 3% in closets in living space. About 74% of the 58 CPP heat pump water heaters were installed in unheated basements. About 21% were installed in heated basements and the remaining 5% were installed in unheated utility rooms and an unheated cellar.
[2] Direct measurements were insufficient to estimate the impact due to the small number of homes with central air conditioners in use during the metering period.
[3] Direct measurements were insufficient to estimate the reduction due to the small number of homes with dehumidifiers in use during the metering period.

Ninety-three percent (93%) of survey respondents reported being very satisfied, or somewhat satisfied with the HPWH. Seven percent (7%) reported that the HPWH did not provide sufficient hot water and 10% reported dissatisfaction with the noise level.

Savings from HPWHs are variable for a number of reasons and are expected to increase as the efficiency of the HPWHs improves. This evaluation covered fiscal years 2015 to 2017 and the HPWHs installed during that time period.

Recognizing the evaluated savings reflect one particular period of time, the recommended changes to the TRM involve calculating the savings using the standard equation and incorporating adjustment factors to account for the evaluation findings.

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Appendix A

Sampling Approach

Appendix A: Sampling Approach

The appendix outlines the sampling approach used to select homes for metering of heat pump water heaters (HPWH) installed as part of the Consumer Products Program (CPP) and Low Income Direct Install Initiative (LIDI). The impact evaluation team originally planned to meter 100 homes (50 homes for each program) for the duration of six to eight weeks, with an extra five homes to account for a variety of issues that could render the metering unusable. By the completion of the metering, a total of 116 homes were metered, with 11 extra homes needed to account for dropouts, unusable data, and scheduling issues.

Short-term *in situ* metering was conducted on a sample of 58 CPP and 58 LIDI homes to estimate heat pump water heater gross savings. Each home was metered for four weeks in the existing operational mode to assess the HPWH efficiency and two weeks in electric resistance mode to determine the water heating load. Metering deployments were staged with the first round starting in October 2017 and the final round of metering ending in September 2018.

Population Overview

Metering was completed at 116 homes with heat pump water heaters, resulting in 99 homes with sufficient metering for the analysis. The initial plan was to meter 105 homes with the intention of completing metering on 50 HPWHs selected from the Consumer Products Program (CPP) and 50 from the Low Income Direct Install (LIDI) program allowing for some attrition. The table below provides a summary of the number of installations for each county accounting for more than 3% of the total CPP and LIDI homes. All other counties are aggregated under the "Other" category.

Table A-1: Installations by County

	LIDI		CPP	
County	Number of Sites	% Total Sites	Number of Sites	% Total Sites
Androscoggin	57	5%	516	7%
Aroostook	222	19%	751	10%
Cumberland	66	6%	1,529	19%
Kennebec	64	6%	956	12%
Knox	35	3%	320	4%
Penobscot	179	15%	1,105	14%
Piscataquis	45	4%	174	2%
Somerset	76	7%	290	4%
York	97	8%	721	9%
Other[1]	320	28%	1,519	19%
Total Sites	1,161	100%	7,881	100%

[1] Each individual county aggregated in the "Other" category accounts for less than 3% of the total CPP and LIDI installations.

Deployment

The impact evaluation team had originally planned concurrent CPP and LIDI on-site metering from the first deployment in October 2017 to the last deployment in August 2018. However, the customer information for the LIDI participants was not available for the first deployment. To keep to the schedule of beginning the first deployment in October, we modified the deployment plan, so an equal number of sites for each program were metered by the end of the six deployments. A summary is provided in the table below.

TABLE A-2: DEPLOYMENT STRATEGY

Deployment	Original Strategy		Final Strategy	
	CPP HPWHs	LIDI HPWHs	CPP HPWHs	LIDI HPWHs
1 – Oct/Nov	6	6	12	0
2 – Dec/Jan	6	6	5	8
3 – Feb/March	6	6	8	7
4 – April/May	11	12	7	9
5- June/July	12	11	13	13
6 – Aug/Sep	11	12	13	21
Total	52a	52a	58b	58b

a The solicitation plan called for conducting metering at 105 sites to ensure that we have viable metering data for 100. This assumption was revisited after each deployment phase was completed.
b A total of 116 sites were metered and 99 had sufficient meter data for the analysis.

Sampling Approach

Cluster sampling was used to reduce evaluation costs associated with traveling over long distances. One-stage cluster sampling was conducted by identifying groups of towns with substantial numbers of both CPP and LIDI installations. The sample sizes were determined using an assumed coefficient of variation (CV) of 0.55. Our experience with a similar project suggested that the 0.55 CV applied to the energy savings and was likely to be substantially higher for the winter and summer peak demand savings. We expected to meet confidence/precision target of 80/10 for gross energy savings and did not expect to meet 80/10 for winter and summer peak kW.[1]

Within a given town, a sufficient number of participants are required in order to ensure that the sample size can be met. Based upon past experience, the West Hill Energy Team estimated a 12 to 1 response rate for the site visits. The LIDI program had only 1,161 participants between FY14 and FY16 whereas CPP had 7,881 participating sites in the same time period.

In order to geographically target and obtain the required sample sizes, we added towns within 20 miles from the towns with more than 90 CPP installation sites. The LIDI sample was selected based on towns within 25 miles from the CPP sampled towns. The sampled towns and number

[1] Due to variability in water heater energy consumption coincident with the ISO NE defined peaks, a much larger sample size would have been required to meet 80/10 for peak savings estimates. Given the small contribution of heat pump water heaters to the overall portfolio demand reductions bid into ISO NE, Efficiency Maine trust opted to maintain a smaller sample size thus resulting in less relative precision.

of sites are summarized in the table below. CPP expected site visit solicitation responses were based on 12 to 1 response rate. Since we were offering a $75 incentive for participation, we assumed a 5 to 1 response rate for the low income program.

TABLE A-3: SAMPLED SITES BY COUNTY[1]

		CPP		LIDI	
Town	**County**	**Number of Sites**	**Expected Responses**	**Number of Sites**	**Expected Responses**
LEWISTON	Androscoggin	541	45	41	8
AUBURN	**Androscoggin**	**353**	**29**	**62**	**12**
CARIBOU	Aroostook	173	14	87	17
PRESQUE ISLE	Aroostook	228	19	50	10
HOULTON	Aroostook	150	12	53	10
SCARBOROUGH	Cumberland	434	36	25	5
PORTLAND	Cumberland	594	49	15	3
WINDHAM	Cumberland	335	27	25	5
GORHAM	**Cumberland**	**433**	**36**	**71**	**14**
WINTHROP	**Kennebec**	**290**	**24**	**50**	**10**
AUGUSTA	**Kennebec**	**789**	**65**	**78**	**15**
BANGOR	**Penobscot**	**901**	**75**	**141**	**28**

[1]The 5 towns in bold letters were selected as part of the final sample because they had sufficient installations to expect to be able to meet the required sample sizes.

We planned to conduct six metering deployments between October 2017 and September 2018. Assuming a higher response rate of 20% for the low-income program, there were 4 towns (Scarborough, Portland, Lewiston and Windham) with few LIDI installations where we did not expect to get enough participants to agree to on-site metering. The three towns in the remote Aroostook County were removed from the sample frame because of the long travel times. Two deployments were conducted in Bangor due to the high participant volume in the town.

Survey Sampling

The web-based survey covered details about use of the HPWH to inform the gross savings analysis and obtain a better understanding of operational issues from the homeowner's perspective. For CPP, the survey also included a battery of net-to-gross (NTG) questions (self-report and program influence).

To increase the sample size for the NTG questions, the CPP survey sample frame was expanded to include a random sample of all participants with HPWH installations and those who had completed on-site metering. As the survey was web-based, there was no need to restrict participation geographically or for any other reason. A $10 incentive was offered for completion of the survey and 50 respondents completed the survey in addition to the 58 respondents in the homes that were metered, for a total of 108 respondents.

Sampling Weights

Sampling weights were calculated for the CPP NTG analysis by dividing the survey respondents into two groups: those with metering and those who only responded to the survey.[2] Sampling weights were not applied to the NTG analysis as the results with and without the sampling weights were extremely close (within 1%).

Sampling weights were incorporated into the gross savings analysis. The results were calculated with and without the sampling weights and fell within 5% for CPP and 1% for LIDI. The sampling weights for the two programs are given in the tables below.

TABLE A-4: SAMPLING WEIGHTS FOR CPP

Town	Number of Homes	Number of Metered Homes	Expansion Weight[1]	Scaled Weight[2]
Winthrop	290	11	26.4	0.5
Gorham	433	4	108.3	1.9
Auburn	353	6	58.8	1.0
Augusta	789	5	157.8	2.8
Bangor	901	23	39.2	0.7
Total	2766	49		

[1] Expansion weight = N (total number of homes)/n (number of metered homes) and expands the results from the survey to the population.
[2] "Scaled weight" is scaled to the sample size.

TABLE A-5: SAMPLING WEIGHTS FOR LIDI

Town[1]	Number of Homes	Number of Metered Homes	Expansion Weight[2]	Scaled Weight[3]
Gorham	71	6	11.8	1.7
Auburn	62	5	12.4	1.8
Augusta	78	7	11.1	1.6
Bangor	141	32	4.4	0.6
Total	352	50		

[1] The first LIDI deployment was in Gorham as the sample frame was not ready for the first meter installations in Winthrop.
[2] Expansion weight = N (total number of homes)/n (number of metered homes) and expands the results from the survey to the population.
[3] "Scaled weight" is scaled to the sample size.

[2] NTG was not estimated for LIDI.

Summary

The West Hill Energy Team completed metering at a total of 116 homes where heat pump water heaters were installed, with the final analysis including the 49 CPP and 50 LIDI sites with complete and usable metered data. The sampling strategy was developed to cluster sites geographically in order to control evaluation costs. The sampling approach is summarized in Table A-6.

TABLE A-6: SUMMARY OF SAMPLING APPROACH FOR HPWH METERING

Sampling Component	Description
Sampling Strategy	One stage cluster sample
Cluster Definition	Groups of contiguous towns
Sampling Unit	Site with HPWH installation
Target Sample Size	100 total: 50 LIDI, 50 CPP
Precision/Confidence	80/10 for energy savings, assuming a coefficient of variation of 0.55; precision of winter and summer peak demand reduction expected to be worse than 80/10
Time Periods/ Deployments	Six deployments conducted from October 2017 to September, 2018
Selection of Towns	Census; 5 towns had sufficient installations to expect to be able to meet the required sample sizes

For the CPP supplemental survey, a random sample was selected of participants who had not completed on-site metering, resulting in 50 additional completed surveys. Sampling weights were not applied to the NTG analysis as the results with and without the sampling weights were extremely close.

Appendix B

Customer Survey Instruments

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Customer Screener Survey

SCREENER

S1. Please enter your ID number as provided in the letter we sent to you

[RECORD ID]

S2. Our records show that you installed a heat pump water heater at <ADDRESS> on <MONTH, YEAR> Is this correct?

1. Yes
2. Date is wrong, correct date _____________
3. Address is wrong, correct address _____________
4. Upgrade was not installed [THANK AND TERMINATE]
5. Something else? _____________________

S3. Who was the contractor that installed your new heat pump water heater?

1. Contractor name: _______________________________

97. DK

S4. Where is your heat pump water heater installed in your home?

1. Heated/Finished Basement

2. Unfinished/Unheated Basement

3. Garage

4. Attic

5. Closet in Living Space

6. Living Space

7. Other [SPECIFY]

S5. Do you have a dehumidifier in the same area as your heat pump water heater?

1. Yes
2. No

96. Don't Know

We are conducting an evaluation of heat pump water heaters. You may be eligible for a $75 incentive to participate in our on-site survey if you meet all of the following conditions:

1. You are available to meet us at your home and allow us to install special meters to measure the energy usage of your water heater. A licensed electrician will install the meters in the circuit breaker.

   Evening and weekend appointments will be available.

2. You will allow a professional electrician to retrieve the meters and return them to Efficiency Maine's evaluator.

3. You will be available to complete a more detailed survey at a later date

C1. Are you willing to participate in our on-site survey?

1. YES
2. NO **[THANK AND TERMINATE]**

C2. Please confirm your name, address with zip code and e-mail

<NAME>

NAME CORRECTIONS: ___________________________

<ADDRESS>

MAILING ADDRESS CORRECTIONS: __________________________

PHYSICAL ADDRESS (if different from mailing): __________________________

ENTER EMAIL: __________________________

ENTER PHONE NUMBER: __________________________

C3. What is the best way to contact you?

1. E-mail
2. Phone
3. Other______________________

C4. [IF C3=2]: When is the best time to reach you?

Times: ____________

ALTERNATIVE PHONE NUMBERS: ______________

C5. We are planning to conduct site visits in early September. When are you likely to be available during this timeframe? Please provide at least three options.

1. Mondays between 7am and 11am

2. Mondays between 11am and 3pm
3. Mondays between 3pm and 7pm
4. Tuesdays between 7am and 11am
5. Tuesdays between 11am and 3pm
6. Tuesdays between 3pm and 7pm
7. Wednesdays between 7am and 11am
8. Wednesdays between 11am and 3pm
9. Wednesdays between 3pm and 7pm
10. Thursdays between 7am and 11am
11. Thursdays between 11am and 3pm
12. Thursdays between 3pm and 7pm
13. Fridays between 7am and 11am
14. Fridays between 11am and 3pm
15. Fridays between 3pm and 7pm
16. Saturdays between 10am and 2pm
17. Saturdays between 2pm and 5pm

C6. [IF PROGRAM = "LIDI"] If you are selected to participate in our study, we will contact you to set up the site visit. If we are not able to reach you, we need to be able to leave a voicemail with a call back number. Does your phone have voicemail?

3. YES
4. NO

West Hill Energy and Computing is under contract with Efficiency Maine Trust to conduct this survey. If you have any questions, please contact West Hill Energy at 1-802-246-1212.

THANK AND TERMINATE

[TERMINATE AT S1:] Thank you for your time.

[TERMINATE AT C1:] Thank you for your time. The information you provided will be helpful in evaluating and improving the program.

[COMPLET SURVEY:] Thank you for your time. If you are selected for a site visit, we will be in touch to let you know the next steps and to confirm the exact time we will be arriving at your home. If you are selected and we cannot leave voicemail or you are not reachable by phone or email after a couple of attempts, please be aware that you will need to contact us at 802-246-1212 to confirm participation.

Customer Detailed Survey

Section		Number of Questions	Topic Summary
SCREENER	S	2	Identify type of rebate/discount received and record contractor information
GENERAL EQUIPMENT INFORMATION	M	2	Information on location and size of space where HPWH is installed
EQUIPMENT OPERATION	E	5	Determine if and why respondent changes the mode of their HPWH
BASELINE INFORMATION	P	8 retrofit/ 4 MOP only asked for CPP participants	Determine condition and type of previous water heating equipment, also determine heating fuel and presence of AC
SELECTION OF EFFICIENT EQUIPMENT	N	3/ 0 if DIY only asked for CPP participants	Determine the influence of the contractor and respondent in the decision to install a HPWH
FREE RIDERSHIP QUESTIONS	FR	4 max / 2 min only asked for CPP participants	Determine what customer would have done without the rebate from the program
CUSTOMER AWARENESS OF REBATE	CA	1 only asked for CPP participants	Determine how respondent learned about the rebate
OCCUPANCY	OCC	2	Determine when the home is occupied
BARRIER QUESTIONS & PAIRWISE	B	4 only asked for CPP participants	Determine the respondents barriers to installing high efficiency and relative importance
FUNDING	FS	3 only asked for CPP participants	Determine the importance of the rebate in choosing the HPWH
Customer Experience with Contractor	CEC	4/ 1 for LIDI 0 for DIY	Scale customer satisfaction with the contractor and relative importance of using EMT contractor list vs other sources for choosing a contractor
Customer Experiences with Equipment	CEE	3	Scale customer satisfaction with the equipment
Customer Demographics	CD	2	Age and income
Total		42 max/ 32 min for CPP	

Sample Keys:

Name

Phone Number

Address

Attribute_1: screener (0=Did not take screener survey, 1=Did take)

Attribute_2: rebate (amount to be shown in FS2)

Attribute_3: diy (0=flagged as not DIY in screener, 1=flagged as DIY in screener)

Attribute_4: program (LIDI or CPP)

Attribute_5: over1year (0= installed less than 1 year ago, 1=installed more than one year ago)

Attribute_6: sitevisit (=1 if completed site visit, 0 if not)

LIDI stands for Low Income Direct Install

CPP stands for Consumer Products Program

Definitions:

EQUIPMENTA: heat pump water heater

Intro: Welcome and thank you for agreeing to participate in the Efficiency Maine Heat Pump Water Heater Survey. Our goal is to gather accurate feedback on the program and how it helped you in the decision making process.

Screener

S0. Our records show that you installed a <EQUIPMENTA> at <ADDRESS> in <MONTH, YEAR> Is this correct?

1. Yes
2. Date is wrong, correct date _____________
3. Address is wrong, correct address _____________
4. Heat pump water heater was not installed [THANK AND TERMINATE]
5. Something else? _____________________

S1. [ASK IF SCREENER=0] Who installed your new <EQUIPMENTA>?

1. [RECORD NAME OF CONTRACTOR]
2. [IF PROGRAM = CPP] You installed it yourself
3. [IF PROGRAM = CPP] A friend or family member installed it
4. Don't know name of contractor

[IF S1=2 OR S1=3, DIY=1; ELSE DIY=0]

S2. [IF PROGRAM = CPP] How did you receive a rebate on the <EQUIPMENTA>?

1. You mailed a rebate claim form to Efficiency Maine
2. You received an instant rebate from your plumber or distributor
3. You are not aware that you received a discount
4. Something else? ______________

General Equipment Information

M1. [IF SCREENER = 0] Where is your <EQUIPMENTA> installed in your home?

1. Heated area in basement (has a thermostat)
2. Unheated area in basement (does not have a thermostat)
3. Garage
4. Attic
5. Closet in living space
6. Living space
7. Other [SPECIFY]

M2. What is the size of the room where the <EQUIPMENTA> is installed?

1. Smaller than 100 square feet (approx 10x10)
2. 100 square feet or larger
3. Don't know

M3. [IF M2=1] How would you describe this room? Choose all that apply

1. A room with a door that is usually open
2. A room with a solid door that is usually closed
3. A room with a louvered door that is usually closed
4. Other (specify) ___________________
5. Don't know

Equipment Operation

E1. How many heat pump water heaters are you currently using in your home?

1. 1
2. 2
3. 3 or more

E2. Heat pump water heaters have several modes of operation, as shown on the control panel of the water heater. Prior to participating in this survey, were you aware that your heat pump water heater has several modes?

1. Yes
2. No

E3. [ASK IF DIY=0 OR S1=1 OR S1=4] [DO NOT ASK IF E2=2] When your contractor installed your heat pump water heater, did he/she explain the different modes?

1. Yes
2. No

E4. [ASK IF E2=1 AND OVER1YEAR=1] During the past year, how many weeks did you have your heat pump water heater in each of these modes?

Please enter a "0" for any modes that you did not use in the past year.

[ROTATE ORDER OF MODES.] [MUST TOTAL 52]

1. Heat pump or efficiency: ____________weeks
2. Hybrid: ________________ weeks
3. High Demand: ___________ weeks
4. Electric: ________________ weeks
5. Vacation: _______________ weeks

E5. [ASK IF E2=1 AND OVER1YEAR=0] Since you purchased the heat pump water heater, how many weeks have you used the water heater in each of these modes?

[ROTATE ORDER OF MODES.] [DO NOT HAVE TO TOTAL TO 52.]

1. Heat pump or efficiency: ____________weeks
2. Hybrid: ________________ weeks
3. High Demand: ___________ weeks
4. Electric: ________________ weeks
5. Vacation: _______________ weeks

E6. [IF MORE THAN ONE MODE SELECTED IN E4 OR E5] Why did you change the mode? Choose as many as apply.

1. You needed more hot water
2. You wanted to use less electricity
3. Heat pump or hybrid mode did not provide enough hot water
4. You put it on vacation mode when you are away
5. Something else? ________________

Baseline Information

[ASK BASELINE QUESTIONS IF PROGRAM = CPP]

P1. Did you replace your existing water heater with the heat pump water heater?

1. Yes, you replaced one existing water heater
2. Yes, you replaced two existing water heaters with the heat pump water heater
3. No, you installed the heat pump water heater in a new home
4. No, the heat pump water heater was installed in addition to your existing water heater
5. Something else? Describe: __________

P2. [IF P1=4] Why did you add the heat pump water heater? [CHOOSE AS MANY AS APPLY.]

1. The existing water heater did not provide enough hot water
2. You remodeled or added new rooms to your home
3. You decided to add a dedicated water heater to a bathroom or kitchen
4. Something else? Describe: __________

P3. [ASK IF P1 = 1 OR 2] Which of the following best describes the condition of the existing equipment that was replaced?

1. It had failed and you needed to replace it immediately (within a week or two).
2. It was about to fail and you expected to have to replace it within six months.
3. It required frequent maintenance.
4. It worked well, but was old and would probably need to be replaced in next couple of years.
5. It was in reasonable condition and not expected to fail in the next few years.
6. It was in good condition, but was too expensive to use.
7. Something else? ___________________________

P4. [ASK IF P1 = 1 OR 2] Prior to installing the heat pump water heater, what fuel did you use to heat your water?

1. Natural Gas
2. Propane
3. Electricity
4. Oil
5. Solar
6. Other [Please describe fuel:_______]

P5. [ASK IF P1 = 1 OR 2] Prior to installing the heat pump water heater, what type of water heater did you use?

1. Stand-alone tank (tank not connected to a boiler)
2. Tankless on demand (on demand unit separate from boiler)

3. Tankless coil (water heated inside the boiler)
4. Tank integrated with boiler (water heated by boiler, stored in a separate tank)
5. Electric stand-alone tank or tankless on demand
6. Solar with electric back up
7. Solar with natural gas or propane back up
8. Something else? ___________

P6. When you decided to purchase your water heater, which other options did you seriously consider? Choose as many as apply.

1. Natural Gas or Propane - Stand-alone tank (tank not connected to a boiler)
2. Natural Gas or Propane - Tankless on demand (on demand unit separate from boiler)
3. Natural Gas or Propane - Tankless coil (water heated inside the boiler)
4. Natural Gas or Propane - Tank integrated with boiler (water heated by boiler, stored in separate tank)
5. Electric stand-alone tank or tankless on demand
6. Oil - Stand-alone tank (tank not connected to a boiler)
7. Oil - Tankless coil or sidearm (water heated inside the boiler)
8. Oil - Tank integrated with boiler (water heated by boiler, stored in separate tank)
9. Solar with electric back up
10. Solar with natural gas or propane back up
11. Don't know
12. Something else: _________

P7. How do you heat your home? [Choose all that apply.]

1. Natural gas boiler or furnace
2. Oil boiler or furnace
3. Propane boiler or furnace
4. Wood boiler or furnace
5. Wood or wood pellet stove
6. Electric baseboard, radiant or electric plug-in heater
7. Oil, propane, or kerosene space heater
8. Natural gas fireplace
9. Propane fireplace
10. Wood fireplace
11. Minisplit or ductless heat pump

12. Geothermal heat pump or solar
13. Other [Please describe type and fuel:_______]

P8. What type of air conditioning do you have? (Choose as many as apply.)

1. Room or window air conditioners
2. Minisplit, ductless or geothermal heat pump
3. Central air conditioning
4. None
5. Something else? Tell us: _________________

Selection of Efficient Equipment

[ASK THIS SECTION IF PROGRAM = CPP]

[ASK N1-N3 IF DIY=0 OR S1=1 or S1=4]

N1. Did your contractor recommend the heat pump water heater?

1. Yes
2. No
3. Not sure_____________________

N2. Which statement is closest to how you made your decision to install the heat pump water heater?

1. The contractor's influence was more important than your own research or other sources of information.
2. Your own research or other sources of information was more important than the contractor's influence.
3. Don't know

[IF N2=1 FACTOR1= "your contractor's influence" AND FACTOR2= "your own research"]

[IF N2=2 FACTOR1= "your own research" AND FACTOR2= "your contractor's influence"]

N3. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Was FACTOR1 …

1. about the same as FACTOR2
2. 2
3. 3
4. 4
5. 5
6. FACTOR1 was the only important factor

7. Don't know

Freeridership Questions

[ASK FREE RIDERSHIP QUESTIONS IF PROGRAM = CPP]

FR1. [DO NOT ASK IF S2=3] The next questions are about what you would have done if Efficiency Maine had not provided a rebate. If no rebates had been available, would you have purchased a new water heater of any type?

1. Yes, you would have purchased a new water heater
2. No, you would not have purchased any type of new water heater
3. Don't know

FR2. [ASK IF FR1 = 1.] Would you have purchased the same <EQUIPMENTA> if the cost were <REBATEAMOUNT> more than you paid? [RANDOM ORDER, 1 TO 5 AND 5 TO 1.]

1. Definitely would not
2. Probably would not
3. Not sure
4. Probably would [GOTO NEXT SECTION]
5. Definitely would [GOTO NEXT SECTION]

FR3. [IF FR2= 1, 2 OR 3:] Would you have purchased a heat pump water heater at a later time or a different type of water heater?

1. Heat pump water heater at a later time
2. A different type of water heater [SKIP TO NEXT SECTION]
3. Don't know [SKIP TO NEXT SECTION]

FR4. [DO NOT ASK IF S2=3, FR2="Probably would not", Definitely would not" or "not sure", FR3=2, 3] The next question is about when you would have purchased a new heat pump water heater if the rebate had not been offered by Efficiency Maine. Would you have made the purchase within six months, six months to one year, or over a year from when you did?

1. Within 6 months
2. 6 months to one year
3. Over one year
4. Don't know

Customer Awareness of Rebate

[ASK THIS SECTION IF PROGRAM = CPP]

CA1. [IF S2 <> 3] How did you first learn that the discount/rebate was available? [SELECT ONE]

1. Efficiency Maine website
2. An ad

3. In store display
4. Your contractor who completed the installation told you about it
5. A different contractor told you about it
6. A family member, friend, or neighbor
7. Did not know about the rebate
8. Other: ______
9. Don't know

Occupancy

OCC1. How many weeks was your home occupied during the past year?

1. All 52 weeks
2. 51-48 weeks
3. Less than 48 weeks

OCC2. [IF OCC1=3] How many weeks was your home occupied in each season?

1. Spring _________________ (maximum of 13 weeks)
2. Summer ___________________(maximum of 13 weeks)
3. Fall ______________________(maximum of 13 weeks)
4. Winter ______________________(maximum of 13 weeks)

Barrier Questions

[ASK BARRIER QUESTIONS IF PROGRAM = CPP]

B1. Thinking back to before the installation and how you selected a heat pump water heater instead of a standard unit, we are interested in your challenges in moving ahead with the project and your concerns about choosing the high efficiency option.

Many homeowners have the following concerns:

- Lack of information, i.e. not sure what to install, want to learn about environmental impacts or greenhouse gas reductions
- Paying the premium for the high efficiency unit, i.e. concerns about payback, whether the extra cost is worth it, covering the cost premium
- Equipment concerns, i.e. noise levels, providing enough hot water, maintenance needs
- Finding a contractor you could trust

Please select any concerns you had by dragging and dropping them into the column on the left. Concerns that were not important to you should remain in the column on the left.

Rank as many as apply in order of importance, with the item at the top indicating the most important.

Please take a minute to consider your choices because the next set of questions will be based on your response

[RANK ITEMS]

1. Lack of information
2. Paying the premium for the high efficiency unit
3. Equipment concerns
4. Finding a contractor you could trust
5. Something else
6. No concerns

[FACTOR1 = Ranked item 1]

[FACTOR2 = Ranked item 2]

[FACTOR3 = Ranked item 3]

[ASK B2 if Ranked item 1 is (1-4) and Ranked item 2 is not blank, and is (1-4)]

B2. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1 on a scale from 1 to 6? Was FACTOR1 …

1. 1 - about the same as FACTOR2
2. 2
3. 3
4. 4
5. 5
6. 6 - FACTOR1 was the only important factor

96. Don't know

[ASK B3 IF RANKED ITEM 1 IS (1-4) AND RANKED ITEM 3 IS (1-4)]

B3. Comparing FACTOR1 to FACTOR3 on scale from 1 to 6, how would you rate the importance of FACTOR1? Was FACTOR1 …

1. 1 - about the same as FACTOR3
2. 2
3. 3
4. 4
5. 5
6. 6 - FACTOR1 was the only important factor

96. Don't know

[ASK B3 IF RANKED ITEM 1 IS (1-4) AND RANKED ITEM 3 IS (1-4) AND (B2 != 6 OR B3 != 6)]

B4. Comparing FACTOR2 to FACTOR3 on scale from 1 to 6, how would you rate the importance of FACTOR2? Was FACTOR2 …

1. 1 - about the same as FACTOR3
2. 2
3. 3
4. 4
5. 5
6. 6 – FACTOR2 was the only important factor

96. Don't know

Funding

[ASK THIS SECTION IF PROGRAM = CPP]

FS1. What were the funding sources you used to pay for the installation of your heat pump water heater? [Choose as many as apply.]

1. Personal savings
2. Incentive or discount from the contractor or manufacturer
3. Rebate or discount from Efficiency Maine
4. Incentive or grant from a municipal or federal program
5. Home equity line of credit
6. Loan from your bank
7. Federal tax credit
8. Credit card
9. Something else? ___________________

FS2. Heat pump water heaters often cost more than standard water heaters. The next question is about how you decided to pay the premium for the heat pump water heater in comparison to a standard one.

Rebate is the <REBATE AMOUNT> discount from Efficiency Maine that you received by mailing a rebate form or directly from your contractor or retailer.

Other influences include your personal savings, other sources of funding or any other factors that were important to your decision making process.

Thinking only about *what tipped your decision to pay the premium* for your heat pump water heater, which statement is closest to how you made your decision. [Choose one.]

1. The rebate was more important than the other influences.
2. Other influences were more important than the rebate from Efficiency Maine.
3. Don't know

[IF FS2=1, THEN FACTOR1= "the rebate" and FACTOR2= "other influences".]

[IF FS2=2, THEN FACTOR1= "other influences" and FACTOR1= "the rebate".]

FS3. Comparing FACTOR1 to FACTOR2 on scale from 1 to 6, how would you rate the importance of FACTOR1? Was/Were FACTOR1 …

1. 1 - about the same as FACTOR2
2. 2
3. 3
4. 4
5. 5
6. 6 - FACTOR1 was the only important factor

96. Don't know

Customer Experiences with Contractor

[ASK CEC1-CEC2 IF DIY=0 OR S1=1 or S1=4]

The next set of questions relates to your experiences with the contractor who installed the new <EQUIPMENTA>.

CEC1. [IF PROGRAM = CPP] How did you select the contractor who installed the heat pump water heater? Choose only one.

1. A contractor you had used in the past
2. Efficiency Maine list of registered contractors
3. Personal research or referral from other friends, family or other resources
4. Something else?___________________

CEC2. [IF CEC1 = 2 AND PROGRAM = CPP]

Some customers have concerns about selecting a contractor they can trust. The next set of questions is about how you selected the contractor who installed your heat pump water heater.

Efficiency Maine's contractor list includes contractors who registered with Efficiency Maine

Other sources for finding a contractor include your personal research or assistance from family or friends

Thinking about how you selected your contractor, which statement is closest to how you made your decision. [Choose one.]

1. Efficiency Maine's contractor list was more important than other sources for finding a contractor
2. Other sources for finding a contractor were more important than Efficiency Maine's contractor list

[IF CEC2=1, THEN FACTOR1= "Efficiency Maine contractor list" and FACTOR2= "other sources for finding a contractor"]

[IF CEC2=2, THEN FACTOR1= "other sources for finding a contractor" and FACTOR1= "Efficiency Maine contractor list"]

[IF FACTOR 1 is "Efficiency Maine contractor list" use "Was" AND IF FACTOR 2 is "other sources for finding a contractor" use "Were" in CEC3.]

CEC3. Comparing FACTOR1 to FACTOR2 on scale from 1 to 6, how would you rate the importance of FACTOR1? Was\Were using FACTOR1 …

1. 1 - about the same as FACTOR2
2. 2
3. 3
4. 4
5. 5
6. 6 - FACTOR1 was the only important factor

96. Don't know

CEC4. How satisfied were you with the contractor who installed the heat pump water heater? [SCALE 1 TO 5, NOT AT ALL TO VERY SATISFIED]

Record: ____________________

Comment: ___________________________________

Customer Experiences with Equipment

CEE1. Please rate your satisfaction with your new <EQUIPMENTA>.

[GRID][SCALE]

1. Very dissatisfied
2. Somewhat dissatisfied
3. Neither satisfied nor dissatisfied
4. Somewhat satisfied

5. Very satisfied

[SUBQUESTIONS]

CEE1a. Overall satisfaction with the heat pump water heater

CEE1b. Noise level

CEE1c. Provides enough hot water

CEE1d. Easy to use settings [such as vacation setting, high use mode, heat pump only mode]

CEE1e. Maintenance

CEE1f. Saving energy or reducing fuel costs

Comments: ____

CEE2. [ASK IF ANY RESPONSE TO CEE1a-CEE1f is 1, 2, or3]

What issues, if any, have you experienced with your heat pump water heater?

RECORD RESPONSE:____________

CEE3. Do you have a dehumidifier in the same area as your heat pump water heater?

3. Yes
4. No
96. Don't Know

CEE4. [IF CEE3 = 1 ELSE SKIP TO CD1] Since you installed the heat pump water heater, does your dehumidifier run the same, more or less? If you have more than one dehumidifier, think about the one closest to the heat pump water heater.

1. You don't have a dehumidifier
2. Runs a lot more
3. Somewhat more
4. About the same
5. Somewhat less
6. A lot less
7. [IF OVER1YEAR=0] Not sure because the heat pump water heater was recently installed
96. Don't know

CEE5. [IF CEE4=5 OR 6] How often did you use your dehumidifier before your heat pump water heater was installed? Your best estimate is fine.

1. Less than 1 month during the year before the heat pump water heater was installed

2. About 1 month
3. 2 months
4. 3 months
5. 4 months
6. 5 months
7. 6 months
8. 7 to 9 months
9. 10 to 12 months
10. Don't know

CEE5. [IF CEE4=5 OR 6] How often do you use the dehumidifier since your heat pump water heater was installed?

1. You removed your dehumidifier after the heat pump water heater was installed
2. Less than 1 month during the year since the heat pump water heater was installed
3. About 1 month
4. 2 months
5. 3 months
6. 4 months
7. 5 months
8. 6 months
9. 7 to 9 months
10. 10 to 12 months
11. [IF OVER1YEAR=0] Not sure because the heat pump water heater was recently installed
96. Don't know

Customer Demographics

The next questions are for statistical purposes only. This information will be combined across all participants and will not be shared with anyone outside of the evaluation team in any way that could identify you or your household.

CD1. What is your age? Is it…

1. 18 to 24
2. 25 to 34
3. 35 to 44
4. 45 to 54
5. 55 to 64

6. 65 or over
7. Refuse

CD2. Including all adults and children, how many people live in your household? Please include all household members who have used your address as their primary residence over the past 12 months.

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7 or more

CD3. Considering the total combined income of all members of your household over the past 12 months was your total income great than or less than…….
[IF CD2 =1] $17,820
[IF CD2=2] $24,030
[IF CD2=3] $30,240
[IF CD2=4] $36,450
[IF CD2=5] $42,660
[IF CD2=6] $48,870
[IF CD2>=7] $55,095

1. Greater Than
2. Less Than
3. Don't know
4. Refuse

CD4. What is the highest grade of schooling you have completed so far?

1. No High School Diploma or GED
2. High School Graduate (includes GED)
3. Associates Degree
4. Bachelor's Degree (4-year degree)
5. Graduate or Professional Degree
6. Refuse

****

TERMINATE AT S0: Thank you for your time.

END OF SURVEY [IF SITEVISIT = 1]: That completes the survey. We may contact you by phone or e-mail if we have any follow up questions. It will take about 6 to 8 weeks to process your $75 incentive.

Thank you very much for your time and thoughtful answers today.

END OF SURVEY [IF SITEVISIT = 1]: That completes the survey. We may contact you by phone or e-mail if we have any follow up questions. It will take about 6 to 8 weeks to process your $10 incentive.

Thank you very much for your time and thoughtful answers today.

Appendix C

Customer Survey Findings

Appendix C: Customer Survey Findings

All participants who completed on-site metering were required to take a detailed customer survey. The customer detailed survey had questions related to participant demographic and home characteristics, sources of awareness, motivations, equipment funding, barriers, and satisfaction. Of the 116 Low Income Direct Install Initiative (LIDI) and Consumer Products Program (CPP) participants who completed on-site metering, 113 completed the customer survey. Additional solicitation for CPP participants was conducted in order to meet the target number of 100 CPP surveys to calculate net-to-gross (NTG). An email blast was sent to 348 participants. Fifty (50) participants completed the survey and received a $10 check incentive. The survey findings are presented below for 107 Consumer Products Program and 56 Low Income Direct Install Initiative participants.

C-1 Equipment Operation

All survey respondents, except one, purchased one heat pump water heater (HPWH). Due to their noise and cooling effect, heat pump water heaters should ideally be installed in unheated and unconditioned basements. Heat pump water heaters use heat from the area they occupy. West Hill Energy analyzed any interactive effects between the HPWH and both the central heating and cooling systems. As explained in the Section 4.4. in the main report, an analysis of the interaction between the heating system and heat pump water heater provided inconclusive results.

Table C-1 and Table C-2 below summarizes the responses on heat pump water heater location based on the customer survey and on-site verification. About 74% of the 58 CPP respondents with on-site visits installed their heat pump water heater (HPWH) in an unheated basement. Approximately 81% of the LIDI respondents with on-site visits installed the water heater in an unheated basement.

TABLE C-1: LOCATION OF HEAT PUMP WATER HEATERS - CPP

	CPP Survey		CPP On-Sites	
Location of Heat Pump Water Heater	Responses (n=106)	Percent of Responses	Responses (n=58)	Percent of Responses
Heated basement	22	21%	12	21%
Unheated basement	74	70%	43	74%
Closet in living space	4	4%	0	0%
Other[1]	6	6%	3	5%

[1] "Other" from survey include living space, attic, washroom and garage. "Other" from on-site include unheated utility rooms and an unheated cellar.

TABLE C-2: LOCATION OF HEAT PUMP WATER HEATERS - LIDI

	LIDI Survey		LIDI On-Sites	
Location of Heat Pump Water Heater	Responses (n=56)[1]	Percent of Responses	Responses (n=58)	Percent of Responses
Heated basement	12	21%	9	16%
Unheated basement	40	69%	47	81%
Closet in living space	3	5%	2	3%
Other[2]	3	5%	0	0%

[1]There were 2 participants who completed the site visit but did not complete the survey
[2]"Other" from survey include 3 respondents who reported "Other" and entered the location as the basement without specifying if it's heated or not.

Heat pump water heaters have different modes of operation, with the heat pump mode being the most efficient. Survey respondents were asked if they were aware of the different heat pump water heater modes. Approximately 93% of the 107 CPP survey respondents reported being aware of the different modes of operation before participating in the study. Of the 56 LIDI survey respondents, 79% said they were aware of the operational modes. About 75% of the CPP respondents reported their contractor explained how to use heat pump water heater operational modes. About 70% of LIDI respondents cited their contractor explained how to use the different modes.

Figure C-1 provides a summary of water heater mode use as reported by the CPP and LIDI survey respondents. About one third (34%) of CPP and three-quarters (77%) of LIDI respondents reported running their heat pump water heater in a single mode, which is typically either heat pump or hybrid mode.

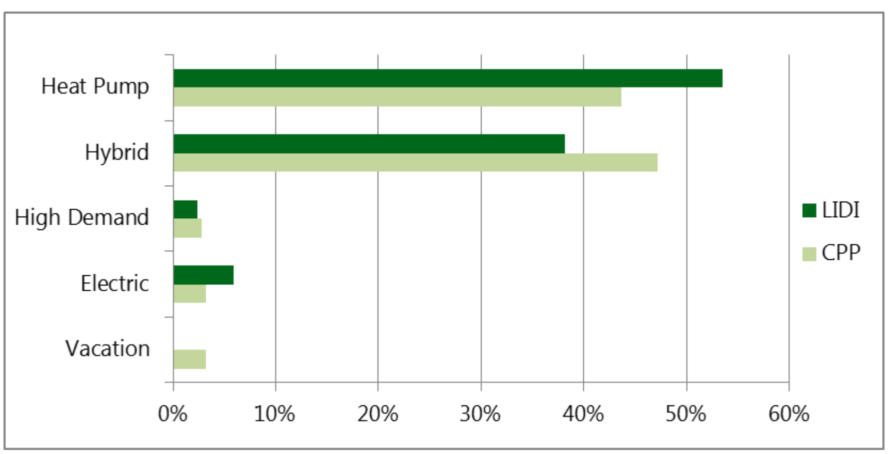

FIGURE C-1: WATER HEATER MODES FOR LIDI (N=52) AND CPP (N=105) SURVEY RESPONDENTS[1]

[1] Respondents were asked this question only if the heat pump water heater was installed over one year prior to the survey.

For respondents who reported using more than one mode, a follow-up question was asked as to why they change the mode. A summary of the responses for both LIDI and CPP are provided in Table C-3 below.

TABLE C-3: REASONS FOR CHANGING HEAT PUMP WATER HEATER MODES

	CPP		LIDI	
Why did you change the mode?	**Responses (n=71)[1]**	**Percent of Responses**	**Responses (n=15)[1]**	**Percent of Responses**
Needed more hot water	59	57%	4	4%
To use less electricity	38	37%	14	13%
Heat pump mode cools space too much	5	5%	1	1%
Put HPWH on vacation mode when away	1	1%	0	0%
Other[2]	1	1%	1	1%

[1]Multiple responses were allowed
[2]One respondent reported changing the mode to see the cost difference and another respondent changed the mode because they wanted less hot water

Twelve (12) respondents reported that they switched modes because they either needed more hot water or wanted to use less electricity. All except one of these respondents also reported using either high demand or electric resistance mode for at least 2 weeks out of the year.

C-2 Equipment Replacement

Homeowners buying heat pump water heaters replaced different types of water heaters for various reasons. Some homeowners replaced an electric resistance water heater (indicating electric resistance is the correct baseline for these homes) and other homeowners replaced other systems, such as integrated hot water from a boiler.

The majority of CPP respondents reported replacing one existing water heater, as shown in Figure C-2 below. Only 8 respondents (7%) installed a heat pump water heater in a new home and 13% installed the HPWH in addition to an existing water heater. All 8 respondents who installed the heat pump water heater in a new home reported they wanted an alternative to an oil furnace or boiler to save money or use a different system that is more reliable and energy efficient.

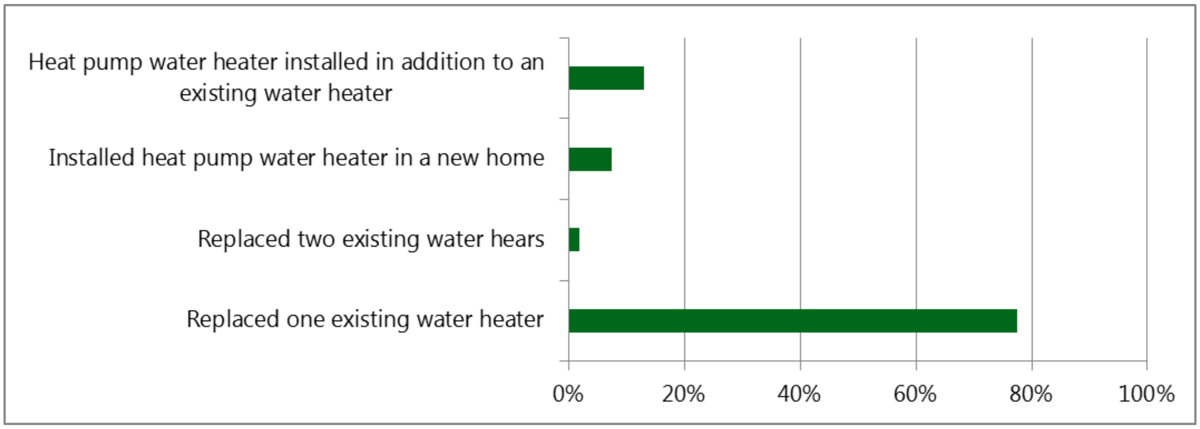

FIGURE C-2: EQUIPMENT REPLACEMENT FOR CPP SURVEY RESPONDENTS (N=107)

Out of 75 respondents who replaced existing water heaters, 20% reported the water heater had failed and needed replacement immediately (within a week or two) and 19% reported that the water heater was about to fail and would have been replaced within six months. About 35% of the respondents cited the existing water heater worked well, or was in reasonable condition, and did not need replacement for a couple years. A summary of the responses is provided in Figure C-3 below.

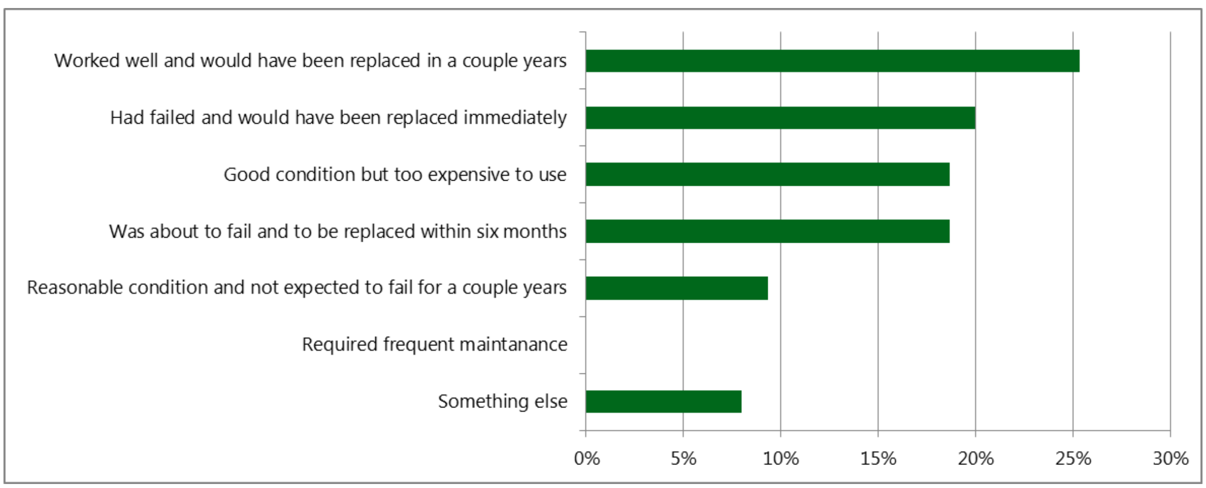

FIGURE C-3: PRE-EXISTING WATER HEATER CONDITION FOR CPP SURVEY RESPONDENTS (N=75)

Respondents were asked the types of water heaters they used before installing a heat pump water heater. A summary of the fuel types and water heater types is provided in Table C-4 below.

TABLE C-4: EXISTING WATER HEATER FUEL AND SYSTEM TYPES FOR CPP RESPONDENTS (N=75)

Heating System Type	Natural Gas		Propane		Electric		Oil	
	Count	%	Count	%	Count	%	Count	%
Stand-alone tank	2	3%	4	5%	20	27%	8	11%
Tankless on demand	1	1%	1	1%	0	0%	2	3%
Tankless coil	0	0%	0	0%	0	0%	4	5%
Tank integrated with boiler	0	0%	1	1%	0	0%	13	17%
Electric stand alone or tankless on demand	0	0%	0	0%	19	25%	0	0%
Total	3	4%	6	8%	39	52%	27	36%

CPP survey respondents were also asked what other water heater options they considered before purchasing a heat pump water heater. A summary of the options is provided in Figure C-4 below. Multiple responses were allowed for this question. Of the 107 respondents, approximately 34% mentioned they considered a natural gas or propane boiler and 36% considered purchasing an electric resistance water heater.

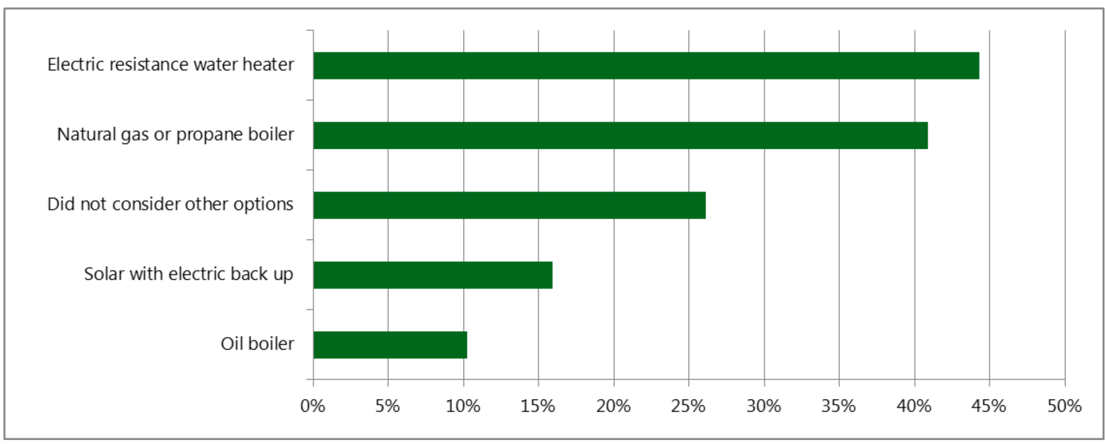

FIGURE C-4: EXISTING WATER HEATER TYPE FOR CPP SURVEY RESPONDENTS (N=88)[2]

As shown in Figure C-4 above, approximately 21% said they did not consider any other options and only 8% considered an oil boiler. A minority of the respondents (13%) considered buying a solar water heater.

C-3 Awareness

The LIDI Program respondents were not asked the rebate awareness questions because the program is a direct install program that pays 100% of the cost and requires all participants to use

[2] Nineteen respondents said, "Don't know" and were removed from the total count

an Efficiency Maine-registered contractor. About 77% of the 107 CPP survey respondents had their equipment installed by a contractor and 23% installed the equipment themselves (including having a friend or family member involved in the installation).

Most of the CPP respondents (82%) became aware of the rebate through Efficiency Maine's website, advertisements, or a contractor. As shown in Figure C-5 below, a lower proportion (18%) of the survey respondents learned about the rebate from a different contractor or other sources (including friends, neighbors or family members).

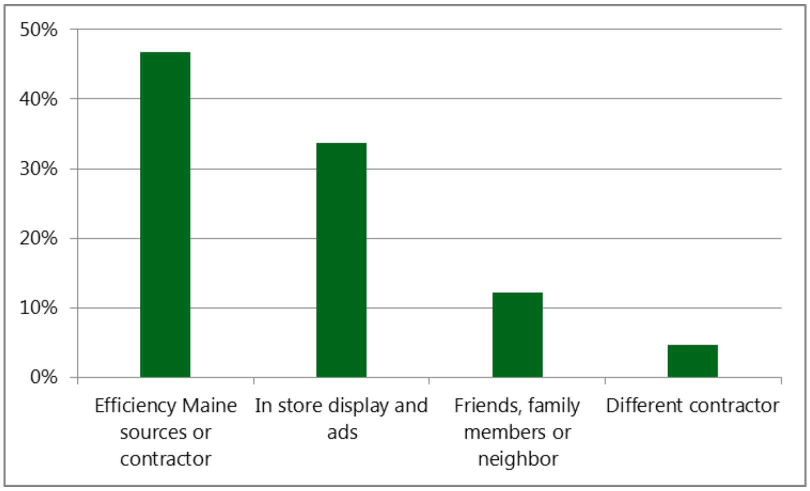

FIGURE C-5: REBATE AWARENESS FOR CPP SURVEY RESPONDENTS (N=107)

C-4 Dehumidifier Use

A heat pump water heater acts as a dehumidifier as it extracts heat from the area where it is located. Program participants are likely to run their dehumidifier less after installing a heat pump water heater for this reason. Out of 107 CPP respondents, 24 (22%) said they have a dehumidifier in the same area as the heat pump water heater. Of the 56 LIDI survey respondents, 11 (20%) reported having a dehumidifier. Table C-5 and Table C-6 below provides a summary of how respondents reported using their dehumidifiers after installing a heat pump water heater.

TABLE C-5: PRESENCE OF DEHUMIDIFIERS

	CPP		LIDI	
Do you have a dehumidifier?	Respondents (n=107)	Percent of Respondents	Respondents (n=56)[1]	Percent of Respondents
Yes	23	21%	11	20%
No	84	79%	43	77%

[1]Two respondents said "Don't know"

TABLE C-6: DEHUMIDIFIER USE AFTER HPWH INSTALLATION

Since installing the HPWH, do you use your dehumidifier …	CPP		LIDI	
	Respondents (n=24)	Percent of Respondents	Respondents (n=11)	Percent of Respondents
About the same	6	26%	5	45%
Somewhat less	6	26%	2	18%
A lot less	8	35%	1	9%
Somewhat or a lot more	0	0%	0	0%
Don't know	3	13%	3	27%

As shown in the table above, respondents with dehumidifiers reported they use the dehumidifier about the same or less since installing the heat pump water heater. Of the 17 respondents who reported using the dehumidifier somewhat or a lot less, 4 respondents (24%) removed the dehumidifier after the heat pump water heater was installed.

C-5 Satisfaction

Respondents rated their satisfaction with the heat pump water heater purchased through the program, as well as with a variety of specific aspects of the equipment. Figure C-6 shows overall equipment satisfaction for both CPP and LIDI participants.

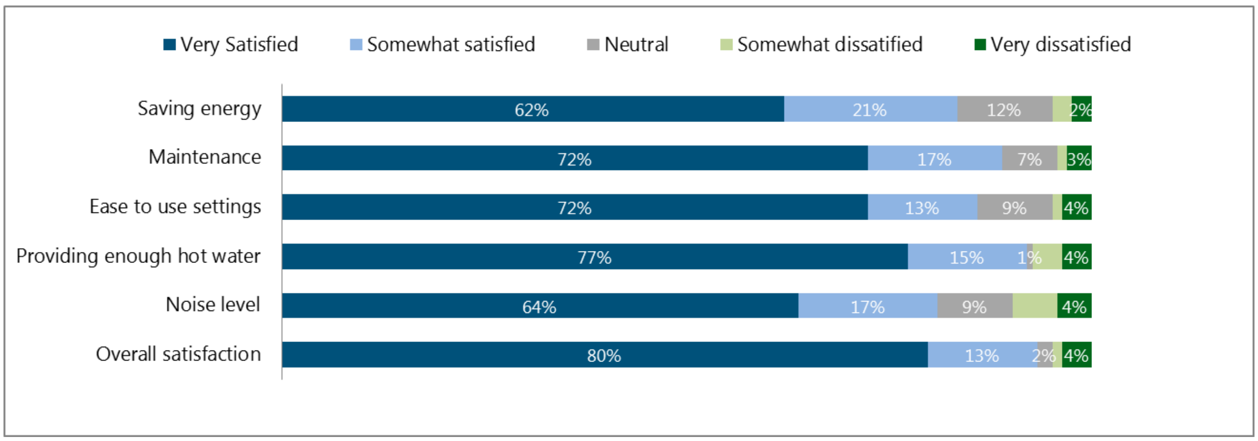

FIGURE C-6: EXISTING WATER HEATER TYPES FOR LIDI (N=52) AND CPP (N=105) SURVEY RESPONDENTS

Overall, the overwhelming majority (93%) of all respondents were, at least, somewhat satisfied with their equipment and four-fifths were very satisfied (80%). In an open-ended question, 12% of the respondents reported having issues with their heat pump water heater such as leaks, cleaning the filter, not having enough hot water in heat pump mode, and technical issues with the display.

C-6 Demographics

Survey respondents were asked several demographic questions pertaining to the number of occupants in their home, annual income, and education levels. The majority of respondents reported their home was occupied year-round, as shown in Figure C-7 below. About 7% of the CPP survey respondents said that the home was occupied for less than 48 weeks, suggesting that a small percentage of heat pump water heaters were installed in second or vacation homes.

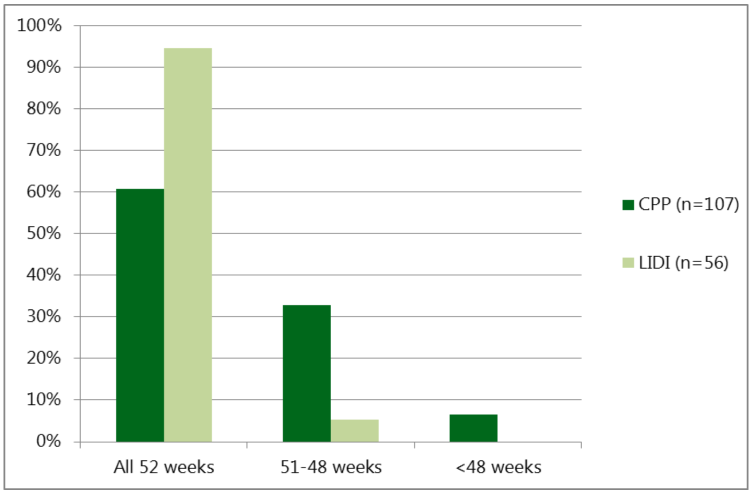

FIGURE C-7: ANNUAL OCCUPANCY FOR LIDI (N=52) AND CPP (N=105) SURVEY RESPONDENTS

As shown in Figure C-8 below, 39% of both CPP and LIDI program participants were 65 years or older. In contrast, a single respondent was under 24 years of age and represented less than 1% of the total. This distribution is consistent with a program targeted to homeowners who tend to be older individuals, thus more likely to own homes than younger individuals.

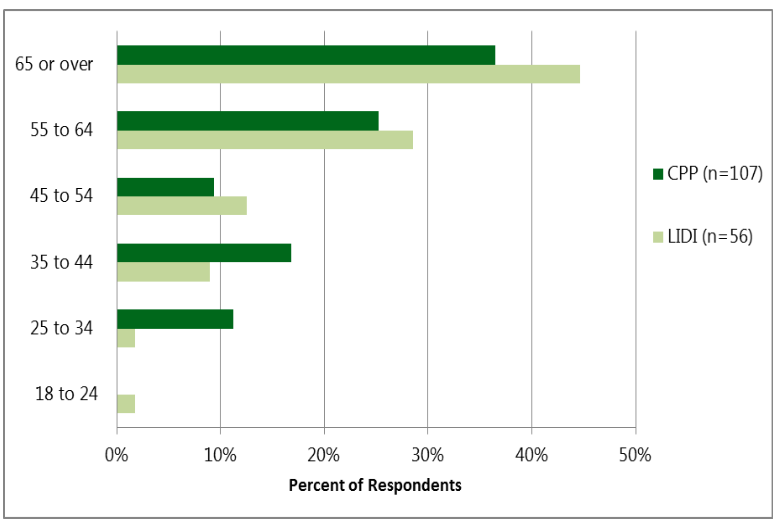

FIGURE C-8: DISTRIBUTION OF PARTICIPANT AGE FOR LIDI (N=52) AND CPP (N=105) SURVEY RESPONDENTS

Overall, the CPP sample population proved to be highly educated compared to the Maine population, with 75% of the 107 surveyed participants having attained at least a college degree. According to US Census Bureau, 30.3% of Maine residents have a bachelor's or higher. For people 25 years old and older, the number with Associate degree or higher is 40.2%.[3] Of the 56 LIDI participants, about 39% of the participants had a bachelor's degree or higher. About 95% of the CPP respondents had total household income above the Low-Income Heating Energy Assistance Program (LIHEAP) income eligibility threshold.[4]

[3] 2013-2017 American Community Survey 5-Year Estimates https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

[4] https://www.benefits.gov/benefit/1558

Appendix D

Heat Pump Water Heater Site Visit Protocols and Forms

Appendix D: Heat Pump Water Heater Site Visit Protocols and Forms

Checklist before Going On-Site

Metering equipment

One Dent meter and 3 voltage clips w\ cables	Program for 2-minute intervals on 2 channels, power to neutral
3 50-Amp CT's	
Two U12 temperature loggers with temperature probes	Program for 2-minute intervals, degree F
One ambient temperature/humidity logger	Program for 2-minute intervals, degree F
1 UX 100 Thermocouple	Use to measure cold water temperature at faucet. Program for 5-second intervals
1 Brand meter	For metering dehumidifier, if needed
Pipe insulation and Electrical tape	For water temperature probes (multiple sizes)

Other

1. Synchronize time on all four meters
2. WHEC badge or business card.
3. Laptop
4. First Aid Kit
5. Mug and hand towel, for measuring water temperature at faucet
6. Headlamp/flashlight
7. Review manufacturer installation specifications and program Dent for correct wiring.
8. Customer Handout form and Release form. Fill in any blank dates on the customer handout. Include phone # to call if there are any questions or concerns.
9. Instructions for electrician for retrieval, with equipment collection checklist

Procedure While On-Site

Explain the site visit and how the meter will be collected to the home owner, provide the customer handout, and answer any questions they may have.

<u>Before the electrician turns off the power record and photograph the following:</u>

HPWH mode setting	Heat Pump Hybrid Electric Resistance
Temperature Setting	

Installation of meters

1. Have electrician install the Dent meter on the HPWH circuit for channels 1& 2. Attach the heating system CT to channel 3 if it is in the same panel. The heating system and channel 1 should be on the same leg. Only the electrician is allowed to work in live electrical panels.
2. Maintain a safe distance from the panel and follow the electrician's direction while the panel is open and the meter is being installed. Wear safety goggles!
3. Photograph Dent installation when electrician has installed meter, but not yet replaced panel cover. Include ID# in photo and record on data collection sheet.
4. Ensure the circuit box cover can close after installation.
5. After the panel is closed, connect to meter via Bluetooth.[1] Confirm meter is receiving reasonable readings (positive, within the expected kW range) and metering is set to record at a 2-minute interval.
6. Identify inlet and outlet pipes. Tape temperature probes to each, at least 3 feet from where the pipe exits the tank (if possible), distance further if the pipes are insulated. Install foam-insulation over the probes. If the hot water pipe splits, install meter before the intersection. Photograph installation and record ID #s.
7. Identify suitable location and install temperature/humidity meter in an unobtrusive location away from any heating, cooling, or air flow influences (e.g. away from air intake, exhaust of the HPWH, and heating or cooling distribution or equipment). Photograph meter placement from near and far. Be sure electrician knows where this meter is located so they will be able to retrieve it.
8. Ask homeowner if they have a dehumidifier and if they are currently using it (or will be used during the metering period). If used, meter the dehumidifier, as well.
9. Measure faucet water temp for both cold and hot water, using UX100 thermocouple. Run water until temperature reaches minimum or maximum temperature, respectively.
10. Note and record area (dimensions) of room.
11. Note and record other Heating/Cooling Equipment in the room.
12. Leave bag for meters, with checklist for electrician, attached to HPWH.

[1] If meter does not have Bluetooth, complete this step before panel is closed via USB cable.

<u>During or after meters are installed, record:</u>

Location of HPWH (conditioned or unconditioned space; specify basement, utility room, etc.)	
Other Heating/Cooling Equipment in the Room	
Measure Size of Room with HPWH (sq. ft.)	
HPWH Model	
HPWH Mode (at beginning of site visit)	
HPWH Temperature setting (at beginning of site visit)	
Date/Time Meters are Installed	
Dent Meter and CT ID #s	
Meter ID inlet pipe	
Meter ID outlet pipe	
Ambient meter ID and location	
Approximate date for switching HPWH to Electric Resistance Mode	
Measure faucet cold and hot water temp	Cold: Hot:
Photograph and record HPWH nameplate and HPWH settings	

1. Arrange with homeowner to switch the HPWH to Electric resistance mode after 4 weeks. Set date/time with the homeowner.
   - Have the homeowner demonstrate they know how to switch modes.
   - Check model to confirm it will stay in electric mode for 7 days.
     - **IF HPWH IS A RHEEM/RUUD MODEL:** Set electric mode to 7 days in settings.
     - **IF HPWH IS A STATE/AO SMITH MODEL:** Hold Mode+Down for 5 seconds until 0 shows (1st menu), press up to 8, press enter (2nd menu), switch from 1 to 0. This will disable the 48-hour automatic switch from electric mode.
   - Ask the homeowner to take and send us a picture once the switch is made (as addressed on the on-site handout)
   - We will send a reminder to the homeowner to switch modes (also reminding them of the original mode).
   - When the electrician returns to retrieve the meters, they will doublecheck the mode was correctly switched from electric back to the original mode.
2. Let the homeowner know the electrician will need to collect the meters in approximately 6 weeks and return them to us. Confirm the homeowner will be available within that time range.

3. Leave a bag on top of the HPWH, with a checklist for the electrician, with the meters to uninstall.

HPWH Model-Specific Switch Directions

Model	Directions
RHEEM OR RUUD	Set electric override time to 7 days in settings.
GEH50DEFJS* GEH50DEEJS* (On site Check Bradford Model if 14 days setting is required)	Go to mode, select electric/standard. Using UP arrow, input number of days = 14 days. Then, press enter.
STATE OR AO SMITH HPTU	Hold Mode+Down for 5 seconds until 0 shows (1st menu), press up arrow to 8, press enter (2nd menu), press down to switch from 1 to 0 or press enter if already 0. This will disable the 48-hour automatic switch from electric mode.
GEH50DEED**	No specific settings needed. Just press mode and it will switch to electric until user changes the mode

Low Income Direct Install Program Devices ISR

As part of the LIDI site visits, you will need to check the ISR for kitchen aerators, bathroom aerators, and LEDs. Below are pictures of what each device looks like.

Kitchen/Bathroom Aerator	Low Flow Showerhead
	

Procedure for Meter Removal

Coordinate an approximate removal date with the homeowner and electrician. Explain the packing and return procedure to the electrician. Provide electrician with a list of steps for removal in the bag left on-site.

1. Uninstall all meters and all accessories (including pipe insulation)
2. Pack all meters in provided bag.
3. Once all meters are collected, ship to WHEC in one box.

Data Collection Form

Efficiency Maine CPP/LIDI HPWH Site Visit Checklist and Data Collection Sheet

<table>
<tr><td>EMT Program:</td><td colspan="2">Electrician:

Phone: Email:</td></tr>
<tr><td>Evaluation ID:</td><td colspan="2">Date: _____/_____/_____ Time: _____:_____</td></tr>
<tr><td colspan="2">Site Contact Name:

Address:

Phone:</td><td>Email:</td></tr>
</table>

General On-site procedures

- ☐ Explain the site visit and how the meter will be collected from the homeowner
- ☐ Give the customer the **handout and release forms**, answering any questions the homeowner might have. Leave checklist for electrician on the HPWH.
- ☐ Tell the customer they will get the $75 check after the metering has been completed and the final, detailed survey taken (online or via phone).

Task	Completed/Response
Determine how the homeowner would like to receive the reminder to switch to Electric Resistance mode. (Remind homeowner they will leave the water heater in electric resistance mode **for 14 days**) Phone(/Text): Email:	**Mode Switch Date: _____/_____/_____**
Has the homeowner demonstrated that they know how to switch modes?	
Ask the homeowner to take and send picture clearly showing the mode switch or confirm the mode switch with West Hill Energy via phone.	
Let the homeowner know the electrician will retrieve the meters in approximately 6 weeks.	**Retrieval Date: _____/_____/_____**
Tell homeowner they will receive a $75 check after completing final, detailed survey online or via phone.	**Online:** **Phone:**
Leave bag and checklist for electrician attached to HPWH.	

***Before the electrician turns off power, record and photograph as follows:**

Model Number	Initial Existing mode	Initial Temperature setting	Photos of Nameplates?	Photos of HPWH settings?

*CHECK MODEL TO ENSURE IT WILL REMAIN IN ELECTRIC MODE

Meter Type	Meter Model and ID	Meters working correctly?	Photos of Meters/ Screen Shot	Time Installed
Dent + CTs	Dent ID CT IDs			
Brand Meter (dehumidifier)				
Hobo inlet pipe temperature		Distance:		
Hobo outlet pipe temperature		Distance:		
Hobo ambient temperature				

Complete after Meter Installation

Location of HPWH (specify basement heated/unheated, utility room, etc.)	
Size of the room with HPWH (sq. ft.)	
Is the space where HPWH is located actively heated and/or cooled?	Heated: Cooled:
Is the space where HPWH is located its own zone?	
Is other heating/cooling equipment in the room where HPWH is located?	
Primary heating system fuel type and model	
Any secondary heating systems? Type/Location?	
What was their previous water heating system?	
Tempering valve present and setting Y N	
Any cooling equipment?	
Dehumidifier? Is it in use?	
Hot water faucet temperature / Cold water faucet temperature	Hot: Cold:

Low Income Direct Install Initiative (LIDI): LEDs, aerators and showerheads checklist

Measure	Install Date	Program Count	Verified Count
LED			
Bathroom aerator			
Kitchen aerator			
Showerhead			

Customer Forms

Customer Handout

Home Visit Summary

The electrician will call you to schedule a return visit and retrieve the meters IN APPROXIMATELY 6 WEEKS.

Thank you for participating in our study to learn about the energy efficiency of your heat pump water heater!

West Hill Energy is contracted by Efficiency Maine to assess energy savings from heat pump water heaters discounted through the Consumer Products Program.

After this site visit, please follow these instructions:

1. On (/ /), change your heat pump water heater to **Electric Resistance Mode and leave it in this mode for 14 days**. A reminder will be sent to you when it is time to change the mode on your heat pump water heater. Take a photograph of the control panel, clearly showing the selected mode change. [Note: changing the mode of the heat pump water heater may increase your electric bill. Please review and sign the separate release form.]

2. Email the photo to Emyli McGrath at westhill@westhillenergy.com or, if you cannot email or text a photo of the heat pump after the mode change, you can call West Hill Energy at 802-246-1212 and confirm the mode change via phone.

4. IN APPROXIMATELY 6 WEEKS, allow the electrician to come back to retrieve all of the installed meters.

5. Complete a more detailed survey. The survey will be offered as a web-based survey, but we can accommodate a telephone survey. We will contact you when the survey is ready.

6. A **$75 check will be mailed to you after you complete the more detailed survey and the meters have been retrieved**.

If you have any questions, please feel free to contact West Hill Energy at 1-802-246-1212.

Thank you for your cooperation with this important study!

Customer Release Form

<u>GENERAL RELEASE</u>

West Hill Energy has a contract with Efficiency Maine to assess energy savings from heat pump water heaters discounted through the Consumer Products Program. As part of this study, West Hill Energy is metering heat pump water heaters installed throughout Maine.

By participating in this site visit, I, ____________________ (print name), agree to perform the following tasks:

1. Change the mode of my heat pump water heater to **Electric Resistance Mode** on:___________and **leave the water heater in this mode for 14 days**
2. Take a picture of my heat pump water heater after I change the mode
3. Send the picture to Emyli McGrath at West Hill Energy, or call our office (802) 246-1212 to confirm the mode change via phone
4. Allow the electrician back in my home to remove the meters in approximately 6 weeks.

I understand my heat pump will run in Electric Resistance Mode for about two weeks. Other than the change in mode, the metering will not affect the operation of the heat pump water heater in any way.

This mode change may increase my electric bill. (West Hill Energy estimates bill increases may range from $10 to $15 for homes with average hot water use.)

To offset this cost and any inconvenience, I will receive **a $75 check in the mail after the metering has been completed at my home and I have completed the final, detailed survey**.

Printed Name: _____________________________

Signature: _____________________________

Date: ______________________

Appendix E

Gross Savings Methods

Appendix E: Gross Savings Methods

This appendix provides additional details about estimating the gross savings and investigating interactive effects. Short-term *in situ* metering was conducted on a sample of 58 Consumer Products Program (CPP) homes and 58 Low Income Direct Install Initiative (LIDI) homes to estimate heat pump water heater (HPWH) gross savings. The key elements of the evaluation design are as follows:

- Metering deployments were conducted in six phases throughout the year from October 2017 to September 2018 to allow for investigating seasonal effects on HPWH performance
- Each home was metered for four weeks in the existing operational mode to assess the use of the HPWH as used by the participants
- Each home was also metered for two weeks in electric resistance mode to determine the hot water energy consumption in electric resistance mode
- Savings were estimated according to the magnitude of hot water load, which is the driving factor that influences the savings

The remainder of this section covers meter deployment, metering, estimating HPWH efficiency, estimating gross savings and heating system interactive effects.

Meter Deployment

Metering was completed between October 2017 and September 2018 to capture both the baseline and efficient use. Deployments were staged into six phases with each home being metered for six weeks (four weeks in the efficient mode and two weeks in electric resistance mode) as shown in Table E-1 below. Metering through the year allowed for a wide range of weather conditions to investigate seasonal effects on heat pump water heater performance. The metering in electric resistance mode was also used to calculate the hot water load as the efficiency of electric resistance heat is known. Additional detail on estimating the efficiency is provided under "Metering" section below.

West Hill Energy developed on-site protocols and a screening survey to solicit program participants for metering; these documents are included as Appendix D. The on-site protocols include a list of the data collected at each site.

TABLE E-1: HEAT PUMP WATER HEATER DEPLOYMENTS TIMELINE

Phase	Deployment	Total Number of Homes	Number of HPWH Metered	
			LIDI	CPP
1	October-November 2017	12	0	12
2	December-January 2017	13	8	5
3	February-March 2018	15	7	8
4	April-May 2018	16	9	7
5	June-July 2018	26	13	13
6	August-September 2018	34	21	13
	Total	116	58	58

After completing four weeks of metering in the existing mode, participants were emailed, texted or called by phone (depending on their method of contact preference) to switch the heat pump water heater to electric mode. Participants were required to email or text a photograph of the water heater panel confirming the mode change. About 60% of the LIDI respondents stated they did not have the equipment necessary to provide the evaluation team with a photo. In such cases, participants were called to switch the mode over the phone, but there was no way to verify whether or not the mode had been successfully switched. A total of nine LIDI and CPP participants did not follow instructions to switch their water heater to electric resistance after 4 weeks of metering.

One hundred and sixteen homes were metered but 17 of the homes returned data that were insufficient for analytical purposes, leaving a total of 99 homes in the analysis (49 CPP and 50 LIDI). The reasons for removal from the analysis are as follows:

- Occupants did not change the mode of the heater from efficient to electric resistance despite repeated reminders (11 homes)
- Meters failed (4 homes)
- The occupants' use changed substantially between the electric resistance and efficient mode metering (2 homes)

Failing to change the mode was the single largest reason for removing homes from the analysis, which was a departure from previous experience with this type of evaluation.[1]

One hundred (100) HPWH/modes were included in the final analysis as the HPWH in one home was metered for a sufficient period of time in both hybrid and heat pumps modes.

[1] In a previous HPWH impact evaluation using the same method of switching modes, all participants switched the mode. (See the Connecticut upstream HVAC and HPWH evaluation report listed in the references section.)

Metering

The metering was conducted for a minimum of 6 weeks (4 in efficient mode and 2 in electric resistance mode). The recorded measurements are shown in Table E2-2.

TABLE E-2: HEAT PUMP WATER HEATER ANALYSIS INPUTS

Inputs[1]	Measurement	Purpose
kW Metering	HPWH kW and Power Factor (whole unit), 2 min interval	Provides input power and kWh of the DHP
	kW of heating system (if possible), 2 min interval	Provides central heating system run time to investigate interactive effects
	kW of air conditioner (if possible), 2 min interval	Provides A/C run time to investigate interactive effects
Temperatures	Inlet HPWH water temperature, 2 min interval	Calculate average tank temperature
	Outlet HPWH water temperature, 2 min interval	
	Room temperature (where HPWH is located), 2 min interval	Assess interactive effects with heating/cooling systems
	NOAA[2] outdoor air temperature, hourly	Assess the correlation between ambient air near the HPWH and outdoor air for seasonal adjustments

[1] Other inputs hourly outdoor air temperature from NOAA to assess the correlation between ambient air near the HPWH and outdoor air for seasonal adjustments
[2]National Oceanographic and Atmospheric Administration

Estimating HPWH Efficiency

The efficiency of HPWH is reported as a Coefficient of Performance (COP), the ratio of the output to input energy. The COP was calculated to compare the efficiency of the metered HPWH units to the reported manufactures specifications and to estimate the savings by occupancy group.

The COP was calculated using the efficiency of the HPWH in electric resistance mode. The kWh/day for the electric resistance mode and efficient mode were used as a ratio to calculate the COP. This calculation assumes that the daily water usage was the same between the two periods. The calculation is done using this equation:

$$COP = \frac{Q}{W} = \frac{m * \Delta T * 8.3}{kWh_{eff} * 3412} = \frac{\frac{kWh_{er} * \eta_{er} * 3412}{\Delta T * 8.3} * \Delta T * 8.3}{kWh_{eff} * 3412} = \frac{kWh_{er} * \eta_{er}}{kWh_{eff}}$$

Where:

Q is the energy (in Btu) needed to heat the water from the inlet temperature to the setpoint temperature (not accounting for the efficiency of the water heater)

W is work of the heat pump in Btu

m is the water flow in gallons/day

ΔT is the temperature change between the inlet and setpoint water

8.3 is the lbs/gallon of water

3412 is the conversion between kWh and Btu

kWh_{eff} is the efficient kWh/day heating the water

kWh_{er} is the electric resistance kWh/day heating the water

η_{er} is the efficiency of the water heater in electric resistance mode (98%, from the HPWH rated EF in electric resistance mode)

The COP was estimated by mode (heat pump and hybrid) and by the magnitude of the hot water load (Q).

Estimating Gross Savings

There are two primary factors that contribute to the HPWH savings: magnitude of the hot water demand and the efficiency of the HPWH. These factors are discussed in Table E-3. The relationship between these two inputs is complex, as the higher the hot water demand, the more likely that the HPWH is set to hybrid mode, which has a lower efficiency.

TABLE E-3: PRIMARY FACTORS CONTRIBUTING TO HPWH SAVINGS

Drivers of HPWH Savings	Main Contributors
Magnitude of hot water demand	Household size, lifestyle, economic status
Efficiency of the HPWH (COP)	Mode of operation[1]

[1] While there are numerous other contributors, such as the location of the water heater, the make and model, and temperatures of the inlet and outlet temperatures, the mode of operation is the main variable that most directly affects the savings.

Occupancy is sometimes used as a proxy for the magnitude of the hot water load. For example, the Residential Energy Consumption Survey (RECS) conducted by the US Energy Information Administration[2] provides electric resistance hot water energy consumption by number of occupants in the home.

In this evaluation, the metering data did not show a strong correlation between occupancy and hot water load.[3] *Post hoc* stratification was conducted on the magnitude of the hot water energy consumption in electric resistance mode rather than occupancy.[4] The hot water energy consumption in electric resistance mode was later adjusted to account for differences in average hot water load between the metered homes and the RECS data, as discussed in Section 3.3.4 in the report.[5]

The metered data in electric resistance mode was used to determine the hot water load, as the efficiency of the electric resistance water heater is known. The COP in efficient mode was

[2] Residential Energy Consumption Survey, "https://www.eia.gov/consumption/residential"

[3] The Pearson correlation coefficient was 0.49, indicating a weak correlation. This finding is most likely due to a combination of the limited sample size and high variability in hot water load.

[4] The sample was evenly divided into three groups according to the average kWh/day in electric resistance mode.

[5] The RECS hot water energy consumption was multiplied by the efficiency of the baseline water heater to calculate the RECS hot water load to make a direct comparison.

estimated by comparing the metering in electric resistance to the efficient mode, as discussed above. The energy savings were calculated from the average daily hot water load and COP calculated by stratum as defined in Table E-4. To calculate the peak demand savings, the kW/kWh ratio was calculated during the ISO peak hours.[6] Survey data was used to apply these savings to the population. The evaluated savings were calculated and scaled up to the population using the steps outlined in Table E-4 below.

Table E-4: Calculating the Evaluated Savings

Analysis Step	Description	Comments
Calculate hot water energy consumption per day in electric resistance mode for each home	The average hot water energy consumption in electric resistance mode was calculated from meter data for each home in units of kWh/day.	
Define strata by hot water energy consumption for each program	The HPWHs were sorted by the magnitude of the hot water energy consumption in electric resistance mode and divided into three equal groups according to the magnitude of the electric resistance hot water energy consumption.	The hot water energy consumption was adjusted by the efficiency of the HPWH in resistance mode to obtain the hot water load. The average number of occupants per home was also calculated.
Calculate average hot water load (kwh/day)	The average hot water load (kWh_{hw}) was calculated for each stratum by multiplying the average efficiency in electric resistance mode by the hot water energy consumption in electric resistance mode. n_h is the total number of observations in stratum h. n is the total number of observations in all strata.	$kWh_{hw,h} = \frac{\sum_{i=1}^{n_h}(kWh_{hw,i})}{n}$
Calculate the average COP by mode	The average COP was calculated for each usage stratum, h, and for both hybrid and heat pump modes, i.	$COP_{h,i} = \frac{kWh_{hw,h,i}}{kWh_{eff,h,i}}$
Calculate the average COP by stratum	The weighted average COP was calculated for each usage stratum, accounting for the percent (p) of HPWHs in hybrid and heat pump modes, i.	$COP_h = \sum_{i=1}^{I}(p_i \times COP_{h,i})$
Calculate annual savings by stratum	The weighted average savings were calculated for each stratum and program, where η_{erTRM} is the efficiency of the baseline electric resistance water heater in the TRM and i and p_i are as defined above.	$kWh_{savings,h} = \sum_{i=1}^{I}\left(\frac{kWh_{hw,h,i}}{\eta_{er_{TRM}}} - \frac{kWh_{hw,h,i}}{COP_{h,i}}\right) \times p_i$
Aggregate the annual savings by program	Add the savings by stratum, adjusting for the percent of the metered HPWH's in each stratum.	$kWh_{savings} = \sum_{h=1}^{H}(p_h \times kWh_{savings,h})$
Calculate peak kW savings	The peak kW savings were calculated by applying a kW/kWh ratio based on the estimated savings from the metered data.	$kW_{saviings} = \left(\frac{kW_{metered}}{kWh_{metered}}\right) * kWh_{savings}$

[6] Per the Efficiency Maine Retail / Residential Technical Reference Manual, version 2017.1, Appendix B – ISO hours are non-holiday weekdays between 5-7 PM for the winter peak, and 1-5 PM for the summer peak.

As a final step, the metered hot water load was compared to the average hot water load in the Northeast, as estimated by RECS[7]. The RECS data provides hot water energy consumption. To make a direct comparison between the metered data and the RECS data, both values were adjusted by the efficiency of the water heaters to obtain the hot water load. The HPWH efficiency in electric resistance mode was 98%, taken from the manufacturers' specifications. For the baseline efficiency, the TRM value of 94.5% was applied to the RECS data. This analysis indicated the metered homes, adjusted for occupancy, used less than the RECS average. As RECS is based on a much larger sample size and there is no reason to expect HPWH users would have lower hot water load, the savings were adjusted to the RECS level for CPP.

The metering of LIDI homes showed substantially lower use than the CPP homes, suggesting LIDI homes are likely to use less than the average for all residential homes. The LIDI savings were adjusted based on the assumption that Maine LIDI and CPP homes have a proportional relationship to average hot water load, i.e., the percent increase from the metering to the RECS hot water load, as calculated for the CPP homes, also applies to LIDI homes (14%).

The results of this analysis are presented in the main report, in Section 4.3.

Heating System Interactive Effects

The West Hill Energy team investigated whether HPWHs increase demand on the heating system, since they remove heat from the area they are in and use it to heat water. Deployments were conducted through the year, as shown in Table E-1, and during the heating season (October to May), the heating system was also metered in 28 households. The heating system was metered if the following applied: the metering period was during the heating season, the heating system was located in the same area as the heat pump water heater, the heating system used electricity to operate, the heating system's circuit could be identified on the panel, the circuit only had the heating system on it, the heating system provided a clear signal of when it was on and off, the fuel supply to the heating system was constant when on, and the metered heating system was the primary source of heat. Many homes did not meet these criteria, so consequently, the heating system was not also metered.

[7] RECS 2015 (Residential Energy Consumption Survey). https://www.eia.gov/consumption/residential/data/2015/. Data for New England was used. The Residential Energy Consumption Survey (RECS) is a periodic study conducted by the U.S. Energy Information Administration (EIA) which collects data on energy-related characteristics and usage patterns on a national representative sample of housing units.

The procedure we utilized for the analysis of this metered data is outlined in Table E-4 below.

TABLE E-4: HEATING SYSTEM INTERACTIVE EFFECTS ANALYSIS PROCEDURE

Analysis Step	Description
Establish heating system on/off thresholds	Each heating system draws a slightly different kW value when turned on. Each home was analyzed by breaking the heating kW over the entire period into 10% percentiles to establish the kW when the heating system was on/off.
Add weather data	Each household was mapped to the hourly weather data of the nearest NOAA weather data station in Maine.
Create temperature bins	The outside air temperature for each hour was broken out into 5°F degree temperature bins
Assess temperature bins	Outside air temperature bins were removed if they had no comparison mode (electric only data / heat pump only data), if the outside temperature was higher than 50°F, or if they had fewer than 20 hours of data.
Calculate Results	The weighted average of how often the water heater turned on in each of the modes was calculated according to the formula below. $$Weighted\ Percent\ on_{mode} = \sum_i HS_{on_i} * Bin_{hrs_i}$$ $$HS_{on} = \%\ of\ time\ heating\ system\ is\ on\ in\ current\ temperature\ bin$$ $$Bin_{hrs} = \frac{number\ of\ hours\ the\ outside\ air\ temp\ is\ in\ the\ current\ temperature\ bin}{total\ hours\ in\ all\ remaining\ temperature\ bins}$$

Households were removed from the analysis if they had odd consumption patterns (e.g. utilized wood heat for a few weeks, then switched back to oil), if they only had warm weather data (the average outside air temperature bin for the house is greater than 40°F), or if they had fewer than 3 temperature bins. A total of 13 homes were included in the final analysis.

The results of this analysis are presented in the main report, in Section 4.4.

Appendix F

Benefit Cost Analysis Details

Appendix F: Benefit Cost Analysis Details

This appendix covers additional details for the benefits cost analysis. The first section provides the inputs that were used for the base case benefit-cost analysis. The second section provides a comparison of the program-level and measure-level Primary Benefit Cost Test (PBCT) and Program Administrator Cost Test (PACT) ratios using the Triennial Plan III (TPIII) and prospective Triennial Plan IV (TPIV) assumptions.

Base Case Inputs

Base case measure-level and program-level PBCT and PACT ratios for the FY17 CPP and LIDI were calculated based on the following benefit cost analysis inputs:

- Measure cost, quantity installed, and incentive costs
- Program delivery costs for FY17
- The expected gross savings for kWh, kW, and water
- Energy period factors (EPF) for each measure promoted by CPP and LIDI

The base case analysis was calculated using Triennial Plan (TPIII) methodology and assumptions (M&As) provided in Table 7-3 in the main report.

Tables F-1 and F-2 show the Base Case inputs for Consumer Products Program (CPP) and Low Income Direct Install Initiative (LIDI), respectively.

TABLE F- 1: CPP BASE CASE INPUTS FOR EACH MEASURE

		Per Unit Savings						
Measures	kWh	Winter kW	Summer kW	Measure Cost	Free-ridership	RR Energy	RR Demand	Participant Spillover
Heat Pump Water Heater	1,942	0.307	0.212	$ 871.83	0.310	1.004	1.000	0.000

TABLE F-2: LIDI BASE CASE INPUTS FOR EACH MEASURE

	Per Unit Savings													
Measures	Gross kWh	Gross Winter kW	Gross Summer kW	Measure Cost	Therms	Propane	Heating Oil	Kerosene	Wood	Water	FR	RR Energy	RR Demand	Participant SO
Heat Pump Water Heater Direct Install	2,091	0.257	0.178	$ 1,350.24	0.00	0	0.00	0	0.00	0.00	0	0.781	1.000	0
LED Low-Income Standard Bulb Long Life	26	0.006	0.004	$ 6.71	-0.01	0	-0.02	0	-0.01	0.00	0	1.000	1.000	0
Low-Flow Bathroom Aerator Direct Install	9	0.000	0.000	$ 9.54	0.00	0	0.00	0	0.00	333.00	0	1.000	1.000	0
Low-Flow Kitchen Aerator Direct Install	84	0.000	0.000	$36.92	0.00	0	0.00	0	0.00	2,696	0	1.000	1.000	0
Low-Flow Shower Head Direct Install	131	0.000	0.000	$72.21	0.00	0	0.00	0	0.00	3,153	0	1.000	1.000	0

Sensitivity Analysis using TPIV Assumptions

At the time the benefit cost analysis was performed for this evaluation, the methodology and assumptions (M&As) for use in cost effectiveness calculations for Triennial Plan IV (TPIV) had not yet been approved by the Maine Public Utilities Commission (PUC). Since the analysis was performed, the Trust has submitted and the Maine PUC has accepted a new set of M&As for TPIV that uses updated avoided costs and treats incentives paid to free-riders as a transfer (the cost to the program is exactly equal to the benefit realized by the participant). The prospective measure-level and program-level PBCT and PACT was calculated based on the approved TPIV M&A parameters, rather than the TPIII parameters. Table F-3 below presents CPP results.

TABLE F-3: CPP RESULTS USING TPIV M&AS

	TPIII Assumptions		TPIV Assumptions	
Measure	**PBCT**	**PACT**	**PBCT**	**PACT**
Heat Pump Water Heater	1.23	1.52	2.19	2.94
Program	1.06	1.27	1.90	2.44

Applying TPIV assumptions resulted in a substantial increase in the program-level PBCT and PACT ratios of 79% and 92%, respectively.

Table F-4 below presents LIDI results under the TPIII and TPIV assumptions. For LIDI, the PBCT and PACT produced the same results because all inputs are the same.[1]

TABLE F-4: LIDI RESULTS USING TPIV M&AS

Measures	TPIII Assumptions	TPIV Assumptions
Heat Pump Water Heater Direct Install	1.09	1.19
LED Low-Income Standard Bulb Long Life	1.49	1.48
Low-Flow Bathroom Aerator Direct Install	1.90	2.40
Low-Flow Kitchen Aerator Direct Install	4.67	5.07
Low-Flow Shower Head Direct Install	3.01	3.33
Program	1.03	1.12

As shown in the table above, using TPIV assumptions, rather than the TPIII assumptions, resulted in a substantial increase in the program-level PBCT and PACT ratios of nearly 9%.

[1] The difference between the PBCT and PACT is that the PACT includes only the costs to the program administrator, whereas the PBCT also includes the participant costs. In LIDI, the program administrator covers all of the costs of the installation at no cost to the participant. Consequently, the results of the PBCT and PACT are the same for LIDI.