WEST HILL ENERGY AND COMPUTING

Efficiency Maine Trust
Home Energy Savings Program
Impact Evaluation

Program Years 2014-2016

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Prepared For

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Table of Contents

Executive Summary ES-1
ES-1 Evaluation Overview ES-1
ES-2 Evaluation Results ES-2
ES-3 Key Findings and Observations ES-4
1 Introduction 1-1
1.1 Evaluation Objectives 1-1
1.2 Evaluation Approach 1-1
1.3 Organization of the Report 1-3
2 Program Description 2-1
2.1 Program Savings 2-2
3 Insulation and Air Sealing 3-1
3.1 Data Sources 3-1
3.2 Methods: Natural Gas Billing Analysis 3-2
3.3 Methods: Unregulated Fuels Billing Analysis 3-2
3.4 Results 3-4
4 High Efficiency Boilers 4-1
4.1 Data Sources 4-1
4.2 Methods: Natural Gas Billing Model 4-1
4.3 Results 4-2
5 Ductless Heat Pumps 5-1
5.1 Methods 5-1
5.2 Baseline Definition 5-3
5.3 Metering Results 5-4
5.4 Calculated COP and Heating Output 5-6
5.5 Comparison of Heat Pumps and Oil Heat 5-7
5.6 Evaluated Savings 5-7
5.7 Comparison to Other Studies 5-8
6 Special Case Study – Homes with High Heat Pump Usage 6-1
6.1 Methods 6-1
6.2 Metering Results 6-3
6.3 Conclusions 6-4

7 Special Case Study – Integrated Controls 7-1
7.1 Methods 7-1
7.2 Results 7-3
7.3 Conclusions 7-3
8 Net-to-Gross Analysis 8-1
8.1 Methods for Estimating Free Riders 8-2
8.2 Methods for Spillover 8-3
8.3 Results 8-5
9 Benefit-Cost Analysis 9-1
9.1 Methods 9-1
9.2 Results 9-5
9.3 Conclusions 9-6
10 Review of TRM Methods and Inputs 10-1
10.1 Air Sealing and Insulation 10-1
10.2 Ductless Heat Pumps 10-3
10.3 Boilers 10-4
11 Findings and Observations 11-1
11.1 Gross Savings 11-1
11.2 Net savings 11-2
11.3 Other Findings 11-2
11.4 TRM Prospective Adjustments 11-4
12 References 12-1

Table of Tables

Table ES-1: Summary of Evaluation Activities ES-2
Table ES-2: Summary of Evaluated Savings per Home by Measure ES-3
Table ES-3: Summary of NTGR by Measure ES-3
Table ES-4: HESP Overall NTGR ES-4
Table ES 5: Summary of Key Contractor and Participant Survey Findings........ES-6
Table ES-6: Summary of Recommended Revisions to the TRM........ ES-7
Table ES-7: Recommended Changes to Inputs to the TRM Calculations for Insulation ES-8
Table 1-1: Summary of Evaluation Activities........1-2
Table 1-2: Report Organization By Chapter 1-3
Table 2-1: HESP *Ex ante* Savings by Year........2-2
Table 2-2: HESP *Ex Ante* Savings by Measure Group for Fiscal Years 2014 to 2016........2-3
Table 2-3: Savings and Participation by Measure Group 2-3
Table 3-1: Comparison of the Natural Gas and Unregulated Fuels Billing Analyses 3-1
Table 3-2: Data Sources 3-1
Table 3-3: Unregulated Fuels Billing Analysis Overview 3-3
Table 3-4: Summary of Air Sealing And Insulation Results 3-4
Table 3-5: Natural Gas Realization Rate for Air Sealing and Insulation 3-4
Table 3-6: Unregulated Fuels Billing Analysis Results 3-5
Table 3-7: Additional Verification Studies Overview 3-6
Table 3-8: Comparison of Home Energy Program Savings in the Northeast........3-7
Table 4-1: Data Sources 4-1
Table 4-2: Billing Analysis Results for Boilers........4-2
Table 4-3: Evaluated Savings for Boiler Replacements........4-3
Table 5-1: Summary of Sampling Plan for Heat Pump Metering 5-1
Table 5-2: Heat Pump Measurements and Inputs 5-2
Table 5-3: Meter Data Analysis Results 5-4
Table 5-4: Summary of Heat Pump Evaluated Savings and Realization Rates........5-8
Table 5-5: Comparison to Other Heat Pump Studies, ...5-9
Table 6-1: Heat Pump Measurements and Inputs for Metering of High Heat Pump Users 6-2
Table 6-2: High User Metered Savings from Heating........6-3
Table 7-1: Measurements and Inputs 7-2
Table 7-2: Meter Data Analysis Results 7-3
Table 8-1: Barriers and HESP Approach........8-3
Table 8-2: FR Results by Measure Group and Methods 8-5
Table 8-3: SO Results for Energy Savings by Measure Group and Method 8-5
Table 8-4: SO Results for Peak Demand Reduction by Measure Group and Method 8-6
Table 8-5: NTGR by Measure Group........8-6
Table 8-6: HESP Overall NTGR........8-7
Table 9-1: Definitions of PBCT and PACT........9-1
Table 9-2: Summary of Approach to BCR Analysis 9-2
Table 9-3: M&A TPIII Parameters for HESP Evaluation Base Case........9-3
Table 9-4: M&A ACDR Parameters for Prospective Base Case PBCTs and PACTs........9-5

Table 9-5: Base Case PBCT and PACT By Measure Using TPIII Assumptions.....9-6
Table 9-6: Select PBCT Comparisons from the Sensitivity Analysis..... 9-6
Table 10-1: Insulation and Air Sealing MMBtu Savings by TRM and Year.....10-1
Table 10-2: Recommended Changes to Inputs to the TRM Calculations for Insulation.....10-2
Table 10-3: Recommended TRM Adjustments to Heat Pumps.....10-4
Table 10-4: Recommended TRM Adjustment to Efficient Boilers.....10-4
Table 11-1: Summary of Key Contractor and Participant Survey Findings.....11-3
Table 11-2: Summary of Recommended Revisions to the TRM.....11-4

Table of Figures

Figure 5-1: Heat Pump Annual Heating Usage.....5-5
Figure 5-2: Heat Pump Annual Cooling Usage.....5-6
Figure 5-3: Measured COP by Outside Temperature.....5-6

Appendices

Appendix A: Natural Gas Billing Analysis Details

Appendix B: Unregulated Fuels Billing Analysis Details

Appendix C: Ductless Heat Pumps: Sampling

Appendix D: Ductless Heat Pumps: Site Visit Protocols and Forms

Appendix E: Survey Instruments

Appendix F: Unregulated Fuels Customer Survey Findings

Appendix G: Ductless Heat Pump Customer Survey Findings

Appendix H: Contractor Ductless Heat Pump Survey Findings

Appendix I: Ductless Heat Pump Analysis Details

Appendix J: Net-to-Gross: Causal Mechanisms

Appendix K: Memo on Cognitive Interview Results

Appendix L: Net-to-Gross Method and Approach

Appendix M: Benefit-Cost Analysis Details

Appendix N: TRM Detailed Analysis

Executive Summary

This report covers impact evaluation and cost benefit analysis conducted for Efficiency Maine Trust's Home Energy Savings Program (HESP). The Home Energy Savings Program offers mail-in rebates to homeowners for installing eligible energy efficiency measures. The rebates are paid directly to the homeowners and participants are required to use an Efficiency Maine registered contractor.

This evaluation covers gross savings for natural gas boilers, ductless heat pump, air sealing and insulation, which account for over 85% of annual *ex ante*[1] energy savings. The net-to-gross ratio (NTGR) was estimated for ductless heat pump, air sealing, and insulation. The analysis used a combination of methods chosen to balance cost and accuracy.

ES-1 Evaluation Overview

West Hill Energy and Computing, in partnership with Ridge and Associates and Analytical Evaluation Consultants ("Impact Evaluation Team"), was selected by Efficiency Maine through competitive bid to conduct an impact evaluation of Efficiency Maine's Home Energy Services Program. Efficiency Maine defined the objectives of the evaluation and the Impact Evaluation Team developed a work plan detailing the evaluation methods. After Efficiency Maine approved the work plan, the Impact Evaluation Team independently completed the evaluation tasks described in this section and Table ES-1 below.

The West Hill Energy Team developed estimates for the gross energy savings, peak demand reduction, and realization rates for measures installed between September 2014 and June 2016 (FY2014 - FY2016) and provided recommendations to improve the accuracy of energy savings claimed prospectively. Additional outcomes of the study included calculating net-to-gross (NTG) and benefit-cost ratios (BCR).

Billing analysis was the primary method used to estimate unregulated fuels and natural gas savings. Ductless heat pump savings were evaluated using on-site measurement and verification. The evaluation activities and outcomes for each measure are presented in Table ES-1 below.

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

TABLE ES-12: SUMMARY OF EVALUATION ACTIVITIES

Evaluation Activity	Determine Baseline	Measure Efficiency	Estimate Annual Load	Estimate kW Peak Impacts	Assess Reasons for Performance	NTGR/ Decision Making
Natural gas billing analysis	● Boilers ● Insulation and air sealing	● Insulation and air sealing	● Boilers ● Insulation and air sealing			
Unregulated fuel billing analysis	● Insulation and air sealing		● Insulation and air sealing			
In-situ metering	● Ductless heat pumps	● Ductless heat pumps	● Ductless heat pumps	● Ductless heat pumps		
Customer interviews	● Ductless heat pumps				● Ductless heat pumps	● Ductless heat pumps ● Insulation and air sealing
Contractor interviews	● Ductless heat pumps				● Ductless heat pumps	● Ductless heat pumps
Manufacturers' data	● Ductless heat pumps	● Boilers ● Ductless heat pumps				

● Boilers ● *Ductless heat pumps* ● *Insulation and air sealing*

The approach to estimating net savings used the self-report method and incorporated responses to program influence questions. Both the self-report and program influence questions were tied to the program's causal mechanisms.

ES-2 Evaluation Results

Evaluated gross savings were lower than *ex ante* savings. For air sealing and insulation, the results were similar from the natural gas and unregulated fuels billing analyses, with realization rates of 50% and 46% respectively. For natural gas boilers, the realization rate was 79% when compared to the Technical Reference Manual (TRM) savings values for the appropriate program year. The realization rate for ductless heat pumps was 67%. A summary of the gross and net savings by measure are summarized in Table ES-2 below.

TABLE ES-1: SUMMARY OF EVALUATED SAVINGS PER HOME BY MEASURE

Measure	Average *Ex ante* Savings per Site	Evaluated Gross Savings per Site	Realization Rate	Evaluated Program NTGR	Evaluated Net Savings
Air Sealing and Insulation (natural gas)	35.1 MMBtu/year	17.2 MMBtu/year	50%	73%	12.2 MMBtu
Air Sealing and Insulation (unregulated fuels)	32.2 MMBtu/year	14.8 MMBtu/year	46%	73%	10.5 MMBtu
High Efficiency Natural Gas Boilers	13.6 MMBtu/year	10.5 MMBtu/year	79%	71%[a]	7.5 MMBtu
Lost Opportunity Ductless Heat Pumps	1,645 kWh/year	1,096 kWh/year	67%	69%	778 kWh
	0.419 Winter peak kW	0.246 Winter peak kW	61%	69%	0.175 kW[2]
	0.103 Summer peak kW	0.060 Summer peak kW	58%	69%	0.043 kW[3]

[a] West Hill Energy did not evaluate boiler NTGR. The 71% NTGR applied to boilers is the program average based on ductless heat pumps, air sealing and insulation measures and weighted to apply to the population.
[2] ISO-NE Forward Capacity Market (FCM) winter peak period is December and January from 5 to 7 PM.
[3] FCM summer peak period is June through August from 1 to 5 PM.

The NTG surveys and analysis were based on program activity from September 2014 and June 2016 (FY2014 – FY2016). The heat pump contractor survey supported the NTG findings from the participant survey. The NTGR results are summarized in Table ES-3.

TABLE ES-2: SUMMARY OF NTGR BY MEASURE

Measure	Initial NTGR[1]	Spillover	Final NTGR[2]
Air Sealing and Insulation	70%	3%	73%
Ductless Heat Pumps	58%	11%	69%

[1] Initial NTGR = 1 – FR (Free rider rate).
[2] Final NTGR = 1 – FR (Free rider rate)+SO (spillover).

The program NTGR was calculated by applying the FR and SO rates shown above to the savings of the evaluated measures. The weighted average was applied to the unevaluated measures.[2] The results of this analysis are shown in Table ES-4.

TABLE ES-3: HESP OVERALL NTGR

	***Ex ante* Savings**	**Net Savings**	**Overall NTGR**
MMBtu Savings (All Fuels)	299,160	213,465	71%

The primary benefit-cost test (PBCT) showed that HESP measures have a primary benefit-cost ratio (PBCR) of 0.99 and program administrator cost (PAC) ratio of 2.17 based *ex post* values. The key drivers of the PBCT and program administrator cost test (PACT) results are the gross realization rate, free ridership, and participant spillover, in that order. The PBCT sensitivity analysis revealed that the program PBCR value for the base case was 0.99 using Triennial Plan III (TPIII) methodology and assumptions (M&As). Applying the alternative cost and discount rate (ACDR) M&A, resulted in a program PBCR value of 1.39.[3]

ES-3 Key Findings and Observations

The findings and observations from the evaluation of gross and net savings and the TRM adjustments for all measures are discussed below.

Insulation and Air Sealing

- Evaluated savings from other, similar programs range from 9% to 22% of pre-installation consumption.
- HESP evaluated savings are well within this range, at 17% for natural gas and 13% for unregulated fuels.
- Small changes in some of the inputs into the TRM analysis result in substantial changes in the savings.[4]
- The TRM modeling results in substantially higher savings than found in the billing analysis.

[2] The FR and SO rates were weighted by the magnitude of the savings of the evaluated measures.

[3] At the time the BCR analysis was performed for this evaluation, the 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). The M&As proposed by Efficiency Maine in the initial filing of the Triennial Plan were used in the sensitivity analysis and dubbed the ACDR data set. Since the analysis was performed, the Trust has submitted and the Maine PUC has accepted a new set of M&As for TPIV that vary slightly from the ACDR in avoided costs values 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 results presented in this report do not reflect the final TPIV M&As.

[4] For example, adding R-2.5 to the pre-install R-values used in the TRM modeling resulted in a reduction in savings of 22% for attic insulation and 60% for basement insulation.

Efficient Boilers

- The billing analysis indicated that boiler consumption was lower than assumed in the 2015 TRM by about 20%. The 2017 TRM was updated and the revised annual consumption is very close to the evaluated consumption.
- Other recent studies in New England indicate that the efficient boilers may not be condensing properly in a small minority of homes; a 2% downward adjustment was made to address this issue.[5]

Ductless Heat Pumps

- Metering indicates that the heat pumps are used substantially less than reflected in the TRM characterization. This result is similar to a recent impact evaluation with metering completed in Vermont.
- A small minority (about 5%) of heat pumps owners have high heat pump consumption; these homes use their heat pumps about 33% more than the metered sample and many of these homes have more than one heat pump.
- Accounting for the high users in proportion to their part of the population increases the realization rate from 67% to 68%.
- Possible drivers of the realization rate are lack of integration with the central heating system, misunderstanding about the operating temperature range, and the relatively low cost of oil.

The evaluation of net savings combined program influence and self-report methods. A couple of observations from this analysis are as follows:

- For air sealing and insulation, the results from the program influence and self-report methods are very close, suggesting that both strategies are measuring the same underlying construct.
- The program influence and self-report metrics for the heat pumps diverged substantially; this outcome indicates that survey respondents recall that they would have installed the heat pump without the rebate, but also that the program influenced their decision in other ways.

While the NTG results were estimated from the participating customer surveys, the responses to the heat pump contractor survey supported the findings and did not suggest that there are additional net savings from contractor activity.

[5] This adjustment was based on a recent study conducted in Connecticut that included direct measurement of condensing boilers. See West Hill Energy (2018) under References.

Survey Findings

The participant and contractor surveys covered other topics about the HESP program. While this evaluation is primarily impact, selected findings regarding the program activities and causal mechanisms are discussed below.

TABLE ES-5: SUMMARY OF KEY CONTRACTOR AND PARTICIPANT SURVEY FINDINGS

Survey Question	Contractors	Ductless Heat Pump Participants	Air Sealing/ Insulation Participants
At least one HESP activity strongly/extremely important in EE[1] installation	>80%	61%	74%
EMT brand makes it easier to sell EE (C)[2]/ EMT is a trusted source of EE information (P)	70%	90%	91%
EMT's support was more important than other sources of support (C)/ Maximum program influence score was 50% or greater	42%	73%	86%

[1]EE = Energy Efficient
[2](C) = contractors, (P) = participants

In addition, heat pump contractors who responded to the survey reported the following:

- Efficiency has increased and selection of heat pump models is better since the HESP rebates started (67% of respondents)
- Two-thirds are more likely to recommend high efficiency units due to the HESP rebates

Even considering that contractors may be motivated to present the program in a positive light, these findings are quite positive and suggest that the HESP program is effective at promoting energy efficiency upgrades.

TRM Prospective Adjustments

The recommended adjustments to the technical reference manual (TRM) are summarized in Table ES-6 and Table ES-7 below.

Table ES-6: Summary of Recommended Revisions to the TRM

Measure	TRM Input	2017 Input	Recommended Revision	Comments
Efficient Boilers	Efficiency of the new boiler	94.5%	92.5%	From CT 2018 study
Ductless Heat Pumps	Heat pump contribution to heating load – single indoor unit	35%	26%	Accounts for lower use
	Heat pump contribution to heating load – multiple indoor units	70%	52%	Accounts for lower use
Air Sealing and Insulation	NTGR	75%	73%	Based on evaluation results
Ductless Heat Pumps	NTGR	75%	69%	Based on evaluation results
All HESP Non-evaluated Measures	NTGR	100%	71%	Based on evaluation results

The Impact Evaluation Team recommends adjusting the insulation TRM savings to the savings found in the bulk fuels and natural gas billing analyses. The results from the billing analysis were used to adjust the inputs into the TRM calculations, as shown in Table ES-7 below.[6] While this process is inexact, it provides the option to adjust the savings for future program changes (such as modifications to the baseline conditions).

[6] Using the inputs provided in Table ES-7, the wall insulation savings are somewhat higher than indicated by the billing analysis. This outcome seems reasonable as wall insulation is rarely installed and there were only a few installations in both the bulk fuels and natural gas billing analyses. Thus, the billing analysis results may not fully reflect the savings from wall insulation.

Table ES-7: Recommended Changes to Inputs to the TRM Calculations for Insulation

Source	Input	Recommended Values Attic	Wall	Basement	Reason
EMT Modeling Spreadsheet	Existing R-Value	14.9	6.2	2.0	Attic: average values Wall: average values + R2.5 for framing Basement: cement wall + R-0.50
	New R-Value	50.3	No change	No change	Attic: average values during analysis period
	Indoor Temperature	60°F	60°F	40°F	Attic & Walls: Billing models indicate 60°F more accurately reflects use Basement: calibrated better to billing models
	CFM 50 Reduction	No change	0	No change	Walls: calibrate to billing models
	Wall Area	No change	998	No change	Walls: increase percent of window/doors and decrease wall area to calibrate to billing analysis
	% of Wall Above Grade	N/A	N/A	25%	Basement: decrease percent of walls above grade to calibrate to billing analysis
	Convection BTU/cf/Delta T	0.014	0.014	0.014	All components: calibrate to billing models
TRM Adjustment	Heating System Efficiency (EFF)	83%	83%	83%	All components: calibrate to billing analysis

1 Introduction

This report covers impact evaluation and cost benefit analysis conducted for Efficiency Maine's Home Energy Savings Program (HESP) for projects completed between September 2013 and June 2016. This evaluation covers ductless heat pumps, insulation and air sealing, and natural gas boilers.

HESP was preceded by HESP1 and RDI (Residential Direct Install), two programs that offered similar measures under different program designs. The Home Energy Savings Program offers financial incentives (mail-in rebates) to homeowners for installing eligible energy efficiency measures. The rebates are paid directly to the homeowners. Participating homeowners are required to use a contractor who is registered with Efficiency Maine Trust (EMT).

1.1 Evaluation Objectives

The impact evaluation objectives, as defined by Efficiency Maine, were to estimate gross energy savings, peak demand reduction, and realization rates for measures installed between September 2013 and June 2016 (FY2014 - FY2016). Evaluated measures consisted of ductless heat pumps, insulation and air sealing, and natural gas efficient boilers. The outcomes for this study include the following:

- Develop gross program energy (kWh) and summer and winter demand (kW) savings for ductless heat pumps
- Estimate annual energy savings for insulation and air sealing from unregulated fuels (propane, oil and kerosene)
- Estimate annual natural gas savings for insulation, air sealing and efficient boilers
- 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 next section provides further detail on the evaluation approach.

1.2 Evaluation Approach

Billing analysis was the primary method used to estimate unregulated fuels and natural gas savings. The results of the billing analysis were weather normalized to the average temperature from the last 6 years. All homes that we could get billing data for were included in the analysis. Ductless heat pump savings were evaluated using on-site measurement and verification. Table 1-1 summarizes evaluation activities for this study.

Table 1-1: Summary of Evaluation Activities

Evaluation Activity	Determine Baseline	Measure Efficiency	Estimate Annual Load	Estimate kW Peak Impacts	Assess Reasons for Performance	NTGR/ Decision Making
Natural gas billing analysis	● (red) ● (gold)	● (gold)	● (red) ● (gold)			
Unregulated fuel billing analysis	● (gold)		● (gold)			
In-situ metering	● (dark)	● (dark)	● (dark)	● (dark)		
Customer interviews	● (dark)				● (dark)	● (dark) ● (gold)
Contractor interviews	● (dark)				● (dark)	● (dark)
Manufacturers' data	● (dark)	● (red) ● (dark)				

● (red) *Boilers* ● (dark) *Ductless heat pumps* ● (gold) *Insulation and air sealing*

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 HESP program and *ex ante* savings
3	Insulation and Air Sealing	Methods and results for the estimation of natural gas and unregulated fuel savings for these measures
4	High Efficiency Boilers	Methods and results for the estimation of savings for natural gas boilers
5	Ductless Heat Pump	Methods and results for the estimation of electric savings for ductless heat pumps
6	Special Case Study – Homes with High Heat Pump Usage	Methods and results for the case study conducted for homes with high heat pump use
7	Special Case Study – Integrated Controls	Methods and results for the case study conducted to estimate heat pump use in homes with integrated controllers
8	Net-to-Gross Analysis	Methods and results for the NTG analysis for insulation and air sealing, and ductless heat pumps
9	Benefit-Cost Analysis	Methods and results for the BCR analysis
10	Review of TRM Methods and Inputs	Summary of recommendations for changes to the TRM related to insulation, air sealing and ductless heat pumps
11	Findings and Observations	Overview of the evaluation findings
12	References	List of key documents used in the preparation of this report

2 Program Description

Efficiency Maine Home Energy Savings Program serves as the framework for market-based weatherization and heating demand reduction achieved through a combination of rebates, financing, and customer education. HESP is designed to raise awareness about the benefits of home weatherization and to encourage Maine homeowners to make energy efficiency upgrades. It serves the residential sector including existing single family, new construction and multifamily homes up to four units.

The Home Energy Savings Program was originally launched in January 2010 as a rebate program that transitioned to a loan program in FY2012. Prior to the renewed availability of rebates under HESP, the Trust supported retail weatherization activities in the state through a combination of the Residential Direct Install Pilot in 2012 and 2013 and the ongoing Home Energy Loan Program. HESP was re-launched as a market-based rebate program in early September 2013 (FY14). While the types of measures offered under the programs from 2010 were similar, the program design and incentives of the re-launched HESP are unique.

FY2015 was the first full fiscal year that HESP rebates were offered under the re-launched program. A fiscal year is defined as starting on July 1st of the previous calendar year and continues through the end of June.

For FY2014 through FY2017, program activity fell into one of three categories of measures: supplemental heating systems, central heating systems, and building envelope improvements. To maintain customer awareness and demand, the program delivered targeted outreach to participating natural gas utility customers, published advertisements in the home improvement section of Maine newspapers and maintained a Web campaign, including advertisements with online media channels, including Hulu, YouTube, Pandora Radio, and Google ads.

2.1 Program Savings

The West Hill Energy Team completed a review of the measure mix for HESP participants. The tables below provide a summary of the kWh and MMBtu by year for FY14-FY16.

TABLE 2-1: HESP *EX ANTE* SAVINGS BY YEAR

Fiscal Year	Number of Measures Installed	Annual Electric Savings (kWh/year)	Annual Natural Gas Savings (MMBtu/year)	Annual Other Fuel Savings (MMBtu/year)[1]
2014	6,248	4,155,840	4,019	44,035
2015	12,696	9,322,005	6,943	80,894
2016	11,279	9,001,908	6,818	79,754
Total	**30,223**	**22,479,753**	**17,780**	**204,683**

[1] "Other Fuel Savings" include oil, kerosene, wood and propane savings.

Most of the efficiency measures installed through the program are building envelope and heating system upgrades. The majority of building envelope and heating system *ex ante* savings are nonelectric. For insulation, air sealing, boilers and furnace measures, approximately 1% of the savings is attributed to electricity. Savings attributable to the ductless heat pumps is entirely electric, as the baseline is a heat pump unit meeting the federal requirements. The table below provides a summary of the total savings by measure for the evaluation population from the program tracking system (effRT).

Table 2-2: HESP *Ex Ante* Savings by Measure Group for Fiscal Years 2014 to 2016

Measure Type	Number of Measures Installed	Electric Savings (kWh/year)	Unregulated Fossil Fuel Savings (MMBtu/year)[1]	Natural Gas Savings (MMBtu/year)
Insulation	4,829	334,373	101,094	10,102
Air sealing	4,950	1,245,368	37,300	3,960
Heat pumps	13,339	22,081,338	0	0
Boilers	2,438	0	22,753	2,257
Furnace/Stoves	790	0	14,782	698
Geothermal	182	-1,249,430	21,112	0
Custom Projects	187	24,886	7,642	764
Central heat pumps	14	43,218	0	0
Total	**30,223**	**22,479,753**	**204,683**	**17,780**

[1] "Unregulated fossil Fuel Savings" includes oil, kerosene, wood, and propane savings.

Table 2-3 below provides a summary of the number of sites by measure type and the associated savings. A review of the quantity of measure installed by measure type across time (FY14-FY16) showed a consistent trend in the measure mix across time. For comparison purposes, both electric and nonelectric savings were converted to MMBtu and aggregated.

Table 2-3: Savings and Participation by Measure Group

Measure Group	Number of Measures	Number of Sites	Savings (MMBtu)	Percentage of Total Savings
Insulation	4,829	3,640	112,336	38%
Air Sealing	4,950	4,948	45,510	15%
Heat pumps	13,339	13,317	75,342	25%
Boilers	2,438	2,434	25,010	8%
Geothermal	790	182	16,849	5%
Furnace/Stoves	182	1,342	15,480	6%
Custom Projects	187	187	8,491	3%
Other	3,508	3,490	147	0%

The impact evaluation focused on verifying insulation, air sealing, heat pump and boiler savings, which account for 86% of the total savings. The next sections are divided into chapters with more details on the methods used to evaluate each of the measures and discussion on the results.

3 Insulation and Air Sealing

This section describes two billing analyses (natural gas and unregulated fuels) conducted to estimate energy savings for air sealing and insulation measures. Billing analysis is an effective tool for impact evaluation for retrofit programs when savings are estimated from the existing condition in the home prior to the installation and the savings are of sufficient magnitude to be found in the billing records.

The two billing analyses have similarities and differences, as explained in Table 3-1.

Table 3-1: Comparison of the Natural Gas and Unregulated Fuels Billing Analyses

Analysis Component	Natural Gas	Unregulated Fuels
Measures	Air sealing and insulation measures were combined as they are often installed together and have the same type of impact on energy consumption.	
Bills	Monthly bills from the utilities	Billing records from fuel dealers
Model	Pooled, cross-sectional, time-series; house-by-house regression conducted as a preliminary step	House-by-house regression only, due to irregular deliveries
Presence of DHW	Determined through the regression analyses	Determined through the regression analyses and customer survey

3.1 Data Sources

The billing analysis combined data from three sources: Efficiency Maine Trust's (EMT's) program tracking system, National Oceanic and Atmospheric Administration (NOAA) weather data, and billing records. Each of these data sources is described in Table 3-2.

Table 3-2: Data Sources

Source	Data used	Purpose
Program (EMT)	Measures installed and *ex ante* savings for each project	Define pre/post period for each home and the installed measures
Billing (Unitil and Maine Natural Gas)	Monthly natural gas billing records for participating homes	Estimate difference in consumption between pre- and post-install periods
Fuel Dealer Records and Participant Survey	Fuel type, quantity delivered, delivery date, tank number, partial fill flag for unregulated fuels	
Weather (NOAA[1])	Hourly outside air temperature, date, hour, station location	Account for differences in weather by calculating the heating degree days for each billing cycle and the annual normalized heating degree days

[1] National Oceanographic and Atmospheric Administration

A more detailed discussion of the data collection preparation and data cleaning is provided Appendices A and B. The participant survey instrument is attached as Appendix E and a summary of the relevant survey responses are included in Appendix F.

3.2 Methods: Natural Gas Billing Analysis

A pre/post billing analysis was conducted to estimate the savings from insulation and air sealing measures using a regression model. A fixed effects model was used to address energy-related characteristics of the home that do not change over time, such as the size of the home and the presence of major energy-intensive equipment. The regression model included weather and program measure as predictor (independent) variables. The response (dependent) variable was the monthly energy consumption, and the regression coefficients for measures were used to estimate the program savings. All homes with sufficient billing data were included in the model.

The steps to calculate the savings were as follows:

1. Combine the data from three major sources and conduct data cleaning to obtain the final list of homes to include in the fixed effects regression models
2. Construct a list of candidate regression models with different configurations of relevant variables to estimate savings
3. Conduct regressions for each of the candidate models
4. Select the best model by identifying the model that provides reliable estimates of the variables of interest and best meets statistical standards[7]
5. Run diagnostics on the final model and make adjustments as needed
6. Calculate savings using 6-year average annual heating degree days and summarize results

Additional details on the billing model, attrition and diagnostics are provided in Appendix A.

3.3 Methods: Unregulated Fuels Billing Analysis

Due to the irregular nature of unregulated fuel deliveries, a house-by-house, two-stage regression was conducted. The process of collecting the bills required numerous steps, as it was necessary to contact participants to identify their fuel dealers and provide permission to request billing records. An overview of the analysis steps is provided in the table below. Further detail on the methods, data cleaning, attrition and model verification is attached in Appendix B.

[7] The R^2 and Aikake Information Criteria are two statistics used to compare models.

TABLE 3-3: UNREGULATED FUELS BILLING ANALYSIS OVERVIEW

Step	Purpose	Method
Data Collection	Collect billing records from fuel dealers and obtain key information about household energy use	Consent forms, fuel dealer requests, detailed survey
Data Cleaning/ Attrition	Combine data from various sources, prepare the billing data and remove households with incomplete or poor-quality data	Apply criteria for inclusion in model
Data Preparation	Develop a complete data set with key fields from various sources	Data manipulation
Billing Model	Conduct modeling and determine characteristics of sample	House-by-house, 2-stage regression
Verification of Results	Assess the results, identify sources of uncertainty, and provide another level of rigor to our analysis	*Post hoc* stratification, review of outliers and influential data points, domestic hot water separation and sensitivity analysis, other sensitivity analyses
Results	Compare verified savings to *ex ante* savings	Ratio estimation

The analysis method involved conducting a house-by-house regression of the heating degree days on fossil fuel consumption for the pre- and post-install periods and compiling the results. The steps to calculate the savings were as follows:

1. Conduct pre and post regression analysis using the heating degree days (HDD) and MMBtu consumption for each home
2. Identify the correct regression model to be used dependent on whether the same fuel was used for both space and water heating (based on survey results)
3. Remove projects without sufficient billing data or with erratic regression results
4. Calculate savings and summarize final results

The savings from the heating measures were determined by calculating the heating energy required per heating degree day separately for the pre- and post-installation period. The difference in the two values was then multiplied by the 5-year annual average HDD for the appropriate weather station.

3.4 Results

The results from the natural gas billing and the unregulated fuels billing analyses were similar, yielding realization rates of 50% and 46% respectively. A summary of the realization rates from the two analyses is provided in the table below.

TABLE 3-4: SUMMARY OF AIR SEALING AND INSULATION RESULTS

Fuel Type	*Ex ante* Savings per Home (MMBtu/year)	Evaluated Savings per Home (MMBtu/year)	Realization Rate
Natural Gas Billing Analysis	35.7	17.9	50%
Unregulated Fuels Billing Analysis	32.2	14.8	46%

Despite the low realization rates, comparison to other, similar programs suggests that the HESP evaluated savings per home are within a reasonable range. The rest of this section describes the results from the pre/post analysis and provides context for interpreting the results in comparison to other programs and to pre-install consumption patterns.

3.4.1 Natural Gas Billing Analysis Results

Air sealing and insulation are often installed together, and it was not possible to separate the savings for these two measures. For the vast majority of homes, only the air sealing, insulation or a combination of the two were installed. As a check, the model was also run including only the homes with air sealing and insulation measures, and the results were extremely close. Table 3-5 provides a summary of the *ex ante* savings and the verified savings.

TABLE 3-5: NATURAL GAS REALIZATION RATE FOR AIR SEALING AND INSULATION

Topic	Variable	Results
Realization Rate	Realization Rate	50%
	90% Confidence Interval	+/-7%
	Relative Precision at 90%[1]	+/- 14%
Average Annual MMBtu per Home	*Ex ante* Savings[2]	35.7 MMBtu
	Evaluated Savings	17.9 MMBtu
	Pre-Install Use	107.6 MMBtu
Savings as Percent of Pre-Install Use	*Ex ante* Savings	33%
	Evaluated Savings[3]	17%
Count of Homes	Number of Homes in the Model	237

[1] Relative precision is the error bound divided by the realization rate.
[2] The annual consumption during the pre-install period was averaged for all homes in the billing model.
[3]The evaluated savings as percent of pre-install use is the average annual evaluated savings divided by the annual average pre-period consumption.

3.4.2 Unregulated Fuels Billing Analysis Results

The final results of the analysis are shown in Table 3-6 below. These results include multiple fuel types, with each household's evaluated fuel savings compared to the deemed. The realization rate is 46% +/- 3%.

TABLE 3-6: UNREGULATED FUELS BILLING ANALYSIS RESULTS

Topic	Variable	Results
Realization Rate	Realization Rate	46%
	90% Confidence Interval	+/-3%
	Relative Precision at 90%[1]	+/- 9%
Average Annual MMBtu per Home	*Ex ante* Savings[2]	32.2 MMBtu
	Evaluated Savings	14.8 MMBtu
	Pre-Install Use	110.1 MMBtu
Savings as Percent of Pre-Install Use	*Ex ante* Savings	29%
	Evaluated Savings[3]	13%
Count of Homes	Number of Homes in the Model	96

[1] Relative precision is the error bound divided by the realization rate.
[2] The annual consumption during the pre-install period was averaged for all homes in the billing model.
[3]The evaluated savings as percent of pre-install use is the average annual evaluated savings divided by the annual average pre-period consumption.

After the savings were estimated, we performed a number of checks and sensitivity analyses to ensure the study was completed as accurately as possible. The table below outlines the additional analysis that was performed to verify the results and the findings.

TABLE 3-7: ADDITIONAL VERIFICATION STUDIES OVERVIEW

Step	Procedure	Finding
Identify suspect low usage	Flagged and removed participants with less than 70 MMBtu of pre-installation usage and missing fuel information.[1]	12 participants were removed
Regression Based Estimate of Savings for Homes with DHW	Tested whether there was a bias in our MMBtu/HDD method by comparing the results of the MMBtu/HDD method to the regression estimators only for homes where we had an estimate of the DHW use.	0.9% decrease in savings
R^2 Sensitivity Analysis	The threshold for leaving records in was reduced to an R^2 of 0.55 from 0.6 and also increased to an R^2 of 0.65 from 0.6	<1% change in savings
Outliers	Identified those with much higher or lower verified savings than other participants and outside a range that seemed reasonable, removing two homes.[2] Two additional homes with >60 MMBtu difference from the *ex ante* savings and missing a fuel source were also removed.	4 participants removed, 1.8% increase in savings
Influential Data Points	Participants were removed one by one and the overall realization rate was recorded. One record was noted to have a <2% impact on the overall results.	Less than 2% change; No change to model

[1] This included homes without completed surveys and homes with completed surveys that we were missing a heating fuel identified in the survey, such as other electricity, wood or a different unregulated fossil fuel.
[2] One home with very low savings (<-30 MMBTU) and one home with very high savings (>70 MMBTU) were removed.

3.4.3 Comparison to Other Programs

Comparison to other similar programs suggests that the savings as a percent of pre-installation use are relatively stable, although realization rates vary widely. Numerous evaluations of residential retrofit programs have been conducted and savings from these programs range from 9% to 22% of pre-installation consumption, as shown in Table 3-8. If the one program that saves 22% is removed, as it targets high use homes that consume in excess of 50,000 BTU/ft², the achieved savings range from 9 to 18%, and HESP natural gas evaluated savings are near the top of this range at 17%.

TABLE 3-8: COMPARISON OF HOME ENERGY PROGRAM SAVINGS IN THE NORTHEAST8

Program	State	Program Type	Average Pre-Install Use (MMBTU/ year)	*Ex ante* Savings (% of Pre-Install Use)	Evaluated Savings (% of Pre-Install Use)	Overall Realization Rate
HES*	MA	Direct and Market	119.5	15%	12%	76%
VGS RMR	VT	Direct	125.5	26%	22%	89%
VGS RLI	VT	Low Income	88.2	26%	16%	62%
EmPower	NY	Low Income	109.0	13%	9%	70%
HPwES	VT	Market Based	91.5	35%	18%	51%
HPwES	NY	Market Based	105.5	25%	16%	65%
EnergyWise	RI	Market Based	116.8	13%	13%	99%
*HESP Natural Gas**	*ME*	*Market Based*	*107.6*	*32%*	*17%*	*50%*
*HESP Unregulated Fuels**	*ME*	*Market Based*	*110.1*	*29%*	*13%*	*46%*

*Includes only insulation and air sealing measures

The U.S. Department of Energy (DOE) estimated savings of 40% are achievable.[9] However, this level of savings is only achievable through deep energy retrofits where the investment far exceeds common efficiency program retrofits. The DOE/National Grid case study achieved high savings and usage that is 40% below the Northeast regional average, but also invested an average of $34.59/ft² or about $51,000 for a 1,500 square foot home.[10] Home retrofit programs do not routinely result in this level of investment. The average cost of a HESP insulation project is about $6,800.

[8] Bartsch, A., Danaher, C. "The Shell Game: Finding Thermal Savings in Residential Retrofit Programs," 2014 Berlin Conference, Berlin, Germany: International Energy Policy and Programme Evaluation Conference, September 2014, p. 6; table is copied from the paper with Efficiency Maine's HESP results added to the bottom.

[9] U.S. Department of Energy (USDOE) 2014. Building America Case Study Whole- House Solutions for Existing Homes National Grid Deep Energy Retrofit Pilot Massachusetts and Rhode Island. http://energy.gov/sites/prod/files/2014/03/f12/case_study_national_grid_der.pdf. Washington, D.C..: U.S. Department of Energy

[10] *Ibid.*

4 High Efficiency Boilers

Natural gas billing analysis was conducted to estimate savings from efficient boilers. Two of the natural gas utilities, Unitil and Maine Natural Gas, provided billing records[11]. The utility billing records were mapped to the HESP participants and standardized.

4.1 Data Sources

The billing analysis combined data from four sources: Efficiency Maine Trust's (EMT's) program tracking system, National Oceanic and Atmospheric Administration (NOAA) weather data, and the two sets of utility billing records. Each of these data sources is described in Table 4-1. A more detailed discussion on data cleaning and attrition is provided in Appendix A.

TABLE 4-1: DATA SOURCES

Source	Data used	Purpose
Program (EMT)	Measures installed and *ex ante* savings for each project	Define pre/post period for each home and the installed measures
Billing (Unitil and Maine Natural Gas)	Monthly natural gas billing records for participating homes	Connect to program data to estimate savings
Weather (NOAA[1])	Hourly outside air temperature, date, hour, station location	Calculate the heating degree days for each billing cycle and the annual normalized heating degree days

[1] National Oceanographic and Atmospheric Administration

4.2 Methods: Natural Gas Billing Model

To calculate annual heating consumption, we conducted separate linear regression models for each home with natural gas data and a boiler measure using only post-install billing data. The post-install period was used for the following reasons:

1. It reflects the actual operating conditions of the efficient equipment
2. As this measure is replaced on failure, the post-install period (rather than the pre-install period) is the correct baseline

The Impact Evaluation Team regressed average daily natural gas consumption on average daily heating degree days (HDD) for each billing period (monthly for almost all bills). The HDD

[11] About 90% of the HESP participants used Unitil as their natural gas utility while Bangor and Maine Natural Gas had the remaining 10%. Bangor Natural Gas did not provide billing records.

were calculated at a base degree of 60°F based on our previous experience with residential billing analyses.[12] The TRM calculation for estimating savings is presented below.

EQUATION 4-1: TRM CALCULATION FOR BOILER REPLACEMENT

$$\Delta MMBtu_{FUEL} = AHL \times \left(\frac{AFUE_{EE}}{AFUE_{BASE}} - 1\right)$$

Where

AHL is the annual heat load (MMBtu/y)

$AFUE_{BASE}$ is the rated efficiency of the baseline code-complaint unit (AFUE %)

$AFUE_{EE}$ is the rated efficiency of the new boiler (AFUE %)

4.3 Results

The results from the billing analysis are summarized in Table 4-2 below. The post-only analysis showed lower consumption than the default values used in the TRM. The large decrease in full load hours compared to the TRM was offset by the size of the installed boilers, which were substantially larger on average than assumed in the TRM (129 vs 80 kBtu/h).[13]

TABLE 4-2: BILLING ANALYSIS RESULTS FOR BOILERS

	Full Load Hours[1] n=184	Annual Consumption (MMBtu) n=214
TRM 2015-2016	1,510	120.8
TRM 2017[2]	N/A	92
Billing Analysis Mean	780	99.3
Billing Analysis Median	722	85.6
90% Confidence Interval[3]	+/-37.8	+/-5.6
Relative Precision at 90% confidence[3]	4.9%	5.6%

[1] Model information was missing for 30 of the homes included in the billing analysis; thus, it was not possible to calculate the full load hours for these homes.
[2] Given the TRM change to use annual heat load rather than capacity and equivalent full load hours and that the TRM adjustments were made against the 2017 TRM, full load hours are listed as "N/A" and annual heat load of 92 MMBtu was assumed.
[3] As sampling was not conducted, the confidence interval and relative precision reflect variability in the model, not sampling error.

[12] Ken Agnew and Mimi Goldberg, "Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol," (NREL) September 2011-September 2016, page 28

[13] The evaluation period covered FY 2014 through FY 2016 and during these years, the TRM used full load hours to determine energy savings. The 2017 TRM changed the savings algorithm to use annual heat load rather than capacity and equivalent full load hours. The result was a reduction in assumed annual consumption of the efficient equipment to 97.4 MMBtu.

Savings were estimated using the assumed baseline (84% AFUE) from the TRM. The post only billing analysis does not take into account the possibility that some boilers are not condensing consistently. A recent Massachusetts study concluded that homes with poorly condensing boilers decrease the average efficiency by about 5%.[14] A recent study in Connecticut indicated a net reduction in efficiency of about 2%[15]. The rated efficiency of the new boilers was adjusted downward by 2% to account for condensing issues. After this adjustment, the realization rate for efficient boilers is 79%.

Table 4-3: Evaluated Savings for Boiler Replacements

Result	Variable	Results
Realization Rate	Realization Rate	79%
	90% Confidence Interval	6%
	Relative Precision at 90%[1]	8%
Average Annual MMBtu per Home	*Ex ante* Savings	13.6
	Evaluated Savings	10.8
Count of Homes	Number of Homes in the Model[2]	214

[1] Relative precision is the error bound divided by the realization rate.
[2] A total of 214 homes were used for the consumption results, only 184 homes were used for the FLH calculation.

[14] "High Efficiency Heating Equipment Impact Evaluation Final Report," prepared for the Electric and Gas Program Administrators of Massachusetts by The Cadmus Group, *et. al.* March 2015

[15] "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 by West Hill Energy & Computing *et al.* July 2018, p. 4-11 https://www.energizect.com/sites/default/files/R1614-1613_ResHVAC_Report_Final_8.29.18.pdf

5 Ductless Heat Pumps

Metering was conducted on a sample of 39 homes to estimate the savings for heat pumps. Two additional evaluation components were added to provide additional insight into the use of heat pumps:

1. Metering of heat pumps in 16 homes with high winter electric use
2. A case study involving the metering of 4 homes with a new integrated controller for heat pumps and central heating systems

This section covers primary data collection activities and metering of the 39 homes used to estimate the savings for ductless heat pumps. The analysis results are provided at the end of this section. The two added components are described in more detail in the following sections.

5.1 Methods

This section discusses data collection and methods used to estimate ductless heat pump savings. The topics in this section include sampling, metering, estimating savings, comparison to Advanced Metering Infrastructure (AMI) data and total household energy use.

5.1.1 Sampling

The sampling strategy was developed to account for Maine's climate zones while also geographically clustering to control evaluation costs. A two-stage sampling was constructed, using stratified random sampling of climate zones for stage 1 and cluster sampling in zip codes for stage 2. Participants were solicited for the metering through a Web-based screener survey. Advanced letters were sent to 541 participants, and 78 completed the screener survey, resulting in 39 homes[16] with completed metering. Details are provided in the Table 5-1 and Appendix C.

Table 5-1: Summary of Sampling Plan for Heat Pump Metering

Sampling Component	Description
Sampling Strategy	Two stage: Stratified Random and Cluster Sampling
Stage 1 Stratification	Climate zone (above and below 7,800 HDD per year)
Stage 2 Cluster	Zip Code (2 zip codes randomly selected in each climate zone)
Sampling Unit	Site with heat pump installation
Sample Size	40 total, 10 completes in each cluster
Precision/Confidence	80/10, assuming a coefficient of variation of 0.50; sample size designed to meet budget

[16] 37 of the homes had both winter and summer metering, one home had only winter metering and one had summer metering due to the participants' schedules.

5.1.2 Metering

The Impact Evaluation Team conducted long-term, on-site metering at 39 homes with heat pumps. The metering was conducted in two phases:

1. February 2017 through July 2017
2. August 2017 through February 2018

The six-month metering period allowed for a wide range of weather conditions, from deep winter through high summer.

If a home had multiple heat pumps, only one of them was metered. The heat pump to meter was selected on-site, alternating between higher and lower units if the homeowner indicated they were used differently. Six of the metered sites had more than one heat pump. Of these six, three higher use heat pumps were metered and three lower use heat pumps were metered.

A solicitation screener survey and on-site protocols were developed and are included as Appendix D. The on-site protocols include a list of the data collected at each site.

5.1.3 Estimating Ductless Heat Pump Savings

Savings from the ductless heat pumps were estimated from the metered data collected on-site. The recorded measurements are shown in Table 5-2.

TABLE 5-2: HEAT PUMP MEASUREMENTS AND INPUTS

Inputs[1]	Measurement	Purpose
kW Metering	Heat pump kW and Power Factor (whole unit), 1 min interval	Provides input power and kWh of the heat pump
	kW of other heating system (if possible), 1 min interval	Provides central heating system run time[2]
Temperatures	Inlet air temperature, 1 min interval	Calculate the temperature difference (how much the air is heated)
	Heat pump output air temperature, 1 min interval	
	Room temperature, 5 min	Provides temperature set point and a check of input temperature
Air Flow	Air velocity (feet/minute), 1 min interval	Measure air velocity to determine fan speed (19 sites)[3]
	Airflow spot measurement (cubic feet/minute)	Measure cfm at each fan speed and one auto cycle

[1] Other inputs include the specific heat and density of air in the temperature range and the hourly outdoor air temperature from NOAA.
[2] This was not used in the final analysis as a number of homes had wood heat as a primary or secondary heating source that could not be easily quantified.
[3] In homes without air velocity meters, an average airflow from the spot measurement was assumed.

A binned analysis was conducted using the hourly outdoor air temperature from the nearest NOAA weather station. The results from this analysis of metered data produced the total kWh used for heating and cooling.

To calculate the savings, the kWh usage was compared to a standard efficiency heat pump with the baseline Heating Season Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) based on appropriate TRM for the program year. The coefficient of performance (COP) was calculated in a two-step process:

1. The heat delivered to the space was calculated using the fan speed coupled with the change in temperature between the inlet and outlet.
2. The COP was determined from the heat delivered to the space and the metered energy of the unit.

Additional detail is provided in Appendix I.

5.1.4 Comparison to AMI Data

The possibility of using AMI data to extend the study results to the population was considered. The metering results were compared to AMI data for the same period. The same approach applied to the metered data was adapted for the AMI data. The AMI data was combined with temperature data based on the house locations and the data was checked for temperature dependency. AMI data and meter data were compared for 22 homes. Only 16 of the homes showed temperature dependence in the AMI data for heating. The meter and AMI results were close on average for those homes, but there was very high variability across the sites. Accordingly, AMI data analysis was not used to adjust the final results. Additional detail is provided in Appendix I.

5.1.5 Total Household Heating Energy Use

For homes with metering, we collected permission to request the unregulated fuel billing records and included these participants in our requests to the fuel dealers. While bills for unregulated fossil fuels were obtained for about half of the metered sites, only one site had sufficient billing records to estimate the reduction in unregulated fuel use. This site showed a reduction in oil usage that was comparable to the heat provided by the heat pump. However, it is not possible to draw inferences from a single home.

5.2 Baseline Definition

Typically, energy efficiency baselines are determined based on whether the installation is a retrofit (baseline is pre-install condition) or market opportunity (baseline is a standard efficiency unit). Heat pumps tend to blur this distinction as they are often installed in existing homes (suggesting retrofit) but the participant may have decided to install a heat pump prior to selecting the efficient model (market opportunity).

After careful analysis of the customer and contractor detailed survey responses, the TRM baseline definition of a standard efficiency heat pump was adopted. The analysis indicated that this baseline was appropriate for the vast majority (about 85%) of the installations and, thus, other adjustments to the baseline would tend to be relatively small in magnitude.

Details about the baseline analysis are provided in Appendix I.

5.3 Metering Results

The results of the metered heat pumps are shown in Table 5-3. The TRM values shown are weighted by the different installation years as the TRM assumptions changed by program year.

TABLE 5-3: METER DATA ANALYSIS RESULTS

	Metering								TRM Values[1]	
	Count	kWh Use	Annual Hours[2]	kWh Savings	kWh Relative Precision at 90%	Peak kW Savings	Peak kW Relative Precision at 90%	Peak kW Savings	kWh Savings
Cooling	38	186	487	134	18%	0.067	19%	0.103	44
Heating	38	2,236	2592	1,026	23%	0.259	22%	0.410	1,602
Total		2,423	3,079	1,161	16%	N/A	N/A	N/A	1,645

[1]These are the weighted values based on the three TRMs used for different install dates
[2]This is the total time running at any load, not the total full load hours.

Figure 5-1 below shows the range in heating use. Seven of the heat pumps use less than 500 kWh, while three use between 500 and 1000 kWh. Of the 38 homes with winter meter data, 11 had annual usage higher than the TRM assumption of 3000 kWh/year and 27 had annual usage lower than the TRM assumption.

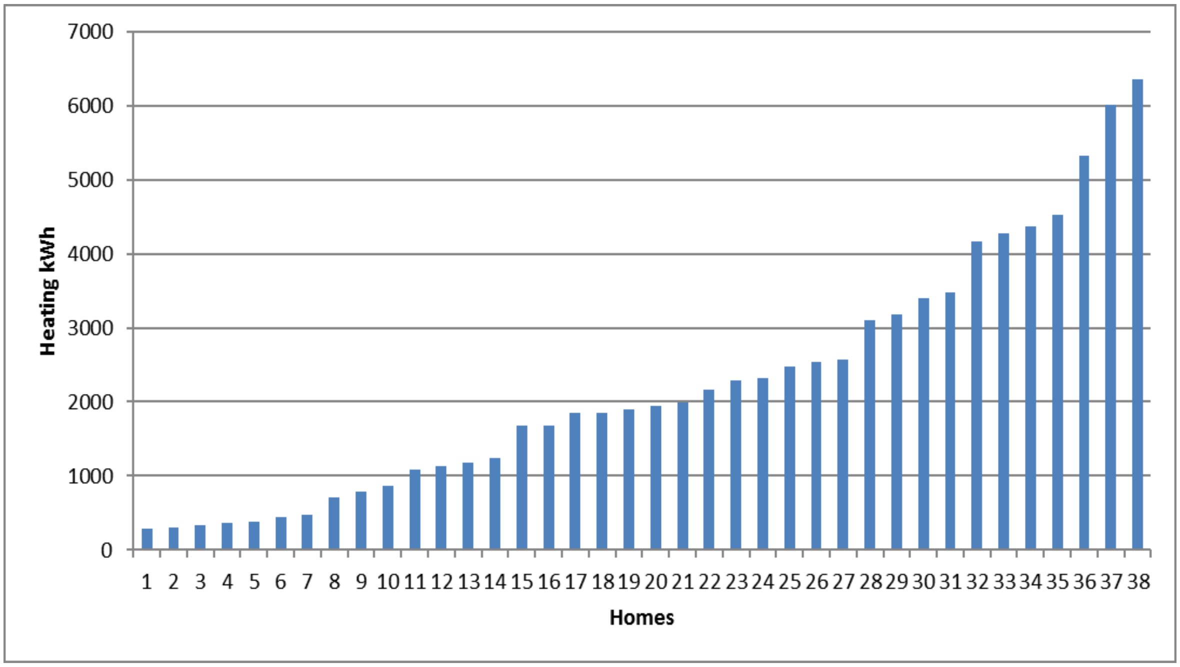

FIGURE 5-1: HEAT PUMP ANNUAL HEATING USAGE

The survey conducted of heat pump participants gave some insight into the low heating usage of some homeowners. The survey responses indicated there are some participants that do not use the heat pump for heating (5% of respondents) and 9% of respondents turn off the heat pump when the temperature is below a threshold between 20 and 40°F.

The summer usage is show in Figure 5-2. There is less difference across homes for the summer usage except for one home with much higher usage. On average the summer kWh is higher than the 112kWh value claimed in the TRM, with 24 of the homes using more kWh for cooling and 14 using less kWh for cooling.

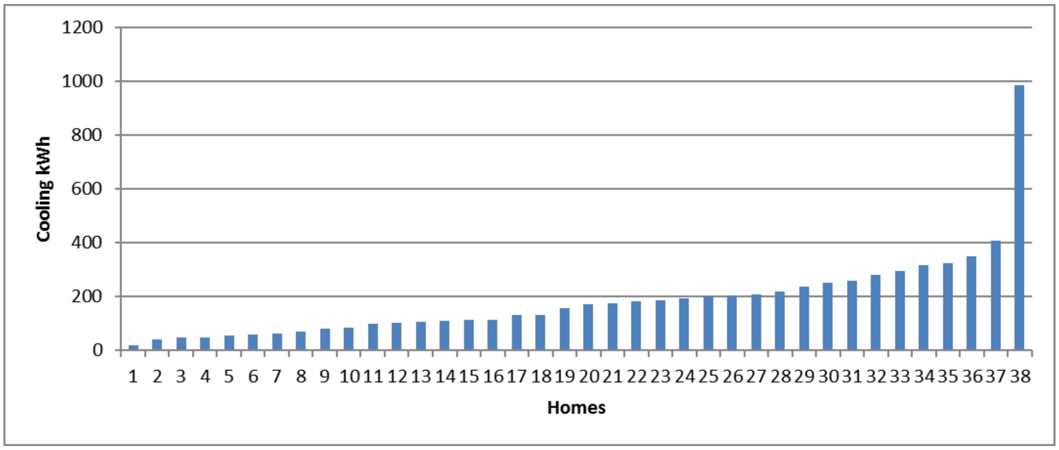

FIGURE 5-2: HEAT PUMP ANNUAL COOLING USAGE

5.4 Calculated COP and Heating Output

The metering of the inlet temperature, outlet temperature and air flow was used to calculate the COP of the heat pumps based on 25 of the 38 metered sites.[17] The average over the metering period was 2.7, which is equivalent to a HSPF of 9.2. This value is lower than the average rated HSPF of 12.3 for the efficient units.[18]

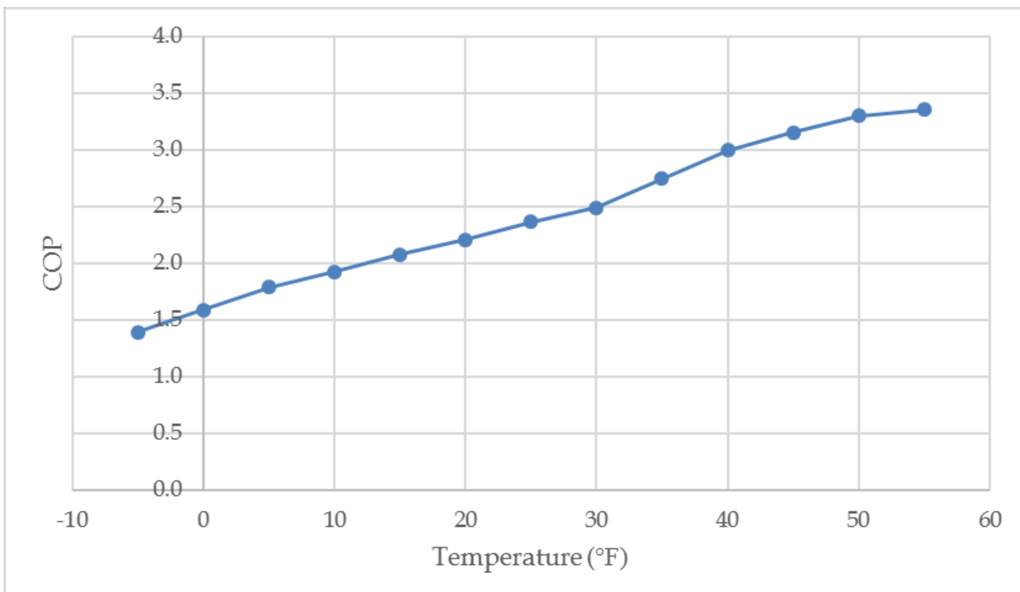

FIGURE 5-3: MEASURED COP BY OUTSIDE TEMPERATURE

[17] Several sites were eliminated from this analysis as the temperature readings were not reliable. In some cases, it appears that the meter may have been moved.

[18] As the HSPF is based on an assumed distribution of seasonal heating temperatures, colder temperatures during the metering than the standard would result in a lower than expected COP. Temperature bin modeling done by Efficiency Maine using Maine specific climate data predicts an average seasonal COP of 2.7, consistent with these results.

There was a high degree of uncertainty in this analysis as the temperature difference between the inlet and outlet temperatures is relatively small (5°F to 35°F) and even a small amount of measurement error can affect the results. Our approach to the metering was to make it as non-invasive as possible and the temperature sensors were installed on the exterior of the unit, as close to the inlet vent and outlet louvre as possible. To obtain more accurate temperature readings would require partial disassembling the unit to place the meter inside; as this approach raises a variety of logistical issues, it was not pursued.

However, it is possible the placement of the heat pumps near the ceiling results in a lower differential as the warmest air in the room is being heated by the heat pump. It is also possible is that some of the temperature meters were not capturing the exact outlet temperature, but a mix of outlet and room air, resulting in lower measured efficiencies.

The heat pump use and kWh and kW savings were calculated using the metered kW draw and the NOAA outdoor temperature. Thus, these calculations were not affected by the indoor temperature readings.

5.5 Comparison of Heat Pumps and Oil Heat

Additional analysis was performed to assess the cost to heat with a ductless heat pump compared with fuel oil over a range of outside temperatures. The fuel oil and electricity costs are based on the six-month average taken in the summer of 2018.[19] The metered heat pump COP results by outside temperature bin from the metering were used to calculate the electricity usage and costs for the heat pump heating by outside temperature.

Based on this analysis the heat pump use is less expensive down to approximately 5 °F. Only about 2% of the total annual hours in Maine are less than 5°F[20], so for most of the time the heat pump will be the lower cost option.

5.6 Evaluated Savings

The summary of the evaluated savings is provided in Table 5-4 below. The savings have been adjusted to account for the 5% of survey participants who do not use their heat pump for heating and 10% who do not use their heat pump for cooling. The realization rates of the winter peak kW and summer peak kW are 61% and 58% respective, with kWh realization rate slightly higher at 67%. The primary reason that the evaluated savings are lower than the *ex ante* savings is the lower than expected use of the heat pumps.

[19] The costs used were $2.73/gallon of fuel oil and $0.15/kWh of electricity. Source: https://www.maine.gov/energy/fuel_prices/archives.shtml

[20] Based on an average of 21 weather stations throughout Maine between 2012 and 2016, not weighted to population.

TABLE 5-4: SUMMARY OF HEAT PUMP EVALUATED SAVINGS AND REALIZATION RATES

Result	Variable	kWh	Winter Peak kW	Summer Peak kW
Energy and Demand Savings	Realization Rate	67%	61%	58%
	80% Confidence Interval	9%	9%	10%
	Relative Precision at 80%[1]	12%	14%	17%
	Ex ante Savings	1,645	0.410	0.103
	Evaluated Savings	1,096	0.246	0.060
Average Annual Consumption (kWh per heat pump)	Program Calculated Consumption	3,000[2]		
	Evaluated Consumption	2,423		
Count of Homes	Number of Homes with Metering[3]	39	38	38

[1] Relative precision is the error bound divided by the realization rate.
[2] This is the program consumption used in the 2016 and 2017 TRM.
[3] 37 of the homes had both winter and summer metering, one home had only winter metering and one had only summer metering due to the participants' schedules.

Several possible causes of the realization rate are discussed below.

- Heat pumps are used less than assumed in the TRM, a finding which is consistent with a recent Vermont study.
- The survey responses indicated there are some participants who do not use the heat pump for heating (5% of respondents) and 9% of respondents turn off the heat pump when the temperature is below a threshold between 20 and 40°F.
- Metered heat pumps had slightly lower rated efficiency than the TRM assumption (HSPF of 12.3 as compared to 12.5).

Another contributing factor could be the relatively low cost of oil during the analysis period, which would make the economics of using the heat pump less attractive to the homeowner.

5.7 Comparison to Other Studies

The results are similar to other heat pump studies conducted in the Northeast recently, as shown in Table 5-5. The heating kWh from the metering is close to the results found in VT, while the summer usage is similar across all three studies. The substantially lower winter usage found in the MA study is likely due to a combination of factors; a substantial number of the heat pumps metered in the MA study were not used for heating and Massachusetts has a somewhat warmer climate than Maine and Vermont.

Table 5-5: Comparison to Other Heat Pump Studies[21,22]

Study Location	Number of Heat Pumps	Annual Heating kWh Use	Annual Cooling kWh Use
ME HESP	38	2,236	186
VT	77	2,085	146
MA Winter 2015[1]	98	683	N/A
MA Summer 2015	114	N/A	159
MA Winter 2016[1]	60	763	N/A

[1] The MA study included non-cold climate heat pumps.

[21] The Cadmus Group, 2017. Evaluation of Cold Climate Heat Pumps in Vermont, Prepared for the VT Public Service Department

[22] The Cadmus Group, 2016. Ductless Mini-Split Heat Pump Impact Evaluation, Prepared for the Electric and Gas Program Administrators of Massachusetts and Rhode Island

6 Special Case Study – Homes with High Heat Pump Usage

The initial metering of heat pumps indicated that the heat pumps were in operation less than assumed in the TRM savings calculations. This result left questions about the potential savings in homes with higher heat pump use. This case study was designed to provide insight by identifying and metering high use heat pump homes. The following sections cover the methods and results.

6.1 Methods

AMI data was used to identify homes with the potential for high heat pump use and a random sample of participants was selected for the metering. Metering was conducted over four months from February to May 2018.

This section discusses data collection activities and methods used to estimate ductless heat pump savings for homes identified as having potential high usage. The sections below cover sampling, metering and estimating savings.

6.1.1 Sampling

The high usage homes were identified by a review of the AMI data and defining the sample frame as homes that showed high temperature dependent usage in the winter. The top 5% of homes in heating related usage were included in the sample. Because of the limited sample, no geographic clustering was used for these homes.

An advance letter with the survey link was sent out to a random sample of 152 participants who were identified as having the potential for high heat pump use. As the participants were contacted, they were screened for any other large electric usage to avoid false signals from the AMI data. Sixteen homes were metered as a part of the final sample. An incentive of $75 was offered to respondents who participated in the metering study.

6.1.2 Metering

The Impact Evaluation Team conducted long-term, on-site metering at 16 homes with heat pumps between February 2018 and May 2018. As the focus of this metering was heating usage, no summer months were included. All of the heat pumps at each of the 16 homes were metered, resulting in a total of 26 heat pumps metered as a part of this round.

A solicitation screener survey and on-site protocols were developed and are included as Appendix D. The on-site protocols include a list of the data collected at each site.

6.1.3 Estimating Savings

Savings from the ductless heat pumps were estimated from the metered data collected on-site. The recorded measurements are shown in Table 6-1 below.

TABLE 6-1: HEAT PUMP MEASUREMENTS AND INPUTS FOR METERING OF HIGH HEAT PUMP USERS

Inputs[1]	Measurement	Purpose
kW Metering	Heat pump kW and Power Factor (whole unit), 1 min interval	Provides input power and kWh of the heat pump
	kW of other heating system (if possible), 1 min interval	Provides central heating system run time
Temperatures	Inlet air temperature, 1 min interval	Calculate the temperature difference (how much the air is heated)
	Heat pump output air temperature, 1 min interval	
	Room temperature, 5 min	Provides temperature set point and a check of input temperature
Air Flow	Air velocity (feet/minute), 1 min interval	Measure air velocity to determine fan speed (19 sites)[2]
	Airflow spot measurement (cubic feet/minute)	Measure cfm at each fan speed and one auto cycle

[1] Other inputs include the specific heat and density of air in the temperature range and the hourly outdoor air temperature from NOAA.
[2] In homes without air velocity meters, an average airflow from the spot measurement was assumed.

While on-site, West Hill Energy technicians used a flow hood to take spot measurements of the air flow (cubic feet per minute) at each fan speed. Typically, there are four or five fan speeds, ranging from low to high. The fan speed coupled with the change in temperature between the inlet and outlet provides a means of calculating the heat delivered to the space from the unit. The heat delivered to the space and the metered energy of the unit allowed us to calculate the COP of the unit at outdoor air temperature ranges. Air velocity meters could only be installed at some of the homes, so an average airflow value was assumed for homes without airflow meter data.

The meter data was combined with hourly outdoor air temperature from the nearest NOAA weather station using the following process:

1. The hourly temperature data was grouped into 5-degree temperature bins for the analysis.
2. The average kW usage and percent on were calculated for each temperature bin and identified as cooling or heating usage.
3. This usage by temperature bin was normalized to an annual kWh, peak summer kW and peak winter kW using the averages of five years of temperature data from 2012 to 2016.

The results from the analysis of metered data were compared to a baseline heat pump using the same baseline HSPF and SEER as in the TRM, using the version corresponding to the install year. As no metered HSPF and SEER were available for the baseline units, the manufacturer's HSPF and SEER were used for the efficient case to maintain consistency with the TRM values.

6.2 Metering Results

The metering results for the high usage heat pumps are shown in Table 6-2. The savings per heat pump are about 30% higher for the high heat pump use homes as compared to the initial metering. In this high use group, some homes have multiple heat pumps and one or more are used substantially less, which lowers the evaluated savings per heat pump. The average usage per home was higher at 5,126 kWh as 9 of the 16 homes had multiple heat pumps. This also results in an average savings per home of 2,112 kWh.

TABLE 6-2: HIGH USER METERED SAVINGS FROM HEATING

Heating	Number of Heat Pumps	kWh Use	Annual Hours[1]	kWh Savings	kWh Relative Precision at 90%	Peak kW Savings	Peak kW Relative Precision at 90%
High Users	26	3,154	3,227	1,361	31%	0.359	30%
Primary Sample	38	2,236	2,592	1,026[2]	23%	0.259	19%

[1]This is the total time running at any load, not the full load hours.
[2] The 1,026 kWh is for heating only, and thus is slightly lower than the 1.096 kWh saved presented in Table 5-4, which includes both heating and cooling savings.

When compared to the TRM savings these high users have a realization rate of 85%, somewhat higher than the general population. As a check on the possible impact of super savers on the evaluated savings, the super saver results were combined with the primary analysis assuming that the method of identifying super savers through the AMI data was accurate. This analysis indicated the realization rate was within 1% of the primary analysis, which verifies the validity of the primary analysis.

6.3 Conclusions

The savings per heat pump are about 30% higher in these high use homes. The metering of the high use homes found that many of these homes had multiple heat pumps and there was often one or more unit that was used substantially less. Consequently, the difference between the savings per heat pump from the initial round of sampling and the high user study is less than may be expected.

7 Special Case Study – Integrated Controls

A second case study was conducted to investigate the operation of Mitsubishi Kumo control system. The Kumo control system is made up of a new line of products designed to allow for the integrated control of the heat pumps and other central heating systems. The system consists of a web-based interface (Kumo Cloud), an external temperature sensor, a single combined thermostat (MHK-1), and a Kumo Station that integrates all the sensors and interfaces directly with the central system valves to provide control over the central heating zone(s). Four participants were selected from the initial round of heat pump metering, so both pre-install and post-install metering data could be collected. The units were installed and initially programmed by Mitsubishi-trained technicians. The following sections discuss the methods and results.

7.1 Methods

This section covers data collection activities and methods used in the second round of metering on homes where a Kumo system was installed.

7.1.1 Sampling

The sample frame was selected from the homes that participated in the initial heat pump study. Four of these homes were appropriate for the Kumo system and the homeowners agreed to participate in the study. Homeowners were allowed to keep the Kumo system, an approximate value of $1,000. No other incentive was provided.

7.1.2 Metering

The Impact Evaluation Team conducted additional long-term on-site metering at four homes with heat pumps between February 2018 and May 2018. These homes were part of the initial heat pump metering. On-site protocols were developed and are included as Appendix D. The on-site protocols include a list of the data collected at each site.

7.1.3 Estimating Measure-Specific Savings

Savings from the ductless heat pumps were estimated from the metered data collected on-site. The recorded measurements are shown in Table 7-1.

TABLE 7-1: MEASUREMENTS AND INPUTS

Inputs[1]	Measurement	Purpose
kW Metering	Heat pump kW and Power Factor (whole unit), 1 min interval	Provides input power and kWh of the heat pump
	kW of other heating system (if possible), 1 min interval	Provides central heating system run time
Temperatures	Inlet air temperature, 1 min interval	Calculate the temperature difference (how much the air is heated)
	Heat pump output air temperature, 1 min interval	
	Room temperature, 5 min	Provides temperature set point and a check of input temperature
Air Flow	Air velocity (feet/minute), 1 min interval	Measure air velocity to determine fan speed (19 sites)[2]
	Airflow spot measurement (cubic feet/minute)	Measure cfm at each fan speed and one auto cycle

[1] Other inputs include the specific heat and density of air in the temperature range and the hourly outdoor air temperature from NOAA.
[2] In homes without air velocity meters, an average airflow from the spot measurement was assumed.

While on-site, West Hill Energy technicians used a flow hood to take spot measurements of the air flow (cubic feet per minute) at each fan speed. Typically, there are four or five fan speeds, ranging from low to high. The fan speed coupled with the change in temperature between the inlet and outlet provides a means of calculating the heat delivered to the space from the unit. The heat delivered to the space and the metered energy of the unit allowed us to calculate the COP of the unit at outdoor air temperature ranges.

The meter data was combined with hourly outdoor air temperature from the nearest NOAA weather station using the following process:

1. The hourly temperature data was grouped into 5-degree temperature bins for the analysis.
2. The average kW usage and percent on were calculated for each temperature bin and identified as cooling or heating usage.
3. This usage by temperature bin was normalized to an annual kWh, peak summer kW and peak winter kW using the averages of five years of temperature data from 2012 to 2016.

The data from the second round of metering was compared to the first round of metering for the same houses. One of the homes had two heat pumps metered as a part of this case study, but only one of the two heat pumps was metered in the original metering.

7.2 Results

A comparison of the usage before and after the installation of the Kumo system for each heat pump is shown in Table 7-2. The second heat pump at Site 4 is the one without pre-Kumo installation data.

TABLE 7-2: METER DATA ANALYSIS RESULTS

Site	Pre kWh	Post kWh	kWh Change	kWh Percent Increase
Site 1	359	632	273	76%
Site 2	1900	3365	1465	77%
Site 3	2287	2388	101	4%
Site 4	2315	2911	596	26%
Site 4	N/A	2,555	N/A	N/A

These homes had a low realization rate in the pre-Kumo install period, with an average realization rates (RR) of 43% across the 4 metered heat pumps. After the installation of the Kumo the RR increased to 56%, still lower than average, largely due to Site 1; this result could be due to the placement of the heat pump in the second floor of the home in an area that was more suited to cooling than heating. If Site 1 is excluded, the resulting realization rate for the remaining three sites is 67%, the same as the average for the homes in the metering study.

Thus, the Kumo system improved the average realization rate for the four units from 43% to 56%, suggesting that the Kumo systems are effective at increasing heat pump use for homes with lower use.

7.3 Conclusions

The installation of the Kumo system resulted in a small to moderate absolute increase in heat pump usage for all of the sites. However, these homes perform the same as the original sample on average after the installation of the Kumo system. Due to the small sample it is impossible to determine the impact of adding the integrated controls for average or high usage homes.

This finding suggests that a contributing factor to the lower-than-expected use of the heat pumps in the initial metering is due to interaction between the heat pump and central heating system controls. It appears that the Kumo system improves the operation of the system as a whole and increases heat pump use. However, the study did not address the total energy use in the home due to the difficulties in obtaining complete billing records for the fossil fuel heating systems.

Due to the small sample size, these results are only preliminary. It appears that the Kumo system shows promise in improving the interaction between the heat pump and central heating systems, increasing the use of the heat pump and potentially improving the efficiency of the heating systems as a whole.

8 Net-to-Gross Analysis

Customer surveys were used to estimate free ridership (FR) and spillover (SO) for insulation and air sealing and for ductless heat pumps using customer surveys. Three approaches were applied:

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

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

Both of these methods rely on the participant's perspective of 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 that they would have made the same choice in the absence of the program.[23] However, program influence questions may tend to overstate program attribution as respondents are more likely to give the socially desirable response.[24] Consequently, the recommended approach to estimating net savings utilizes the self-report method and incorporates program influence.

HESP has numerous strategies for reaching customers and contractors to encourage the installation of energy efficient measures. These strategies constitute the conceptual framework for the program design; they are the causal mechanisms designed to encourage and achieve energy efficiency. A key part of the customer survey and NTG research was constructed to assess how these causal mechanisms work from the customer's perspective and the program influence questions were directly tied to the program's causal mechanisms. The survey instruments can be found in Appendix E and the memo outlining the causal mechanisms is included as Appendix J.

As the NTG approach relies on the customer decision-making process, cognitive interviews were conducted to understand how customers talk about the program and perceive the program's causal mechanisms. These interviews influenced the survey instrument design for customers. The memo discussing the cognitive interviews is provided in Appendix K.

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

[24] 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

8.1 Methods for Estimating Free Riders

Free riders were estimated using self-reports, program influence and a combination of the two. Each of these three approaches is described below and a more detailed explanation of the methods is provided in Appendix L.

8.1.1 Self-Report

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

1. Likelihood of installation
2. Timing

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 states that 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.

8.1.2 Program Influence

Program influence was assessed in three stages:

1. What are the barriers experienced by the customer?
2. How did HESP assist the customer with overcoming these barriers?
3. How important was HESP's contribution to overcoming the barriers in comparison to other influences?

Respondents who identified the barriers relevant to them and how HESP assisted them in overcoming their barriers were included in the program influence analysis. The one exception was cost, as all respondents were asked about the influence of the rebate.[25]

Through the cognitive interviews and other research, five barriers were identified and HESP's approach to overcoming these barriers was assessed.[26] A summary is provided in Table 8-1.

[25] This adjustment was made based on previous experience suggesting that some customers will not identify cost as a barrier but will also state that the rebate was important in their decision to move forward.

[26] Parlin, K., Rieseberg, S and Wörlen, C. "Bringing Order to Chaos: Developing a Comprehensive Framework for Understanding Barriers." 2018 Vienna Conference, Vienna, Austria: International Energy Policy and Programme Evaluation Conference, June 2018. Wörlen, C., Rieseberg, S. and Lorenz, R. "The Theory of No Change." 2016 Amsterdam Conference, Amsterdam, Netherlands: International Energy Policy and Programme Evaluation Conference, June 2016.

TABLE 8-1: BARRIERS AND HESP APPROACH

Barrier	HESP Approach
Costs	Incentives/rebate and financing
Lack of information	EMT provides customer education in numerous ways
Lack of trust in contractors	Contractors are selected from HESP's list of registered vendors
Equipment concerns	EMT registered vendors are highly knowledgeable about the measures and associated issues
Lack of Time	EMT's package of the registered vendor list, rebates, and easily available information about measure installations saves time for the customer

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 was used for the respondent.

8.1.3 Combining Self-Report and Program Influence

The two methods were combined as follows:

1. The program influence and self-report 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.

This approach addresses the possible overstatement of the program influence questions and understatement of the self-report method.

8.2 Methods for Spillover

There are several types of spillover generated by energy efficiency programs:

- Inside spillover: participants install more energy efficiency measures outside of the program due to their positive experience in the program
- Outside spillover: participating contractors and vendors recommend and install efficiency measures outside of the program due to their experiences with the program
- Nonparticipant spillover: nonparticipants hear about efficiency measures indirectly as a result of energy efficiency programs and decide to install efficiency upgrades on their own

In this evaluation, only participant inside spillover was estimated.

The general approach to estimating spillover is as follows:

1. Determine whether additional energy-savings measures were installed after the *ex ante* measure(s)
2. Assess whether the measure was installed outside of an EMT program, including comparing installations to HESP program records to remove measures installed through the program
3. Adjust for program influence on these additional installations
4. Estimate the energy savings per home for the additional measures based on *ex ante* savings (where applicable), the Maine TRM or other TRM's and/or other relevant evaluations

As with free ridership (FR), both self-report and program influence approaches were used to estimate the EMT influence.[27] The wording of the self-report likelihood question was similar to the FR question and was asked for each spillover measure installed. The program influence question was asked for all spillover installations as a group and was only asked if the respondent indicated that they had positive interactions with EMT.[28]

The measures included in the spillover analysis include the following: attic, basement and wall insulation, blower-door assisted air sealing, triple pane replacement windows, efficient furnace and boiler, ductless heat pump, ENERGY STAR room or window air conditioner, clothes washing machine, dishwasher and dehumidifier.

For ductless heat pumps, the participant survey indicated that a number of respondents received incentives for a single heat pump but installed multiple heat pumps at the same time. As it appeared that the program was influential in these additional installations, they were considered to be spillover. The spillover likelihood question was not asked for these respondents and the spillover program influence question was used to estimate EMT's influence.

A recent evaluation completed for NYSERDA's Home Performance with Energy Star program indicated that envelope measures installed outside of the program do not save as much as the measures installed through the program. Consequently, the spillover savings for these measures were adjusted downward by 55% based on the results of that study.[29]

[27] The self-report questions were asked for each measure; the program influence questions were asked for all additional measures as a group due to survey length.

[28] Positive interactions included stating that their experiences with EMT made them more likely to install energy efficiency equipment, they consider EMT a trusted source of information about energy efficiency and/or they are likely to take advantage of EMT services in the future.

[29] "Home Performance with ENERGY STAR® Program Impact Evaluation Report (PY2010-2013): Final Report," Volume 4. Prepared for the New York State Energy Research and Development Authority by ERS. Principal Investigator: West Hill Energy and Computing. November 21, 2016.

8.3 Results

Results are presented for separately for free riders and spillover and then integrated to estimate the overall net-to-gross factors.

8.3.1 Free Riders

The FR results from the two methods are shown in Table 8-2. For insulation and air sealing, the self-report and program influence methods gave results that were within 2%. For heat pumps, the results were more divergent.

TABLE 8-2: FR RESULTS BY MEASURE GROUP AND METHODS

Measure	Free Riders			NTGR (1 - Free Riders)		
	Self-Report	Program Influence	Combined SR & PI	Self-Report	Program Influence	Combined SR & PI
Insulation/Air Sealing	31%	29%	***30%***	69%	71%	***70%***
Ductless Heat Pump	47%	35%	***42%***	53%	65%	***58%***

The Impact Evaluation Team recommends using the combined approach based on both the self-report and program influence methods, as these results address both the downward and upward biases inherent in each method. This analysis indicates that the FR is 30% for air sealing and insulation and 42% for ductless heat pumps.

8.3.2 Spillover

The following tables show the spillover for energy (kWh and MMBtu) and peak demand savings. The results from the two methods are reasonably close as shown in Table 8-3.

TABLE 8-3: SO RESULTS FOR ENERGY SAVINGS BY MEASURE GROUP AND METHOD

Measure	Electric kWh Savings			MMBtu Savings per Participant[1]		
	Self-Report	Program Influence	Combined SR & PI	Self-Report	Program Influence	Combined SR & PI
Insulation/Air Sealing	6.2%	8.4%	7.3%	1.7%	3.7%	2.8%
Ductless Heat Pump	5.7%	6.7%	6.2%	0.2 MMBtu	0.4 MMBtu	0.3 MMBtu

[1] SO measures included insulation, efficient furnaces and clothes washers, which generate kWh and MMBtu savings. The MMBtu savings for heat pumps are presented as the per participant MMBtu savings as no MMBtu savings were claimed for heat pumps. These SO savings are included in the program-level NTGR.

Typically, inside SO rates tend to be low for many residential programs, often in the range of 1% to 2%. The HESP electric kWh spillover rates are unusually high for both the heat pump and insulation/air sealing measures. This result is primarily due to the number of heat pumps that were installed outside of the HESP program.

TABLE 8-4: SO RESULTS FOR PEAK DEMAND REDUCTION BY MEASURE GROUP AND METHOD

Measure	Winter Peak kW Reduction[1]			Summer Peak kW Reduction		
	Self-Report	Program Influence	Combined SR & PI	Self-Report	Program Influence	Combined SR & PI
Insulation/Air Sealing	0.004 kW	0.004 kW	0.004 kW	0.2%	0.4%	0.3%
Ductless Heat Pump	5.5%	6.3%	5.9%	6.9%	9.5%	8.2%

[1] Winter kW peak reduction for insulation and air sealing is reported here as the per participant kW reduction as no winter peak kW savings were claimed for these measures. These SO savings are included in the program-level NTGR.

8.3.3 Net-to-Gross Ratio

The net-to-gross ratio (NTGR) is calculated as follows:

EQUATION 8-1:

$$NTGR = 1 - FR + SO$$

Where

FR is the free rider rate

SO is the spillover rate

The NTGR by measure group is provided in Table 8-5.[30] These values incorporate the self-report and program influence methods.

TABLE 8-5: NTGR BY MEASURE GROUP

Measure	1 - FR	SO	NTGR
Air Sealing/Insulation	70%	3%	73%
Ductless Heat Pumps	58%	11%	69%

[30] The overall SO was calculated by converting the electric kWh savings to MMBtu and combining with the fossil fuel MMBtu savings. The conversion factor was 3,412 Btu/kWh, which accounts only for the electricity consumed on site and not the additional energy required to generate the electricity.

8.3.4 Overall Program NTGR

The program NTG was calculated by applying the FR and SO rates shown above to the savings of the evaluated measures. The weighted average was applied to the unevaluated measures.[31] The results of this analysis are shown in Table 8-6.

TABLE 8-6: HESP OVERALL NTGR

	Ex ante Savings	Net Savings	Overall NTGR
MMBtu Savings (All Fuels)	299,160	213,465	71%

[31] The FR and SO rates were weighted by the magnitude of the savings of the evaluated measures.

9 Benefit-Cost Analysis

Efficiency Maine defined the Primary Benefit Cost Test (PBCT) in accordance with the Triennial Plan III (TPIII)[32] and the Program Administrator Cost Test (PACT) in accordance with the National Action Plan for Energy Efficiency.[33] Definitions of the PBCT and PACT are given in Table 9-1.

TABLE 9-1: DEFINITIONS OF PBCT AND PACT

Benefit/Cost Test	Description	Benefits	Costs
Maine Primary Benefit Cost Test (PBCT)	Compares program administrator plus customer costs to utility resource savings. Reflects the perspective of all utility customers (participants and non-participants).	Avoided costs of electric energy and unregulated fuels savings	Costs to purchase and install the energy efficiency measure, to operate the program, extra fuel use due to measure installations
Program Administrator Cost Test (PACT)	Compares the program administrator costs to supply-side resource savings. Reflects the perspective of utility, government agency, or third party implementing the program	Avoided costs of electric energy and unregulated fuels savings	Only costs incurred by the program administrator (excludes participant costs)

The results from the PBCT and PACT can be interpreted as follows:

- PBCT: Benefit/Cost Ratio (BCR) >1, the benefits exceed the costs for the service territory or region as a whole
- PACT: BCR > 1, an energy efficiency program is a lower-cost approach to meeting load growth than a wholesale energy purchase and new generation resources (including delivery and system costs)

The Impact Evaluation Team examined key inputs to the PBCT and PACT including realization rates (RRs), net-to-gross ratios (NTGRs) and spillover rates.

9.1 Methods

The research objective for the benefit-cost analysis was to estimate the cost-effectiveness of individual measures for fiscal year 2017. The objectives and approach of the BCR analysis are summarized below in Table 9-2 and described further in subsequent sections.

[32] Efficiency Maine, Triennial Plan for Fiscal Years 2017-2019.

[33] "Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers, A Resource of The National Action Plan for Energy Efficiency," November 2008, http://www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf

TABLE 9-2: SUMMARY OF APPROACH TO BCR ANALYSIS

Step	Description
Verify calculations in HESP Cost Effectiveness Analysis tool	Verify that the calculations in the Cost Benefit Analysis Tool (CBAT)[1] are consistent with the California 2001 Standard Practice Manual (SPM) and the California Cost-Effectiveness Tool (CET)
Calculate FY17 measure-level and program-level PBCT and PACT ratios	Based on Triennial Plan III 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 for electric and natural gas and 6) the RGGI discount rate
Conduct sensitivity analyses of measure-level PBCT and PACT ratios	Sensitivity analysis based on changes to assumptions regarding free ridership, NTGRs, RRs, spillover, and carbon benefits
Calculate base case measure-level and program-level PBCT and PACT ratios using alternative assumptions	Calculate the prospective base case measure-level and program-level PBCTs and PACTs using Alternative Avoided Cost and Discount Rate (ACDR) assumptions regarding the six parameters listed in the second objective

[1] HESP Cost Effectiveness Analysis (HCEA) is the Excel-based implementation of the CBAT calculations and was used to verity the calculations.

9.1.1 Verifying HCEA Calculations

To meet the first objective outlined in Table 9-2, the Impact Evaluation Team compared the calculations in the California Standard Practice Manual (SPM) and the California Cost-Effectiveness Test tool (CET) to those in the HESP Cost Effectiveness Analysis (HCEA) tool documentation. The *National Standard Practice Manual for Assessing Cost-Effectiveness of Energy Efficiency Resources*[34] was used as the primary reference for typical cost and benefit accounting practices.

9.1.2 Measure Level PBCTs and PACTs Using TPIII Assumptions

The following information was used to calculate *ex ante* measure level BCRs for the PBCT and PACT for the 15 measures promoted in FY17:

- Measure cost, quantity installed, and incentive costs
- Program delivery costs for FY17
- The expected gross savings for kWh, kW, natural gas therms, as well as savings for propane, heating oil, kerosene, wood and water
- Energy period factors (EPF) for air sealing, insulation, central heat pump and geothermal heat pump installations
- The quantity and costs associated with the Building Bonus

[34] Woolf, Tim, Chris Neme, Marty Kushler, Steven R. Schiller, and Tom Eckman. (2017). *National Benefit-Cost Framework for Assessing Cost-Effectiveness of Energy Efficiency Resources.* Prepared for the National Efficiency Screening Project.

The TPIII parameters that were used to calculate the base case PBCT and PACT ratios are presented below in Appendix M, Table M-1.

TABLE 9-3: M&A TPIII PARAMETERS FOR HESP EVALUATION 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	6.5%
RGGI discount rate	2.43%

In addition, the evaluated FR, participant SO and NTGRs for air sealing/insulation and ductless heat pumps were applied (See Section 8.3.4.). For the other measures, the weighted average of the evaluated measures was applied.

Ex ante gross savings estimates in the HCEA for kWh, kW, therms, propane, heating oil, kerosene, and wood 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 are provided in Appendix M. These inputs were entered into the HCEA spreadsheet to calculate the expected program-level and measure-level PBCT and PACT ratios for FY17.

9.1.3 Sensitivity Analysis

To meet the third objective in Table 9-2, the Impact Evaluation Team explored alternate ways of counting the benefits and costs currently used in the HCEA spreadsheet and identified additional benefits and costs that could be counted. We systematically varied the base case FR, realization rates, and participant SO rates for each measure. We also included varying amounts of carbon reduction benefits and assessed the impacts of eliminating the payments of incentives to free riders as a cost. More specifically, each scenario was tested one at a time with the following five alterations:

1. Incentives to free riders were removed as a cost.[35]
2. FR for each measure were varied above *and* below the base case values by 30%, 20% and 10%.
3. Realization rates for each measure were varied above *and* below the base case values by 30%, 20% and 10%.
4. SO rates for each measure were varied above *and* below the base case values by 10%, 20% and 30%.
5. Included carbon benefits, starting at $4.02 per ton (the June 2018 clearing price in the RGGI CO_2 allowance market[36]). This starting price was then increased by 10%, 20% and 30%. We also included, as another point of comparison, the pricing of carbon at $15/ton, the current price set by the California Cap and Trade Program (CA C&TP).[37]

The results from these sensitivity tests revealed the key drivers of the PBCT and PACT ratios *i.e.* the extent that RR, NTGR and SO each account for changes in results. Confidence intervals around the *ex post* PBCT and PACT results were calculated using the standard errors from the billing analysis computed with propagation of error methods. Appendix M provides detailed results for each sensitivity test.

9.1.4 Prospective PBCTs and PACTs using ACDR Assumptions

To meet the fourth objective in Table 9-2, prospective base case measure-level and program-level PBCT and PACT ratios that used the ACDR M&A parameters were created as listed in Table 9-4. The TPIII inputs are included for comparison purposes.

[35] This is consistent with the recommendation made in Woolf, Tim, Chris Neme, Marty Kushler, Steven R. Schiller, and Tom Eckman. (2017). *National Benefit-Cost Framework for Assessing Cost-Effectiveness of Energy Efficiency Resources.* Prepared for the National Efficiency Screening Project (p. 99). With respect to the issue of how to treat incentives paid to free riders, the NSPM states: 1) Financial incentives paid to free riders are a cost ***only if*** the cost-effectiveness test ***excludes*** participant impacts; otherwise the value of the financial incentive to the participant offsets the cost of the financial incentive to the utility system. In other words, the net cost of free riders is zero under any test that includes participant impacts. 2) No benefits from free riders should be included in any cost-effectiveness test.

[36] Potomac Economics. *Market Monitor Report for Auction 40*. Prepared for: RGGI, Inc., on behalf of the RGGI Participating States, June 2018.

[37] Note that the CPUC currently uses $66.37 per ton of CO_2 reduction in demand-side cost-effectiveness analyses. This value is almost five times the current price set by the California Cap and Trade Program, since regulators considered the current price of $15/ton to undervalue the price due to the immaturity of the carbon market. The CPUC staff (R.16-02-007) has recently recommended this price of $66.37/ton be increased to $150/ton by 2030.

TABLE 9-4: M&A ACDR PARAMETERS FOR PROSPECTIVE BASE CASE PBCTS AND PACTS

Parameter	ACDR	TPII
Avoided cost data set	AESC 2018[1]	LEI High
Net or Gross	Net	Net
Include incentives to free riders as cost	Yes	Yes
Year 1[2]	2018	2017
Default discount rate	2.8%	6.5%
RGGI discount rate	2.8%	2.43%

[1] Avoided Energy Supply Costs Study of 2018.
[2] For AESC 2018, there are no values for 2017. As a result, the Year 1 value is set to 2018

9.2 Results

This section presents the results the from the benefit cost analysis. Appendix M includes additional details about the sensitivity tests conducted to fulfill the third and fourth research objectives.

9.2.1 Consistency of Benefit Cost Calculations

The basic formulas for the PBCT and PACT and the PBCT and PACT calculations from the Cost Benefit Analysis Tool (CBAT) are all presented in Appendix M. A comparison of these equations revealed that, while the form of the CBAT, PBCT and PACT calculations are somewhat differently specified than the formulas, they are algebraically equivalent.

9.2.2 Measure-Level Benefit-cost Ratios

Using the *ex post* values estimated by the Impact Evaluation Team (See Table 9-4), the PBCT and PACT results were calculated for each of 15 measures. The results are presented in Table 9-5.

TABLE 9-5: BASE CASE PBCT AND PACT BY MEASURE USING TPIII ASSUMPTIONS

Measures	PBCT	PACT
Air Sealing	0.94	1.46
Attic Insulation	1.20	6.35
Attic Insulation (NG Only)	0.62	1.21
Basement Insulation	0.91	2.59
Wall Insulation	1.04	3.03
Ductless Heat Pump	1.18	1.48
Ductless Heat Pump multiple indoor units	1.34	2.95
Boiler	1.29	3.28
Furnace	2.78	6.68
Pellet Boiler	0.72	3.95
Pellet Stove	2.76	13.18
Wood Stove (72%->75%)	2.75	12.90
Central Heat Pump	1.24	3.91
Geothermal HP Closed Loop	0.82	4.63
Geothermal HP Open Loop	0.80	4.58
Program-Level	**0.99**	**2.17**

TABLE 9-6: SELECT PBCT COMPARISONS FROM THE SENSITIVITY ANALYSIS

Scenario	M&A	FR Incentives as Costs	Carbon	Program PBCT
Base Case	TPIII	Included	None	0.99
Exclude FR Incentives	TPIII	Excluded	None	1.11
Add Carbon Pricing	TPIII	Included	Starting Price	1.04
Use ACDR M&A	ACDR	Included	None	1.39

9.3 Conclusions

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

- While the specifications of the CBAT PBCT and PACT equations are somewhat different than the SPM/CET equations, they are for the most part algebraically equivalent, with two exceptions:
  - The CBAT includes the costs of *ex post* impact evaluations
  - The London Economics High and AESC 2018 avoided costs do not embed all the cost associated with mitigating carbon emissions

  Each of these exceptions will lower the PBCT and PACT ratios for HESP.

- The calculation of the base case PBCT and PACT for each measure using the *ex post* values revealed that six of the measures have a PBCT ratio of less than 1 while none of the measures have a PACT less than one.
- The exclusion of rebates to free riders as a cost increases the program-level PBCT ratio by 12% to 1.11. For certain measures, the effects can be substantial, ranging from 11% to 25%.
- The inclusion of carbon benefits in future PBCT and PACT calculations can produce small to moderate increases in the PBCT and PACT ratios. However, the effect of using the CA C&TP price of $15 increased the PBCT and PACT ratios by 18%. Moreover, for some measures, the increase was quite substantial (>50%).
- 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, including carbon benefits, and including rigorous estimates of market effects.
- The key drivers of the PBCT and PACT ratios are the gross realization rate, free ridership, and participant spillover, in that order.
- While not explored in this analysis, excluding the cost of *ex post* impact evaluations and including additional non-energy benefits[38] (such as local economic development, reduced utility disconnects, and greater comfort and improved health for building occupants) will also increase the PBCT and PACT ratios.

[38] 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.

10 Review of TRM Methods and Inputs

This section provides a discussion of TRM adjustments based on the evaluation results. TRM adjustments are recommended for air sealing, insulation, ductless heat pumps and boilers, as explained in the sections below.

10.1 Air Sealing and Insulation

EMT developed the TRM savings for air sealing and insulation using its modeling tool. Modifications to the modeling tool were made over time, resulting in changes to the savings over time. A comparison of savings values across different TRM documents is provided in Table 10-1 below.

Table 10-1: Insulation and Air Sealing MMBtu Savings by TRM and Year

	ME - 2015	ME - 2017
Air Sealing	8.2	10.0
Attic Insulation (All fuels except natural gas)	25.5	19.3
Attic Insulation (Natural gas)	25.5	30.6
Wall Insulation	22.5	71.5
Basement Insulation	20.3	38.1
Savings if all 3 insulation measures and air sealing were installed[1]	76.5	138.9
Average Annual Consumption[2]	123.4	123.4

[1] Excludes attic insulation for natural gas homes to avoid double counting
[2] From the unregulated fuels billing analysis

The modeling approach used by EMT results in substantially higher savings than found in the billing analysis. There are numerous energy impacts that are not captured in these calculations and substantially impact the results. A more detailed discussion is provided in Appendix N.

The Impact Evaluation Team recommends adjusting the TRM savings to the savings found in the bulk fuels and natural gas billing analyses. While this process is inexact, it provides the option to adjust the savings for future program changes (such as modifications to the baseline conditions). The TRM savings are calculated in two steps:

1. Estimate MMBtu heating and cooling savings in the EMT modeling spreadsheet
2. Adjust the savings to account for the efficiency of the heating system, the percent of homes with cooling and other, relevant factors listed in the TRM

The results from the billing analysis were used to adjust the inputs into the TRM calculations, as shown in Table 10-2 below.[39]

TABLE 10-2: RECOMMENDED CHANGES TO INPUTS TO THE TRM CALCULATIONS FOR INSULATION

		Recommended Values			
Source	**Input**	**Attic**	**Wall**	**Basement**	**Reason**
EMT Modeling Spreadsheet	Existing R-Value	14.9	6.2	2.0	Attic: average values Wall: average values + R2.5 for framing Basement: cement wall + R-0.50
	New R-Value	50.3	No change	No change	Attic: average values during analysis period
	Indoor Temperature	60°F	60°F	40°F	Attic & Walls: Billing models indicate 60°F more accurately reflects use Basement: calibrated better to billing models
	CFM 50 Reduction	No change	0	No change	Walls: calibrate to billing models
	Wall Area	No change	998	No change	Walls: increase percent of window/doors and decrease wall area to calibrate to billing analysis
	% of Wall Above Grade	N/A	N/A	25%	Basement: decrease percent of walls above grade to calibrate to billing analysis
	Convection BTU/cf/Delta T	0.014	0.014	0.014	All components: calibrate to billing models
TRM Adjustment	Heating System Efficiency (EFF)	83%	83%	83%	All components: calibrate to billing analysis

These values reflect program implementation during the evaluation period. If EMT is interested in modifying the baseline for attic insulation, the Impact Evaluation Team recommends all inputs remain the same, except for the pre-existing R-value, which should be calculated as follows:

[39] Using the inputs provided in Table 10-2, the wall insulation savings are somewhat higher than indicated by the billing analysis. This outcome seems reasonable as wall insulation is rarely installed and there were only a few installations in both the bulk fuels and natural gas billing analyses. Thus, the billing analysis results may not fully reflect the savings from wall insulation.

Equation 10-1: Modified Pre-Installed R-Value

$$Rvalue_{Pre} = R_{Insul} + R2.0$$

Where

$Rvalue_{pre}$ is the pre-existing R-value to be entered into EMT's spreadsheet tool

Rinsul is the R-value of the pre-existing insulation

R2.0 is the estimated R-value of the framing members

The Impact Evaluation Team recommends a minimum pre-existing R-value of R-7.5 (for homes with average attic insulation of R-5.5 or below) to avoid overstating savings, even in homes with very low insulation levels.

10.2 Ductless Heat Pumps

The TRM calculation for the heat pump savings is based on a temperature dependent model which assumes the heat pumps heat 35% of the heating demand. This assumption results in an assumed 3,000 kWh of usage on average for heating, compared to the average of 2,236 kWh found in this evaluation.

The simplest way to reduce the TRM assumed runtime to a value similar to that found in this evaluation is to adjust the percent of heating demand met by the heat pump. The 2016 and 2017 TRM use a heat pump heating contribution of 35% in their modeling. We recommend a value of 26% instead of 35%, which will result in similar annual consumption to the results of this study when using the TRM model. The 35% value is only used for single indoor unit heat pumps in the 2017 TRM, while a value of 70% is used for multiple indoor unit heat pumps. Only five multi-indoor unit heat pumps were metered as a part of this study, so limited data was available, but a similar adjustment may be necessary.

The second difference noted between the metered heat pumps and the TRM heat pumps was the average efficiency. The TRM has a slightly higher average efficiency (12.5 vs 12.3 HSPF) when weighted by the different installation years. As the efficiency assumptions have changed over the program years, this small difference is likely due to a slightly different mix of models installed in the sample.

Table 10-3: Recommended TRM Adjustments to Heat Pumps

Suggested Adjustment	TRM Value	Recommended Value	Comments
Heat Pump Contribution to Heating Load – Single Indoor Unit	35%[a]	26%	Results in annual use similar to the average from this study
Heat Pump Contribution to Heating Load – Multiple Indoor Units	70%[b]	52%	Proportional adjustment based on the study results

a This value is use for all heat pumps in the 2016 TRM and single indoor unit heat pump in the 2017 TRM.
b The multiple indoor unit heat pumps contribution to heating is likely also overstated. Most of the units in the study were single indoor unit heat pumps and it was not possible to develop separate estimates for single and multi-indoor unit heat pumps. However, the study results show a substantial difference between the estimated and actual consumption levels, which should apply to the multi-indoor units heat pumps as well.

10.3 Boilers

The billing analysis suggested modifying the values for the full load hours and the average capacity of the installed boilers. However, these two adjustments largely cancel each other out and the annual heating load from the billing analysis is 96% of the TRM value. The Impact Evaluation Team does not recommend making changes to these inputs.

Two recent studies in New England indicate that the efficient boilers do not condense correctly in a minority of the homes, resulting in a 5% (MA) and 2% (CT) downward adjustment to the efficiency. Metering of boilers was not within the scope of this evaluation. Consequently, the Impact Evaluation Team recommends that the efficiency of the new boiler be adjusted downward by 2% to account for condensing issues based on the CT study.

Table 10-4: Recommended TRM Adjustment to Efficient Boilers

Suggested Adjustment	TRM Value	Recommended Value	Comments
Efficiency of the New Boiler	94.5%	92.5%	Adjustment based on CT study showing that a minority of boilers were not condensing properly[1]

[1] 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 by West Hill Energy & Computing et al. July 2018, p. 4-11

11 Findings and Observations

This section presents the findings and observations. Some of the key conclusions from this evaluation are explored below.

11.1 Gross Savings

Insulation and Air Sealing

- Evaluated savings from other, similar programs range from 9% to 22% of pre-installation consumption.
- HESP evaluated savings are well within this range, at 17% for natural gas and 13% for unregulated fuels.
- Small changes in some of the inputs into the TRM analysis result in substantial changes in the savings.[40]
- The TRM modeling results in substantially higher savings than found in the billing analysis.

Efficient Boilers

- The billing analysis indicated that boiler consumption was lower than assumed in the 2015 TRM by about 20%. The 2017 TRM was updated and the revised annual consumption is very close to the evaluated consumption.
- Other recent studies in New England indicate that the efficient boilers may not be condensing properly in a small minority of homes; a 2% downward adjustment was made to address this issue.[41]

Ductless Heat Pumps

- Metering indicates that the heat pumps are used substantially less than reflected in the TRM characterization. This result is similar to a recent impact evaluation with metering completed in Vermont.
- A small minority (about 5%) of heat pumps owners have high heat pump consumption; these homes use their heat pumps about 33% more than the metered sample and many of these homes have more than one heat pump.

[40] For example, adding R-2.5 to the pre-install R-values used in the TRM modeling resulted in a reduction in savings of 22% for attic insulation and 60% for basement insulation.

[41] This adjustment was based on a recent study conducted in Connecticut that included direct measurement of condensing boilers. See West Hill Energy (2018) under References.

- Accounting for the high users in proportion to their part of the population increases the realization rate from 67% to 68%.
- Possible drivers of the realization rate are lack of integration with the central heating system, misunderstanding about the operating temperature range and the relatively low cost of oil.

11.2 Net savings

The evaluation of net savings combined program influence and self-report methods. Some of the observations from this analysis are as follows:

- For air sealing and insulation, the results from the program influence and self-report methods are very close, suggesting that both strategies are measuring the same underlying construct.
- The program influence and self-report metrics for the heat pumps diverged substantially; this outcome indicates that survey respondents recall that they would have installed the heat pump without the rebate, but also that the program influenced their decision in other ways.

While the NTG results were estimated from the participating customer surveys, the responses to heat pump contractor survey supported the findings and did not suggest that there are additional net savings from contractor activity.

11.3 Other Findings

The participant and contractor surveys covered other topics about the HESP program. While this evaluation is primarily impact, selected findings regarding the program activities and causal mechanisms are discussed below.

Table 11-1: Summary of Key Contractor and Participant Survey Findings

Survey Question	Contractors	Ductless Heat Pump Participants	Air Sealing/ Insulation Participants
At least one HESP activity strongly/extremely important in EE[1] installation	>80%	61%	74%
EMT brand makes it easier to sell EE (C)[2]/ EMT is a trusted source of EE information (P)	70%	90%	91%
EMT's support was more important than other sources of support (C)/ Maximum program influence score was 50% or greater	42%	73%	86%

[1]EE = Energy Efficient
[2](C) = contractors, (P) = participants

In addition, heat pump contractors who responded to the survey reported the following:

- Efficiency has increased and selection of heat pump models is better since the HESP rebates started (67% of respondents)
- Two-thirds are more likely to recommend high efficiency units due to the HESP rebates

Even considering that contractors may be motivated to present the program in a positive light, these findings are quite positive and suggest that the HESP program is effective at reaching this market to promote energy efficiency upgrades.

11.4 TRM Prospective Adjustments

The recommended adjustments to the TRM are summarized in Table 11-2.

TABLE 11-2: SUMMARY OF RECOMMENDED REVISIONS TO THE TRM

Measure	TRM Input	2017 Input	Recommended Revision	Comments
Attic/Roof Insulation	Air Sealing Savings	6.5	6.0	Use NY TRM method
	Savings without Air Sealing	24.0	11.1	Use NY TRM method
Wall Insulation	Air Sealing Savings	13.8	6.0	Use NY TRM method
	Savings without Air Sealing	57.7	7.1	Use NY TRM method
Basement Insulation	Air Sealing Savings	5.0	6.0	Use NY TRM method
	Savings without Air Sealing	33.1	3.6	Use NY TRM method
Efficient Boilers	Efficiency of the New Boiler	94.5%	92.5%	From CT 2018 study
Ductless Heat Pumps	Heat pump contribution to heating load – single indoor unit	35%	26%	Accounts for lower use
	Heat pump contribution to heating load – multiple indoor units	70%	52%	Accounts for lower use
All HESP Measures	NTGR	100%	71%	Based on evaluation results

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Appendix A

Natural Gas Billing Analysis Details

Appendix A: Natural Gas Billing Analysis Details

This appendix includes additional details on natural gas billing analysis data sources, attrition and regression model results. The analysis combined data from three sources: Efficiency Maine Trust's (EMT's) program tracking system, National Oceanic and Atmospheric Administration (NOAA) weather data, and utility billing records. Each of these data sources is described in greater detail below.

A-1 Program Data

The program data was used in three ways:

1. To characterize the population of participating homes with natural gas service
2. To make a data request to the utilities for billing data
3. To identify the measures installed and timing of the installation in each home

Each of these steps in the evaluation is described briefly below.

A-1.1 Population of Homes with Natural Gas Service

Homes with natural gas service are not explicitly identified in EMT's program tracking database and EMT began collecting natural gas account information part way through the evaluation cycle. Consequently, the population of homes with natural gas service was identified using two sources:

1. The rebate amount, which was included in the program tracking data, was different for natural gas homes
2. EMT provided a list of homes with account information covering the latter part of the evaluation period

The account and natural gas rebate information was combined to identify homes with natural gas. While the evaluation team could only request billing data for homes with account information, the evaluated energy savings from the billing analysis were applied to homes that either received a natural gas rebate or had account information.

A-1.2 Utility Data Request

Account information is required for making a data request to the utilities. For those participants with natural gas account information, EMT provided a file containing the name of the utility, account numbers, and the HESP enrollment number. Using this file and the program tracking data initially provided, the West Hill Energy Team developed a list of participants with the utility and account number and sent data requests to the utilities.

A-1.3 Measure Identification for the Billing Analysis

A critical component of the billing analysis is identifying the measures installed in each home and defining the pre-install and post-install periods. West Hill Energy used measure descriptions from the program data to identify installed measures and group them by type. West Hill Energy identified measures with expected natural gas savings and grouped them into categories as follows: air sealing, insulation, boiler replacement, furnace replacement, and "other."[1]

A-2 Weather Data

The impact evaluation team aggregated weather data from Maine's 23 active weather stations that collected readings by intervals of an hour or less than an hour. The national weather service maintains a database of geographic coordinates by zip code. This data was used to calculate the distance between the geographic coordinates of each zip code and each of the 23 active weather stations maintained by NOAA. Each zip code was assigned to a weather station based on the shortest distance between the coordinates.

A review of the NOAA weather data was completed to determine whether the data was sufficiently reliable for this analysis. Weather stations were flagged as potentially insufficient if missing reads accounted for more than 1% of the read days. Additional detail is provided below.

A-2.1 Weather Data Cleaning

The first step in the data cleaning process was to normalize the data to hourly readings. For observations with 15-minute intervals, an hourly average was calculated. Once the data was normalized at the hourly level, a thorough review was completed to assess the magnitude of data gaps and interpolate where possible. If an hourly reading was missing but previous and following hour were available, the average of the previous and following were applied to the missing hour, longer gaps were flagged and replaced with data from the nearest weather station.

A summary of the potentially problematic weather stations is provided in the table below.

TABLE A-1: WEATHER STATION SELECTION

Weather Station	Number of Sites	% of Total Sites	% Missing Reads
Bar Harbor	3	1%	8%
Waterville	10	2%	6%
Auburn	69	12%	3%
Presque Isle	6	1%	1%

[1] "Other" category includes seventeen (17) central heat pumps and twenty-five (25) ductless heat pumps.

West Hill Energy conducted a review of the distance to the second closest weather station, with the following results:

- Bar Harbor & Waterville - an alternative weather station was identified within 10 miles of both weather stations
- Auburn & Presque Isle - the second nearest weather station was sufficiently far from the homes (at least 20 miles from the geographic coordinates). In the case of Auburn, the missing reads were primarily from a period of time not relevant to this analysis. In both cases, we would expect the error introduced by selection of the second closest weather to be higher than that introduced by the missing reads.

Based on this analysis, the closest weather stations were used to fill the gaps for Bar Harbor and Waterville, and data interpolation from the existing weather data was used from Auburn and Presque Isle.

A-3 Utility Data

Two of the natural gas utilities, Unitil and Maine Natural Gas, provided billing records. The utility billing records were mapped to the HESP participant and standardized. The monthly billing data included the following key fields:

- Account identifier
- Date of current and previous reads
- Amount of natural gas consumed (therms)

This information was combined with the measure identifiers from the program data and the weather data to create the regression file.

A-4 Attrition

There is no sampling error for a large-scale regression model, as all participants with sufficient billing history were included in the model. The primary concern was the possibility of bias. Two primary types of bias were considered:

1. Participants without available or sufficient consumption history were excluded from the model (attrition) and may be different from the population as a whole.
2. External influences could create change in energy usage and affect the results of the billing analyses.

These two topics are discussed below for the pre-/post-billing analysis conducted to estimate savings from air sealing and insulation.

A-4.1 Attrition in the Pre-/Post-Model (Insulation and Air Sealing)

The table below shows a summary of the number of accounts and the data received from the utilities.

TABLE A-2: DATA RECEIVED FROM THE UTILITIES

Utility	Number of Participants with Account Information	Number of Participants with Data	Percentage of Participants with Data
Unitil	709	554	78%
Maine Natural Gas	29	22	76%
Total	790	576	73%

Table A-3 shows the number of homes eliminated from the model and the reason for elimination.

TABLE A-3: ATTRITION IN THE BILLING MODEL

	Number of Sites
Data Provided from Utility	**576**
Insufficient Pre or Post	280
Extremely Low or High Consumption	18
Erratic Consumption, Zero Reads, etc.	38
Account mismatch	3
Included in Model	**237**

This level of attrition is common in billing models of this type. If a set of homes with similar energy characteristics were removed from the model, it is possible that bias could be introduced. In this case, there is little or no additional information about the homes to construct a comparison of the homes in the model and the excluded homes.

Some of the critical factors unlikely to be affected by attrition in the context of this study are weather effects (directly included in the model), the fixed characteristics of the homes (housing stock, appliance holdings, etc.), and program delivery strategies (which were constant over all projects). Examples of factors that are not incorporated in the model are discussed below.

- If specific, large contractors are better or worse at recording the pre- and post-conditions and if all homes completed by one or more of these large contractors are completely removed from the analysis, attrition could present a potential source of bias.
- Some participants moved during the analysis period and could not be included in the analysis since the billing records did not cover the critical months before and after the installation. Thus, participants who tend to move often are effectively removed from the analysis as a group.

In this evaluation, the 11 contractors who accounted for two-thirds of the projects[2] were well-represented in the model, so this issue is unlikely to introduce bias to the evaluated savings. Moving is part of random activity in the residential sector, and frequent movers are likely to be a small part of this activity. In general, random variations are unlikely to introduce directional bias into the analysis as long as there are enough homes in the model.

A-4.2 Attrition in the Post-Only Model (Boilers)

Homes were removed from the boiler analysis for the following reasons:

1. Insufficient billing data (less than one full heating season in the post period) (6 homes)
2. R^2 below 0.70, suggesting that natural gas use is not linear with temperature and the method described above is not effective for estimating heating consumption (3 homes)
3. Very low or very high consumption, outside the expected range of residential heating use (1 home)
4. The model installed was a furnace rather than a boiler (3 homes)

Homes without heating system equipment model information were excluded from the calculation of full load hours (FLH), resulting in a slightly smaller population for that calculation.

Homes in categories 2 and 3 (R^2 and high or low use) were eliminated as they are not expected to be representative of typical residential use and may reflect transition periods (such as the property changing hands or non-representative periods of vacancy). A sensitivity analysis was conducted to assess whether excluding these homes had a substantial effect on the analysis. The results suggest that the impacts are quite small: annual consumption may be slightly overstated (by about 1%).

A-5 External Effects

A billing analysis is based on the assumption that overall changes in household consumption can be used to calculate the savings from participation in efficiency programs. Energy use may be affected by widespread economic changes, or other factors outside the influence of the program.

In a two-stage model where the regression is conducted only at the household level,[3] a comparison group is sometimes used to account for external effects. However, a comparison group may introduce additional uncertainty in the model, as it includes naturally occurring efficiency and the end result cannot be clearly interpreted as either gross or net savings.[4] In addition, defining an equivalent comparison group can be a complicated process.

[2] "Projects" in this context refers to all homes with natural gas and air sealing or insulation measures.
[3] While household regressions were conducted in this evaluation as part of the data cleaning process, the final results were estimated from pooled models including all eligible homes.
[4] Randazzo, K.; Ridge, R.; and Wayland, S. (2017, in revision). Observations on Chapter 8 of the Uniform Methods Project: A Discussion of Comparison Groups for Net and Gross Impacts. Opinion Dynamics, submitted to PG&E

Non-program changes, both internal (such as changes in occupancy) and external (such as changes in energy prices), were addressed in the pooled billing analysis as follows:

1. The fixed effects model accounts for the factors in each home that remain stable over time
2. The timing variables account for widespread changes in energy use across all homes in the model and the model covered the period of August 2012 through April 2017
3. The model includes all homes meeting the criteria for inclusion, indicating random changes internal to the household should not bias the results[5]

In addition, previous research indicates large, pooled models do not produce biased estimators when compared to a model incorporating detailed survey data regarding changes in household composition and energy use.[6]

A-6 Regression Model

Table A-6 below summarizes the model output. The "estimators" column is the regression coefficient and reflects the measure savings. Negative values indicate savings (lower use in the post-installation period).

TABLE A-4: SUMMARY STATISTICS FOR THE NATURAL GAS REGRESSION MODEL

Measure	Estimator[1]	t-value[2]	Unit of Estimator	Number of Homes
Air sealing/insulation	-.0302	12.0	Therms/Heating Degree Day	138
Furnace replacement	-.0303	7.3	Therms/ Heating Degree Day	12
Boiler replacement	-.0165	10.8	Therms/ Heating Degree Day	80
Heat Pump[3]	-.0181	7.9	Therms/Heating Degree Day	27
Other	.0052	1.8	Therms/Heating Degree Day	17
Heating Degree Days (HDD)[4]	House-specific HDD		Heating Degree Day	242
R-Squared[5]		0.96		

[1] The "estimator" is the regression coefficient and reflects the impact of the variable on the change in average daily use.
[2] The t-value of a regression coefficient measures whether the value of the coefficient is statistically different from zero. The t-statistic is the regression coefficient divided by its standard error. A t-value of 1.64 or higher indicates the coefficient is statistically different from zero at the 90% confidence level.
[3] Heat pumps were included as natural gas use may decrease in homes with a heat pump and omitting this variable would increase in the variability in the model. However, there were too few homes in the model with heat pumps (25) to reliably estimate the natural gas savings.
[4] The heating degree days were calculated from a base of 60°F, based on previous modeling experience.
[5] The R^2 measures the proportion of variability in a regression data set that can be explained by the model. An R^2 of 1.0 indicates that the regression perfectly fits the data. A fixed effects regression as used in this analysis tends to have a high R^2 as the model compares each home to itself.

[5] For example, some houses will experience an increase in occupancy and others a decrease. As these changes are random, they will cancel each other out.
[6] Megdal & Associates, LLC, West Hill Energy & Computing, Inc. NYSERDA 2007-2008 Empower New York Program Impact Evaluation Report

A-6.1 Regression Model Diagnostics

The impact evaluation team reviewed the data and assessed the results to ensure that the savings estimates are statistically sound. As part of this process, model diagnostics were performed. The model was checked for influential homes, heteroskedasticity (unequal variances) and autocorrelation. Multicollinearity could occur if measures are installed as a bundle or there is substantial overlap among measures, *i.e.*, most homes with insulation also receive air sealing. This issue was addressed through the configuration of the model variables.[7]

The analysis of influential homes did not identify any specific homes that had an undue influence on the results. The model exhibits a mild degree of heteroskedasticity. Heteroskedasticity tends to result in overstatement of the variance, and it may also signify some level of misspecification of the model. Due to the complex nature of energy consumption, all models have misspecification of some type. There is no test to determine the effects of model misspecification. However, the Goldfeld-Quandt test statistic for heteroskedasticity was 3.30, which is substantially lower than found in other, similar evaluations and suggests that heteroskedasticity or model misspecification is unlikely to be affecting the results.[8]

The regression model also exhibits autocorrelation, as is common with billing models. Autocorrelation occurs when the observations are not completely independent; this occurs in billing models as the bill for a home during one month is generally related to the bill for the next month. Autocorrelation leads to understatement of the variances but does not affect the magnitude of the estimators.

A-7 Boiler Regression Model

A house-by-house regression was conducted to estimate the post-install annual consumption for the boilers. The results below were recorded from each model:

1. The R^2, which reflects the strength of the relationship between heating degree days and consumption
2. The heating slope coefficient (therms/HDD), which reflects the magnitude of the relationship between heating degree-days and consumption
3. The intercept, which reflects therms of base use, such as water heating or cooking

[7] Multicollinearity is addressed through careful review of the data to identify where measure installations overlap and by bundling measures that are commonly installed as a group. If the regression coefficient for a measure indicates extra use rather than savings, it could be a sign of multicollinearity and further review is indicated. An example of how multicollinearity was addressed in this evaluation is that all insulation measures were included in the same measure group, as efforts to try to develop separate estimators were unsuccessful.

[8] The Goldfeld-Quandt (GQ) test statistic uses the F-test and a value of 1.0 indicates no heteroskedasticity. In other natural gas billing analysis, West Hill Energy has found that a GQ test statistic around 6 is not uncommon. Thus, the value of 3.3 in this evaluation suggests that heteroskedasticity is present, but at a lower level than expected.

Billing analysis models were tested with and without intercepts for each home. The R^2 from each model and the sign of the heating slope and intercept were used to determine which model was a better fit. The heating slope was used to calculate annual heating consumption, as shown in the equations below.

Annual Heating Use = Heating Slope (therms/HDD) x Normalized HDD

Where

Annual Heating Use = Normalized therms per year used for space heating

Heating Slope = Regression estimator for the HDD (therms/HDD)

Normalized HDD = 5-year normalized HDD60 for nearest weather station

This value was then used to calculate the equivalent full load hours (EFLH). In addition, the TRM estimate of annual heating use was compared to the results of the billing analysis.

Appendix B

Unregulated Fuels Billing Analysis Details

Appendix B: Unregulated Fuels Billing Analysis Details

This appendix includes additional details on the unregulated fuels data collection, attrition and billing model details.

B-1 Data Collection

The data collection process involved the following steps:

1. Sending out advance letters with a consent form and link to the web-based survey
2. Receiving the consent forms and sending a reminder to those who did not respond
3. Contacting fuel dealers to request records for those participants who sent a consent form
4. Receiving and entering the fuel dealer's billing records
5. Sending incentives to the participants ($25) and the fuel dealers ($25 for the first 10 fuel records, plus $1 for each customer after the first 10)

The results of the data collection process are outlined in the table below. The impact evaluation team relied on the process of mailing letters with the consent form and survey link to customers to solicit responses. The survey collected information about heating systems and household characteristics to improve our understanding of the unregulated fuels analysis.

The consent forms were used to request billing data from all of the fuel dealers for each customer. A total of 169 fuel dealers were identified by the customers.

Table B-1: Billing Data Collection Overview

	Total Sent	Total Returned	Total Surveys Completed
Consent Forms with Survey Link	938	463	299
Total Billing Data Requests to Fuel Dealers	456	289	-

Weather data was obtained from the National Oceanographic and Atmospheric Administration (NOAA) for 10 weather stations in Maine. The hourly temperature data was cleaned and reviewed for gaps. Gaps of up to four hours in a row were filled by interpolating from the previous and next temperature read. This weather data was used to calculate heating degree days and the heating degree days were applied to the billing records for each participant.

B-2 Data Cleaning and Attrition

The billing records received from fuel dealers were reviewed and participants were removed from the billing model for the reasons outlined in the table below.

TABLE B-2: DESCRIPTION OF ATTRITION CATEGORIES

Attrition Category	Description
Not Enough Data	The data provided for the household had too few records, or too short a billing period to allow for analysis.
Poor Quality Data	Homes where the data did not meet our standards, as identified by the regression outputs, survey results, and patterns of use.
Outliers or Influential Data Points	Households with wide and unexplained swings in consumption and having an influential effect on the realization rate.

A summary of the attrition is included in table below. Of the 463 participants with signed consent forms, billing records were received for 289 (62%) and 33% of these projects were included in the final model.

TABLE B-3: ATTRITION SUMMARY

	Remaining Number of Participants	Number Removed	% of Total Billing Records
Total Billing Records Received	289	-	-
Not Enough Data	177	112	61%
Poor Quality Data	100	77	35%
Outliers or Influential Data Points	95	5	33%
Accounts in final model	95	-	33%

B-3 Billing Model Details

A house-by-house regression was conducted. Two models were run for each home, one with an intercept (representing base loads like water heating) and one without an intercept. Selecting the correct regression model was informed by using the survey data and the regression results. For homes with survey data, those using the same fuel for space heating and water heating utilized the intercept model and those without used the no intercept model. In a few cases, the participant did not complete the detailed survey. In these cases, the intercept and non-intercept regression models were tested and the model with the better fit was used.

The regression results were reviewed and homes were dropped for the following reasons:

- Negative heating slopes
- Coefficient of determination (R^2) less than 0.65
- Negative intercepts for homes with the same fuel used for heating and hot water

The verified savings were calculated using the 60°F base heating degree days (HDD) for all homes, as a review of the regression results indicated the 60°F base HDD provided more reliable results for the majority of homes.

For homes without baseline domestic hot water heating (DHW) usage, the regression equations were used and normalized using a 5-year average annual HDD. For homes with DHW usage, the savings from the regression equations were not used as a number of regressions showed large variations in DHW usage between the pre and post period. The DHW usage was averaged between the pre and post and removed from total to leave only heating usage. The energy required for space heating per heating degree day was calculated separately for the pre- and post-installation period. The difference between the two values was then multiplied by the 5-year annual average HDD for the appropriate weather station.

Appendix C

Ductless Heat Pumps Sampling

Appendix C: Ductless Heat Pump Sampling

MEMORANDUM

TO: Laura Martel, Efficiency Maine

FROM: Claire Danaher and Kathryn Parlin, West Hill Energy

DATE: January 20th, 2017

RE: Sampling Plan for Ductless Heat Pumps Metering

The purpose of this memo is to outline the sampling approach used to select homes for metering of ductless heat pumps installed as part of the Home Energy Savings Program (HESP). Metering will be completed for the duration of 6 months in 40 homes. The first phase of metering will occur for 20 homes starting early February and continuing into July, and the second round of metering will start early August and continue until January 2018. This memo serves to outline the sampling approach used to select the homes where the metering will be completed.

C-1 Population Overview

Per the evaluation plan, metering will be completed for ductless heat pumps installed in 40 homes. The table below provides a summary of the number of installations by county for county's accounting for more than 5% of the total installations. All other counties are aggregated under the "Other" category.

Table C-1: Installations by County

County	Number of Sites	% Total Sites	Average Heating Degree Days
Piscataquis	3,822	29%	8,710
Aroostook	1,682	13%	9,346
York	1,598	12%	7,386
Knox	1,205	9%	7,470
Cumberland	916	7%	7,381
Other	4,045	30%	7,906

C-2 Sampling Approach

The West Hill Energy Team selected stratified random sampling for this project. Stratified ratio estimation is appropriate when there are a few sites with high savings and many sites with small savings. However, all HESP homes are assumed to have the same level of average savings for heat pumps, making stratified random sampling a better choice.

Geographic stratification was selected for three major reasons:

1. To be representative, the sample needed to take Maine's climate zones into account
2. The analysis plan calls for comparing the metering to AMI data to develop an adjustment factor and AMI data is more likely to be available in specific regions
3. Geographic clustering helps to control evaluation costs

After considering a number of strategies for geographic stratification, the West Hill Energy Team decided on using the average number of heating degree days (HDD) by town as the stratification variable. Towns were grouped into those with greater than 7600 HDD and those with fewer than 7600 heating degree days. The table below provides a summary of the numbers of towns and sites within these two strata.

TABLE C-2: UPPER LEVEL STRATIFICATION

Climate Zone	Number of Zip Codes	Number of Sites	Percentage of Total Sites
<7600 HDD	226	8,285	62%
>7600 HDD	404	4,983	38%
Total	630	13,268	100%

The West Hill Energy Team defined geographic clusters by zip code. The sampling plan calls for defining four geographic areas (zip codes) and completing 10 site visits with metering in each of the four areas (for a total of 40 site visits).

Within a given zip code, a sufficient number of participants is required in order to ensure a sufficient sample size. Based upon past experience, the West Hill Energy Team estimated a 10-to-1 response rate for participation in site visits. Towns with fewer than 100 participants were excluded from the sample as we would not expect to be able to complete the target number of site visits.

From the zip codes with more than 100 participants with heat pumps, two zip codes from within each stratum were randomly selected. The towns of Waterville and Scarborough were randomly selected from the towns with fewer than 7600 HDD. The towns of Dover-Foxcroft and Bangor were randomly selected from the towns with greater than 7600 HDD.

The towns of Dover-Foxcroft and Scarborough have fewer than 150 participants and all participants will be solicited for participation in the study. Waterville and Bangor have more than 150 participants, 100 participants were randomly selected for solicitation to participate in the study.

C-3 Conclusions

The West Hill Energy Team will be completing metering at a total of 40 homes where ductless heat pumps were installed. The sampling strategy was developed to account for Maine's climate zones while also geographically clustering to control evaluation costs.

Table C-3: Summary of Sampling Plan for Heat Pump Metering

Sampling Component	Description
Sampling Unit	Site with ductless heat pump installation
Sampling Strategy	Stratified random sample and cluster sampling
Upper Level Stratification	Climate zone (2 strata)
Lower Level Cluster Sampling	Zip code (2 zip codes in each climate zone)
Sample Size	40 total, 10 completes in each stratum
Precision/Confidence	80/10, assuming a coefficient of variation of 0.50; sample size designed to meet budget

Appendix D

Ductless Heat Pumps Site Visit Protocols and Forms

Appendix D: Ductless Heat Pump Site Visit Protocols and Forms

This appendix contains the protocols for the heat pump metering.

Table D-1: Measurements

	Meter	Measurement	Purpose
	Dent Elite-Pro	Heat pump kW and PF (whole unit); record kW of other heating system (if any and possible)	Provides input power and kWh of heat pump and heating system run time
Hobo UX120-006M	Inlet air temperature	Inlet Air Temperature	Calculate the temperature difference (how much the air is heated)
	Outlet air temperature	Heat pump output air temperature	
	Air velocity	Air velocity (feet/minute)	Measure air velocity to determine fan speed
Hobo Pendant	Ambient Air	Room Temperature	Provides temperature set point
TSI AccuBalance Balometer	Airflow	Airflow spot measurement (cubic feet/minute)	Measure cfm at each fan speed and one auto cycle
	None	Outdoor ambient air temperature	From NOAA – use to normalize results

On-Site Preparation

Table D-2: Meters

Meter Type	Attachments	Quantity	Metered Variables	Reading Interval	Max Data Storage Duration
Dent Elite-Pro	3 CTs, Voltage Leads and Connector Cable	1	kW, PF	1 min	~200 days
Hobo UX120-006M	Temperature Probe	2	Temp	1 min	~180 Days
	Airflow Probe	1	Airflow (feet/minute)		
Hobo Pendant	None	1	Temp	5 min	~180 Days
TSI AccuBalance Balometer	None	1	Air Flow	Spot measurement	

TABLE D-3: EXPECTED RANGE OF READS

Meter Type	Variable	Expected Range
Dent Elite-Pro	Heat pump-kW	0.5>kW<4
	Heat pump-PF	-1 and 1
TSI AccuBalance Balometer	Feet/Min	200-700

Other Equipment

1. Laser measure (to measure area of space served by ductless heat pump)
2. Electrical tape
3. Zip ties
4. Badge/ID
5. Laptop
6. First Aid Kit
7. Review manufacturer installation specifications and program Dent for correct wiring.
8. Synchronize time on all four meters
9. Coordinate with homeowner and electrician.
10. **Customer Handout form and Release form**, detailing our work and what we expect after we leave.
11. Instructions for electrician on retrieval visit with checklist for equipment to collect with place for us to write in meter ID#

On-Site Procedures

Explain the site visit and how the meter will be collected to the homeowner, give them the customer hand-out and answer any questions they have. Discuss return trip to download data and coordinating with the electrician to have the meters removed. Complete the steps below and fill out the site visit check list as each step is completed.

1. Discuss site visit with homeowner, answer any questions, and have release to be signed
2. Record location of heat pump and take a photograph
3. Note and record other heating/cooling equipment in the room
4. Record temperature and fan speed setting upon arrival
5. Photograph and record heat pump name plate
6. Have electrician install the Dent meter on the heat pump circuit for channel 1& 2. Attach the heating system CT to channel 3 if possible. Heating system and Channel 1 should be on the same leg. Only the electrician is allowed to work in live electrical panels.
7. Maintain a safe distance from the panel and follow the electrician's direction while the panel is open and meter is being installed.
8. Confirm Dent meter is getting reasonable readings (positive, within the expected kW range) and metering is set to record at a 1-minute interval.
9. Photograph Dent installation when electrician has installed meter but not replaced panel

cover.

10. Ensure the circuit box cover can close after installation.
11. Install Hobo UX120 logger with one temperature probe near the air inlet. Secure the other temperature probe and the airflow sensor in the exhaust air stream. Photograph installation. See Figure 1 to determine whether to install airflow sensor.
12. Install Hobo Pendent logger in an acceptable location near thermostat or heat pump control.
13. Set up air flow hood. Record time and cfm at each fan speed. Take three measurements at each fan speed, 20 seconds apart.
14. The West Hill Energy Team will schedule a time to retrieve data and reprogram the meters at approximately the three-month mark. The tentative time for retrieving data and reprogramming the meters is the first week of May. A date and time will be determined with the homeowner.
15. Discuss retrieval procedure with homeowner for the 5 ½ month mark. The tentative week for the retrieval is the 17th-21st of July. Explain that the electrician will need to collect the meters and return them to us.

CFM Testing protocol

1. Create a seal between flow hood and exhaust fan
2. Use the manual/average logging option
3. Log each fan speed for one minute, synchronized with velocity meter -start on minute mark, for each fan speed setting
4. Set unit in "Auto" and turn thermostat up 2 degrees and log one full cycle until heat pump powers down

Procedure for Downloading Meter Data

1. When downloading data, name each file with the case ID and the type of data, for example: OutletAirTemp1234
2. After downloading data, reprogram the meters using the same set up for the second half of the meter period.

Procedure for Removal

Coordinate a removal date and time between the homeowner and electrician. Explain the packing and return procedure to the electrician. Provide electrician with list of equipment at each site and the steps for removal.

1. Uninstall all meters and all accessories
2. Return to West Hill Energy. The delivery mechanism (mail/pickup) will be determined at a later date.

Airflow Sensor Decision Tree

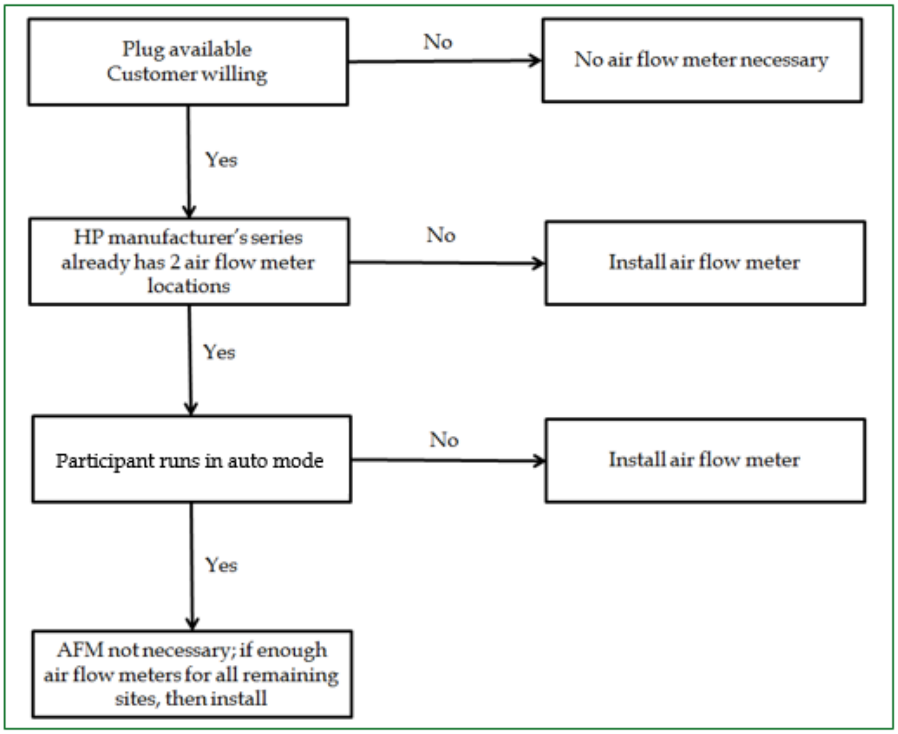

FIGURE D-1: AIRFLOW SENSOR DECISION TREE

Customer Forms

Customer Handout

Home Visit Summary
West Hill Energy will return to reprogram meters on approximately: ____/____/_____
The electrician will return to retrieve the meters on approximately: ____/____/_____

West Hill Energy is contracted by Efficiency Maine to assess energy savings from ductless heat pumps discounted through the Home Energy Savings Program (HESP). Thank you for participating in our study to learn about the energy efficiency of your ductless heat pump!

After this site visit, please follow these instructions:

1. On or near (/   /   ), allow West Hill Energy to come back to download data and reprogram the meters.

2. On or near (/   /   ), allow the electrician to come back to retrieve all of the installed meters.

3. 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.

4. A **$75 check will be mailed to you after you complete a more detailed survey and the meters have been picked up**.

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

GENERAL RELEASE

West Hill Energy has a contract with Efficiency Maine to assess energy savings from ductless heat pumps discounted through the Home Energy Savings Program (HESP). As part of this study, West Hill Energy is metering ductless heat pumps installed throughout Maine.

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

1. Allow the electrician to return in about three and half months to uninstall the meters.
2. Complete a more detailed survey. West Hill Energy will contact you regarding the completion of this survey at a later date.

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

Printed Name: ________________________________
Signature: ________________________________
Date: ________________________

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

Appendix E
Survey Instruments

Table of Contents

Customer Screener Survey: Ductless Heat Pumps 1
Detailed Customer Front End Survey: Ductless Heat Pumps 4
Detailed Customer Back End Survey: Ductless Heat Pumps 24
Detailed Contractor Survey: Ductless Heat Pumps 45
Detailed Customer Survey: Unregulated Fuels 59

Appendix E: Survey Instruments

This appendix contains the survey instruments used for the customer and contractor surveys.

E-1 Customer Screener Survey: Ductless Heat Pumps

Name	
Phone Number	
Address	
Town, Zip	
e-mail address	
Equipment Installed	Ductless Heat Pump
Number of heat pumps installed	
<CONTRACTOR>	

SCREENER

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

Our records show that you recently installed a high efficiency ductless heat pump.
S2. Do you remember the installation of the new heat pump?
1. Yes
2. No [THANK AND TERMINATE]

S3. When was your heat pump installed?
[RECORD MONTH AND YEAR]
97. DK

S4. According to our records, **<CONTRACTOR>** installed your new heat pump. Is this correct?
1. Yes, it's correct
2. No, Correct contractor name: ________________________________
97. DK

S5. How many outdoor heat pump units do you currently have installed?
1. 1
2. 2
3. 3
4. 4+
97. DK

S6a. [IF S5=1] Is your heat pump a single head or multi-head? (A multi-head unit is one where there are two or more indoor units attached to a single outdoor unit.)
1. Single head
2. Multi-head

97. DK

S6b. [IF S5>1] How many of your heat pumps are single head and multi-head?
Single head ________________
Multi-head _________________
97. DK

S7. What type of home do you have?
1. Single family home
2. Multifamily building
3. Mobile home
4. Other [RECORD____________]

S8. When is your home occupied? (Choose as many as apply)
1. Winter
2. Summer
3. Spring
4. Fall
5. Other [RECORD: _____________]

S9. Is the heated area of your home …
1. Less than 2,000 square feet
2. More than 2,000 square feet

We are conducting an evaluation of high-efficiency ductless heat pumps. 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 your energy use.
   Evening and weekend appointments will be available.
2. You will allow a professional electrician to retrieve the meters, which will be returned to Efficiency Maine.
3. You are willing to provide us with your electricity delivery account number and permission to request your electric bills from your utility.
4. You will be available to complete a more detailed survey in the future.

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: ___________

C5. Please select an option below to provide us with your electric bill account number:
1. [RECORD ACCOUNT NUMBER]______________________
2. E-mail the image to survey@westhillenergy.com
3. Text the image: +1-XXX-XXX-XXXX

If you choose to e-mail or text the image, please do so within 48 hours. We will not be able to contact you for a site survey until we receive a legible image of your electric account number.

C6. We are planning to conduct site visits in mid-February 2017. When are you likely to be available during this timeframe? Please select three options.

1. Mondays between 7am and 11am
2. Mondays between 11am and 3pm
3. Mondays between 3pm and 7pm
4. Saturdays between 10am and 2pm
5. Saturdays between 2pm and 5pm

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 S2:] 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.

[COMPLETE SURVEY:] Thank you for your time. If you are selected for an on-site survey, 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.

Customer Screener Survey: Homes with High DHP Usage

Name	
Phone Number	
Address	
Town, Zip	
e-mail address	
Equipment Installed	Ductless Heat Pump
Number of heat pumps installed	
<CONTRACTOR>	

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 ductless heat pump 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 was not installed [THANK AND TERMINATE]
5. Something else? _____________________

S3. A single heat pump unit is a heat pump with a single outdoor unit and a single indoor unit.

A multihead heat pump unit is a heat pump where two or more indoor units are attached to a single outdoor unit.

How many of the heat pumps installed in your home are single head and how many are multihead?

Single head ________________ [ONLY ALLOW NUMBERS TO BE ENTERED]
Multihead _________________[ONLY ALLOW NUMBERS TO BE ENTERED]
Comment: __________________[ALLOW TEXT]
97. DK

SURVEY DIRECTIONS: Please fill in both the single heat and multihead boxes. Enter a zero if you did not install that specific type of heat pump.

[TOTHP = # SINGLE + # MULTIHEAD]

S4. In addition to your heat pump(s), do you have any other electric heaters that you use on a regular basis? (Choose as many as apply)

1. Electric baseboard heat
2. Electric radiant heat
3. Electric space heater
4. You do not have any electric heaters in addition to the heat pump(s)
5. Something else? ______
97. DK

S5. [IF S4 <=3] Which of the following best describes how you use the electric space heat?

1. Throughout the entire heating season from September to May
2. Only during the coldest months from December to February
3. Only in the Spring and Fall
4. Only on the coldest days
5. Rarely
6. Not at all
7. Something else? __________________
96. Don't know

[IF TOTHP>2 OR S5 = 1 OR 2, THEN THANK AND TERMINATE.]

S6. What type of home do you have?

1. Single family home
2. Multifamily building
3. Mobile home
4. Other [RECORD____________]

S7. When is your home occupied? (Choose as many as apply)

Year Round
Winter
Summer
Spring
Fall
Other [RECORD: _____________]

S8. Is the heated area of your home …

1. Less than 2,000 square feet
2. More than 2,000 square feet

S9. What other equipment, if any, do you use in your home that consume a lot of electricity? (for example hot tubs, ice makers or greenhouses?)

1. You **do not** have any high electric use equipment

2. [RECORD RESPONSE] ____

We are conducting an evaluation of high efficiency ductless heat pumps. You may be eligible for a $100 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 your energy use.
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: __________________________
<PHYSICAL ADDRESS>
PHYSICAL ADDRESS CORRECTIONS: _________________________
<MAILING ADDRESS>
MAILING ADDRESS CORRECTIONS:_________________________
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 to mid-February 2018. When are you likely to be available during this timeframe? Please provide at least three options.

Mondays between 7am and 11am

Mondays between 11am and 3pm

Mondays between 3pm and 7pm

Tuesdays between 7am and 11am

Tuesdays between 11am and 3pm

Tuesdays between 3pm and 7pm

Wednesdays between 7am and 11am

Wednesdays between 11am and 3pm

Wednesdays between 3pm and 7pm

Thursdays between 7am and 11am

Thursdays between 11am and 3pm

Thursdays between 3pm and 7pm

Fridays between 7am and 11am

Fridays between 11am and 3pm

Fridays between 3pm and 7pm

Saturdays between 10am and 2pm

Saturdays between 2pm and 5pm

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 AFTER S2 OR S5:] Your home is not eligible for the study. We appreciate your responses and 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.

[COMPLETE 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.

Detailed Customer Survey : Ductless Heat Pumps Operation

Section	Purpose	Evaluation Component	Questions
Measure Installed	Verify installation of program measures	Billing analysis	M1
Stratification Questions	Assess whether we are meeting EMT stratification requirements	Billing analysis	ST1-ST4 (4)
Equipment Operation	Modes, fans, thermostat, reasons for installation	BA	EQ1 to EQ8 (8)
Heating System & Fuel Use Information	Identify and assess level of secondary fuels	BA	HS1-HS3 (min 1/max 3)
Thermostat Use	Thermostat use and changes over time	BA	T1-T3 (5)
Water heater	Water heating fuel	BA	WH1-WH2 (2)
Air conditioning	Presence and use of A/C	BA	CO1-CO2 (2)
Contractor	Satisfaction, training/advice on operation	BA	CN1-CN6 (min 2/max 6)
Fuel Bills	Fuel bill changes	BA	F1-F2
Spillover	Additional heat pump installations	NTG	SO1-SO5 (min 1/max 5)
Closing	Any other comments about EMT program	None	C1 (1)
Total			Min 30/ Max 40

NAME	EVALUATION ID
ADDRESS	Address where heat pump was installed
REBATEAMOUNT	[Rebate amount for MEASURE1 to try to jog recall for respondents who do not indicate they received a rebate]
SCREENER	Binary, 1 if completed screener survey; otw, 0
PHASE1	Binary; 1= Part of phase 1 on-site solicitation
SITE VISIT	Binary, 1= Completed site visit
YEAR	Year of participation (1, 2, or 3)

NOTE: Words highlighted in yellow should be in yellow text.

INSTALLED MEASURES

M1. [IF SCREENER=0] Our records show that you installed a ductless heat pump at <ADDRESS> in <MONTH>, <YEAR> Is this correct?

1. Yes
2. Date is wrong
3. Address is wrong
4. Ductless heat pump was not installed
5. Yes, and installed a second ductless heat pump

M1a. [IF M1_2==”Y”] What is the correct date? ____

M1b. [IF M1_3 ==”Y”] What is the correct address? _______________

M1c. [IF M1_5=”Y”] When was the second ductless heat pump installed? ________

[IF SCREENER=0 AND M1=4, THANK AND TERMINATE.]

STRATIFICATION QUESTIONS

ST1. What type of home do you live in?

5. Single family home
6. Multifamily building
7. Mobile home
8. Other [RECORD_____________]

ST2. [IF ST1 == 1] Is the heated area of your home …

3. Less than 2,000 square feet
4. More than 2,000 square feet

97. DK

ST3. Did you install the ductless heat pump in . . .

1. A new home
2. An existing home
3. An addition to an existing home
4. Something else?

ST4. A single head heat pump unit is a heat pump with a single outdoor unit and a single indoor unit.

A multihead heat pump unit is a heat pump where two or more indoor units are attached to a single outdoor unit.

How many of the heat pumps installed in your home are single head and how many are multihead?

[ARRAY]

[SUBQUESTIONS]

1. Single head ________________
2. Multihead _________________

[ANSWER OPTIONS]

Numbers 0 - 5

DK. Don't know

SURVEY DIRECTION: "Please fill in both boxes. Enter a zero if you did not install that specific type of heat pump."

RESPONDENT IS PSEUDO-RANDOMLY ASSIGNED TO FRONT END QUESTIONS OR BACK END QUESTIONS WITH THE FOLLOWING FORMULA:

IF ((st1 == 3) OR (st1 == 4) OR (st4_2 >= 1))

THEN surveytype = 1

ELSE surveytype = (rand(1,2))

SURVEYTYPE VALUES:

1. Front End

2. Back End

TOTALHP = MAX((st4_1 + st4_2),HPRBTNUM)

[IF MINIMUM TARGET HAS BEEN MET, TERMINATE.]

[MINIMUM TARGETS: 40 COMPLETES IN EACH OF THESE GROUPS –

A. <YEAR> = 1
B. <YEAR>=2
C. <YEAR>=3
D. SINGLE FAMILY < 2,000 SQUARE FEET (ST1/ST2)
E. SINGLE FAMILY > 2,000 SQUARE FEET (ST1/ST2)
F. MULTIFAMILY (ST1, MAY NOT MEET QUOTA)
G. MOBILE HOME (ST1, MAY NOT MEET QUOTA)
H. SINGLE HEAD HEAT PUMP (ST4)
I. MULTI HEAD HEAT PUMP (ST4, MAY NOT MEET QUOTA)

NOTE: <YEAR> IS IN SAMPLE FRAME; OTHERS FROM QUESTIONS ST1 TO ST4.]

[NOTE: THE GROUPS ARE NOT MUTUALLY EXCLUSIVE, AND ONE RESPONDENT COULD BE IN SEVERAL GROUPS. IT IS FINE TO GO OVER THE LIMIT IN ANY ONE GROUP IN ORDER TO MEET THE MINIMUM TARGET IN ANOTHER GROUP.]

EQUIPMENT OPERATION

EQ1_1 – EQ1_5: Repeat EQ1 up to 5 times. PUMPNUM = ORDINAL VERSION OF HEAT PUMP UP TO TOTALHP (first, second, etc…). If TOTALHP=1, then do not display PUMPNUM.

EQ1_z. [IF ST3=2 – HP INSTALLED IN EXISTING HOME] Why did you decide to install the PUMPNUM ductless heat pump?

[SUBQUESTIONS]

1. You did not have heat in an area of your home and wanted to add it
2. Your previous heating system did not provide enough heat or needed to be replaced
3. You did not have air conditioning and wanted to add it
4. Your previous air conditioner did not provide enough cooling or needed to be replaced
5. You wanted to improve the energy efficiency of your home
6. You wanted to save money on your heating bills
7. You wanted to save money on your air conditioning bills
8. Something else?

96. None of the above
98. Don't know

EQ2_1 – EQ2_5: Repeat EQ2 up to 5 times. PUMPNUM = ORDINAL VERSION OF HEAT PUMP UP TO TOTALHP (first, second, etc…) If TOTALHP=1, then do not display (hpx).

EQ2.

How do you use your PUMPNUM heat pump? For each month in the last year, indicate the heat pump modes you used. Your best estimate is fine. If you used the heat pump in more than one mode during the month, please select all modes used.

[ARRAY (NUMBERS/Checkbox layout)]

[Y-SCALE]

1. November
2. December
3. January
4. February
5. March
6. April
7. May

8. June
9. July
10. August
11. September
12. October

[X-SCALE]

1. Heating
2. Cooling
3. Fan only
4. Dehumidification only
5. Heat pump off

EQ3Intro. [IF TOTALHP>1] For the remainder of the questions, please focus on the ductless heat pump you use the most.

EQ3. How often do you clean the filter in your heat pump?

1. Once a month
2. Once every 2-5 months
3. Once every 6 months
4. Once a year
5. Never cleaned the filter
6. Something else?

96. Don't know

EQ4. During the heating season, some people turn off their heat pump in response to the outdoor temperature. Do you turn off your heat pump when it gets really cold outside?

1. Yes, you turn if off when the outdoor temperature is below a certain temperature
2. No, you do not turn off your heat pump when it is below a certain temperature outside
3. You do not use the heat pump during the heating season
4. Don't know

EQ4TEMP. [IF EQ4 == 1] Please indicate the temperature at which you turn off the heat pump during the heating season: _____ Fahrenheit

EQ5. During the heating season, do you turn off your heat pump when it gets really warm outside?

1. Yes, you turn if off when the outdoor temperature is above a certain temperature
2. No, you do not turn off your heat pump when it is above a certain temperature
3. You do not use the heat pump during the heating season
4. Don't know

EQ5TEMP. [IF EQ5 == 1] Please indicate the temperatures at which you turn off the heat pump during the heating season: _____ Fahrenheit

EQ6. During the summer, some people turn off their heat pump in response to the outdoor temperature. Do you turn off your heat pump when it gets cool outside?

1. Yes, you turn if off when the outdoor temperature is below a certain temperature
2. No, you do not turn off your heat pump in response to the outside temperature during the summer
3. You do not use the heat pump during the summer

96. Don't know

EQ6TEMP. [IF EQ6 == 1] Please indicate the temperatures at which you turn off the heat pump during the summer: _____ Fahrenheit

EQ7. How do you usually set the fan on your heat pump during the heating season?

1. Automatic
2. Quiet/Very Low
3. Low
4. Medium
5. High
6. Do not use the heat pump during the winter
7. Something else?

EQ8. How do you usually set the fan on your heat pump during the summer?

1. Automatic
2. Quiet/Very Low
3. Low
4. Medium
5. High
6. Do not use the heat pump during the summer
7. Something else?

HEATING SYSTEM & FUEL USE INFORMATION

HS1. [IF ST3==2] Please select all of the heating system(s) you used during the last four years. [ALLOW MULTIPLE RESPONSES.]

1. Oil boiler or furnace [FUEL(i)="oil boiler or furnace"]
2. Propane boiler or furnace [FUEL(i)="propane boiler or furnace"]
3. Kerosene boiler or furnace [FUEL(i)=" kerosene boiler or furnace"]
4. Propane stove or fireplace [FUEL(i)="propane stove or fireplace"]
5. Kerosene room or space heater [FUEL(i)="kerosene room or space heater"]
6. Propane room or space heater [FUEL(i)="propane room or space heater"]
7. Natural gas boiler, furnace or space heater [FUEL(i)="natural gas heat"]
8. Cord wood stove, boiler or furnace [FUEL(i)="wood heater"]
9. Wood pellet stove, boiler or furnace [FUEL(i)="wood pellet heater"]
10. Electric baseboard [FUEL(i)="electric baseboard heater"]
11. Electric space heater [FUEL(i)="electric space heater"]
12. Ductless heat pump [FUEL(i)="ductless heat pump"]
13. Something else? _______________

HS2. [IF ST3 ==2] Comparing the winter after you installed the ductless heat pump to the winter before the work, did you change the way you use each fuel?

[SUBQUESTIONS] [ASK FOR EACH FUEL SPECIFIED IN HS1, VALUES 1-11]

1. Oil boiler or furnace
2. Propane boiler or furnace
3. Propane stove or fireplace
4. Propane room or space heater
5. Kerosene boiler or furnace
6. Kerosene room or space heater
7. Natural gas heater
8. Wood heater
9. Wood pellet heater

10. Electric baseboard heater
11. Electric space heater

[ANSWER OPTIONS]

1. You used the fuel a lot more before the heat pump was installed
2. Somewhat more
3. About the same
4. Somewhat less
5. A lot less
6. Did not use the fuel at all before the heat pump was installed
96. Don't know

HS3. When you decided to purchase your ductless heat pump, which other options did you seriously consider? [RANDOMIZE RESPONSES 1-5.]

1. Installing a less efficient ductless heat pump that would not qualify for a rebate from Efficiency Maine
2. Expanding or replacing your existing central heating system
3. Adding a non-electric space heater or stove
4. Adding an electric space heater or electric baseboard heater
5. You did not consider any other options
6. Something else? Specify: ____________________

HS4. Are your heating bills higher, lower or the same since you installed the heat pump? Please consider all of your heating bills, including oil, propane, wood and electricity.

1. Higher
2. The same
3. Lower
4. You do not use the heat pump for heating
96. Don't know

THERMOSTAT USE

T1. How do you set the thermostat on the heat pump (IF TOTAL HP>1 "that you use the most")?

3. Set at one temperature and leave it
4. Set back with programmable thermostat
5. Manually adjust (including use of the heat pump remote control)
6. Change temperature setting remotely with WiFi or phone app
7. Combination of setback methods (manual, programmed, remote)
8. Something else? ____________________________

96. Don't know

T2. What are the thermostat settings for heating on your heat pump? If you don't know the answer for one of the options below, please enter 0.

Daytime temperature setting: _______________

Nighttime temperature: _________

T3. Is there a thermostat for your central heating system located in the same area of your home as your heat pump?

1. Yes
2. No
3. You do not have a central heating system
96. Don't know

T4. [IF T3 == 1] Thinking about the central heating thermostat that is nearest to the heat pump, do you set this thermostat higher or lower than the heat pump thermostat during the coldest months of the year?

1. Central heating thermostat is set at a higher temperature than the heat pump thermostat
2. Central heating thermostat is set at the same temperature as the heat pump thermostat
3. Central heating thermostat is set at a lower temperature than the heat pump thermostat
4. You manually adjust the thermostat on the central heating system based on the indoor temperatures
5. Something else? ___________________
96. Don't know

T5. [IF T3 == 1] How many thermostats (zones) does your central heating system have?

1. 1
2. 2
3. 3 or more
96. Don't know

WATER HEATING

WH1. What fuel do you use to heat your water?

1. Natural gas (not propane)
2. Electric (not heat pump)
3. Heat pump/hybrid
4. Propane
5. Fuel oil
6. Kerosene

7. Solar with electric back up
8. Solar with propane or natural gas back up
9. Something else? ____________
96. Don't know

WH2. What fuel did you use to heat your water prior to installing the heat pump?

1. Natural gas (not propane)
2. Electric (not heat pump)
3. Heat pump/hybrid
4. Propane
5. Fuel oil
6. Kerosene
7. Solar with electric back up
8. Solar with propane or natural gas back up
9. Something else? ____________
96. Don't know

AIR CONDITIONING

CO1. Before installing your heat pump, did you use an air conditioner?

1. Window or room AC
2. Central air conditioning
3. Something else? ________
4. Did not have air conditioning
96. Don't know

CO2. [IF CO1 < 4] After installing your heat pump, do you use your window or central air conditioner …

1. A lot more
2. Somewhat more
3. About the same
4. Somewhat less
5. A lot less
6. No longer use the air conditioner
96. Don't know

CO3. [IF CO1 < 4] Are your air conditioning bills higher, lower or the same since you installed the heat pump?

1. Higher
2. The same
3. Lower
4. You do not use the heat pump for air conditioning
5. You did not have air conditioning before the heat pump was installed
96. Don't know

CONTRACTOR

CN1. How satisfied were you with the contractor who installed the heat pump

1. 1 – Not at all satisfied
2. 2
3. 3
4. 4
5. 5 – Very satisfied

CN1COMMENT. [OPTIONAL TEXT] Why did you rate your contractor a [ANS FROM CN1]?

____

CN2. Did you receive any training or advice on how to use your heat pump?

1. Yes
2. No
96. Don't know

CN3. [IF CN2==1] Who provided the advice?

1. The contractor who installed your heat pump
2. Efficiency Maine Heat Pump Tips e-mail
3. Efficiency Maine Web site, video and/or discussions with Efficiency Maine staff
4. Friends or family
5. Your fuel dealer
6. Other (specify): ______

CN4. [IF CN2==1] What topics were covered in the advice?

1. How to use the remote control

2. How to adjust vane/air-flow direction for heating and cooling
3. How to clean the filter
4. How to use the mode settings (fan, heating, cooling or dehumidification)
5. Recommended temperature setting for heat pump
6. Recommended temperature setting for central heating system
7. How to operate your heat pump in very cold outdoor temperatures
8. Other tips (specify): ________

97. Don't remember

CN4TEMP. [IF CN4_5 == "Y" OR CN5_6 == "Y"]What were the recommended temperature settings? If you cannot remember, please enter 99.

[IF CN4_5 == "Y"]Recommended temperature setting for heat pump:

[IF CN4_6 == "Y"]Recommended temperature setting for central heating system:

CN5. [IF CN4_7 == "Y"] What were you told about how to operate your heat pump in very cold temperatures? If you cannot remember, enter a zero.

RECORD RESPONSE: ____________________

CN6. [IF CN2 =1] Did you follow the advice?

RECORD RESPONSE: ____________________

SPILLOVER

SO1. [IF TOTALHP>1] You mentioned that you are using more than one heat pump. Did you install any of these heat pumps without receiving a rebate from Efficiency Maine?

1. Yes
2. No

96. Don't know

SO2. [SO1==1] Of the heat pumps you purchased without a rebate, how many are of the same or higher efficiency than the one you installed through Efficiency Maine's program?

Numbers 1-5

DK. Don't Know

SO3. [SO1==1 AND SO2 >=1] Would you have installed heat pump(s) of the same or higher efficiency if you had never participated in an Efficiency Maine program?

[ARRAY] [LIST NUMBER OF SUBQUESTIONS + SO2]

[SUBQUESTIONS]

1. Heat Pump 1
2. Heat Pump 2
3. Heat Pump 3
4. Heat Pump 4
5. Heat Pump 5

[ANSWER OPTIONS]

1. You definitely would not have installed a heat pump of the same efficiency
2. You probably would not have
3. You probably would have
4. You definitely would have
5. You are not sure what you would have done

SO4. [SO1==1 AND SO2 >=1] The next question is about how you decided to install the efficient heat pump(s) outside of the Efficiency Maine programs. Let's consider the influences that contributed to your decision in two groups:

Your previous experience with Efficiency Maine, which may have increased your awareness of energy efficient heat pumps.

Other factors, including all other influences on your decision.

What was more important to your decision to install the efficient heat pumps without receiving a rebate?

1. Your experiences with Efficiency Maine
2. Other influences

96. Don't know

[IF SO4=1, THEN FACTOR1= "your experiences with Efficiency Maine" and FACTOR2= "other influences". IF SO4=2, THEN FACTOR2= "your experiences with Efficiency Maine" and FACTOR1= "other influences". IF SO4=DK, GO TO CD1.]

[IF RESPONSE IS ""your experiences with Efficiency Maine" Change "was" to "were"

SO5. Comparing FACTOR1 to FACTOR2, 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 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 identifies 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

96. Refuse

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

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8 or more

96. Refuse

CD3. [IF CD2 != 96] Considering the total combined income of all members of your household over the past 12 months, was your total income 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. Yes
2. No

96. Don't know

97. Refused

CD3A. [IF CD2 == 96 OR CD3==96 OR CD3 ==97] [IF SURVEY IS DONE OVER THE PHONE, STOP AS SOON AS ANYONE SAYS "YES" TO ANY RESPONSE.]

Does anyone in your household receive assistance from any of the following sources?

- Fuel Assistance through LIHEAP
- MaineCare
- TANF program through DHHS
- WIC Food assistance
- Child Care assistance program though DHHS
- Medicaid
- Food Stamps
- Medicare Part D subsidy
- Weatherization assistance from a Community Action Agency
- Assistance with energy costs through a Low Income Assistance Plan from your electric company
- Free or reduced-cost meals in a school breakfast or lunch program

1. Yes
2. No
96. Don't know
97. Refused

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. Bachelors Degree (4-year degree)
5. Graduate or Professional Degree
96. Refuse

CLOSING QUESTION

C1. [OPTIONAL TEXT] Is there anything else you would like to tell us about Efficiency Maine's Home Energy Savings Program? RECORD:___________________

END OF SURVEY: 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 incentive.

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

Detailed Customer Survey: Ductless Heat Pumps NTG

Section	Purpose	Evaluation Component	Questions
Measure Installed	Verify installation of program measures	NTG	M1
Stratification Questions	Assess whether we are meeting EMT stratification requirements	NTG	ST1-ST4 (4)
Efficiency Maine	EMT services used	NTG	EMT1-EMT2 (min 1/max 2)
Causal Mechanisms	Identify causal mechanisms used	NTG	CM1-CM5 (5)
Contractor Influence	Determine contractor influence on decision to install	NTG	CI1-CI2 (2)
Self Report FR	Assess FR	NTG	FR1-FR2 (min 1/ max 2)
Barriers	Identify barriers and relative importance of barriers	NTG	B1-B7 (min 1/ max 7)
Program Contribution	Assess program contribution to decision to install	NTG	PC1-PC10 (min 1/ max 6)
Additional Installations/ Spillover	Additional heat pump installations	NTG	SO1-SO5 (min 1/max 5)
Demographics		None	CD1-CD4 (4)
Closing	Any other comments about EMT program	None	C1 (1)
Total			Min 22/ Max 40

NAME	EVALID
ADDRESS	Address where heat pump was installed
REBATEAMOUNT	[Rebate amount for MEASURE1 to try to jog recall for respondents who do not indicate they received a rebate]
SCREENER	Binary, 1 if completed screener survey; otw, 0
PHASE1	Binary; 1= Part of phase 1 on-site solicitation
SITE VISIT	Binary, 1= Completed site visit
YEAR	Year of participation (1, 2, or 3)

NOTE: Words highlighted in yellow should be in yellow text.

INSTALLED MEASURES

M1. [IF SCREENER=0] Our records show that you installed a ductless heat pump at <ADDRESS> in <MONTH>, <YEAR> Is this correct?

6. Yes
7. Date is wrong
8. Address is wrong
9. Ductless heat pump was not installed
10. Yes, and installed a second ductless heat pump

M1a. [IF M1_2==”Y”] What is the correct date? ____

M1b. [IF M1_3 ==”Y”] What is the correct address? ______________

M1c. [IF M1_5=”Y”] When was the second ductless heat pump installed? _______

[IF SCREENER=0 AND M1=4, THANK AND TERMINATE.]

STRATIFICATION QUESTIONS

ST1. What type of home do you live in?

9. Single family home
10. Multifamily building
11. Mobile home
12. Other [RECORD____________]

ST2. [IF ST1 == 1] Is the heated area of your home …

5. Less than 2,000 square feet
6. More than 2,000 square feet
97. DK

ST3. Did you install the ductless heat pump in . . .

5. A new home
6. An existing home
7. An addition to an existing home
8. Something else?

ST4. A single head heat pump unit is a heat pump with a single outdoor unit and a single indoor unit.

A multihead heat pump unit is a heat pump where two or more indoor units are attached to a single outdoor unit.

How many of the heat pumps installed in your home are single head and how many are multihead?

[ARRAY]

[SUBQUESTIONS]

2. Single head ________________
2. Multihead _________________

[ANSWER OPTIONS]

Numbers 0 - 5

DK. Don't know

SURVEY DIRECTION: "Please select at least 2 answers."

RESPONDENT IS PSEUDO-RANDOMLY ASSIGNED TO FRONT END QUESTIONS OR BACK END QUESTIONS WITH THE FOLLOWING FORMULA:

IF ((st1 == 3) OR (st1 == 4) OR (st4_2 >= 1) OR (SITEVISIT == 1))

THEN surveytype = 1

ELSE surveytype = (rand(1,2))

SURVEYTYPE VALUES:

3. Front End
4. Back End

TOTALHP = MAX((st4_1 + st4_2),HPRBTNUM)

EFFICIENCY MAINE

EMT1. Have you taken advantage of any of these offerings from Efficiency Maine? . **Please consider your answer carefully as other questions are based on your responses.**

1. Home energy audit from a contractor registered with Efficiency Maine
2. Efficiency Maine's Web site
3. Reading articles by Efficiency Maine in newspapers, magazines or Web sites
4. Efficiency Maine's list of registered vendors
5. Rebate from Efficiency Maine for installing energy upgrades
6. Energy Loan through Efficiency Maine
7. Something else? _____________
8. None of the above

EMT2. [IF EMT1_5 == "Y"] Our records show that you received a rebate of <REBATEAMOUNT> for the ductless heat pump. Do you recall receiving the rebate?

1. Yes

2. No
96. Don't know

PCMTIME. [EQUATION] Potential causal mechanism for time barrier. EMT may help save time through providing information or through the list of registered vendors.

IF (EMT1_1:EMT1_4 == "Y"} THEN PCMTIME=1 ELSE PCMTIME=0

PCMEQUIP. [EQUATION] Potential causal mechanism for equipment concerns barrier. EMT may help address equipment concerns through providing information or the expertise of registered vendors.

IF (EMT1_1:EMT1_4 == "Y"} THEN PCMEQUIP =1 ELSE PCMEQUIP =0

CAUSAL MECHANISMS

CM1. Thinking about the installation of the ductless heat pump ductless heat pump, please rate the importance of the following sources of information in deciding the specifics of what to install.

[ARRAY]

[SUBQUESTIONS]

1. Your contractor who completed the installation
2. A different contractor
3. Home energy audit from an auditor who was on Efficiency Maine's list of registered vendors
4. Personal research or previous knowledge
5. Assistance from family, friend or acquaintance who participated in one or more Efficiency Maine programs
6. Efficiency Maine Web site
7. Contact with Efficiency Maine's trained staff
8. Something else?

[ANSWER OPTIONS]

1. Not important at all
2. Slightly Important
3. Moderately Important
4. Strongly Important
5. Extremely Important
6. Not Applicable

CM1other. [CM1_8 >=3] What is the something else? ________________

CM2. Many customers have concerns about paying the costs for the energy savings and achieving savings. Please record your response to the following statements. [ARRAY]

[SUBQUESTIONS]

1. You were concerned about covering the upfront costs of the ductless heat pump.
2. You needed financing to pay for the ductless heat pump.
3. You were uncertain whether you would see the expected savings in your energy bills.
4. You had concerns about the payback or return on investment.

[ANSWER OPTIONS]

1. Strongly disagree
2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

CM3. How did you select the contractor who installed the ductless heat pump? Please rate the following sources by importance to you. [ARRAY]

[SUBQUESTIONS]

1. A contractor you had used in the past
2. Efficiency Maine's list of registered vendors
3. Personal research
4. Assistance from a home energy auditor who was on Efficiency Maine's list of registered vendors
5. Referral from family, friend or acquaintance who participated in an Efficiency Maine program
6. Something else?___________________

[ANSWER OPTIONS]

1. Not important at all
2. Slightly Important
3. Moderately Important
4. Strongly Important
5. Extremely Important
6. Not applicable

CM3other. [CM1_6 >=3] What is the something else? _________________

CM4. Please rate each of the following statements. [ARRAY]

[SUBQUESTIONS]

1. Using an energy auditor and/or contractor who was on Efficiency Maine's list of registered vendors made it easier for you to move ahead with installing the ductless heat pump.
2. You would have preferred to use a different contractor who was not on Efficiency Maine's list of registered vendors to do the work.

[ANSWER OPTIONS]

1. Strongly disagree
2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

CM5. Please rate each of the following statements. [ARRAY]

[SUBQUESTIONS]

1. Efficiency Maine is a trusted source of information about energy efficiency.
2. Your experience with Efficiency Maine has made you more willing to invest in improving the efficiency of your home.
3. Efficiency Maine makes investing in efficiency easier by packaging the efficient equipment, qualified contractors, incentives and relevant information.

[ANSWER OPTIONS]

1. Strongly disagree
2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

CMINFO. [EQUATION] Respondent identified causal mechanism for information barrier

IF ((CM1_1 >=3 AND !=6) OR (CM1_3 >=3 AND !=6) OR (CM1_5 >=3 AND !=6) OR

(CM1_6 >=3 AND !=6) OR (CM1_7 >=3 AND !=6))

THEN CMINFO =1 ELSE CMINFO=0

CMCONT. [EQUATION] Respondent identified causal mechanism for contractor barrier

IF (((CM3_2<3) AND (CM3_4<3) AND(CM3_5<3)) OR CM4_2>3)

THEN CMCONT=0 ELSE CMCONT=1

CMBRAND. [EQUATION] Respondent identified causal mechanism relating to EMT brand

IF ((CM5_1>3) OR (CM5_2>3) OR (CM5_3>3))

THEN CMBRAND=1 ELSE CMBRAND=0

BMONEY. [EQUATION] Money could be a barrier

IF ((CM2_1>3) OR (CM2_2>3) OR (CM2_3>3) OR (CM2_4>3))

THEN BMONEY =1 ELSE BMONEY =0

BREASON. [EQUATION] [IF BMONEY == 1] CM2 response identifying money concern

IF (CM2_1 > 3) THEN BREASON="upfront costs"

ELSE IF (CM2_2 >3) THEN BREASON = "finding financing"

ELSE IF (CM2_3 >3) THEN BREASON = "uncertainty of savings"

ELSE IF (CM2_4 >3) THEN BREASON = "payback or return on investment"

OTHERINFO. [EQUATION] Respondent identifies non-EMT sources as important

IF ((CM1_2 >=3 AND !=6) OR (CM1_4 >=3 AND !=6) OR (CM1_8 >=3 AND !=6))

THEN OTHERINFO =1 ELSE OTHERINFO =0

OTHERCONT. [EQUATION] Respondent identifies non-EMT sources as important

IF ((CM3_1 >= 3) OR (CM3_3 >=3) OR (CM3__6 >=3) OR (CM4_2 > 3))

THEN OTHERCONT =1 ELSE OTHERCONT =0

CONTRACTOR INFLUENCE

CI1. Which statement is closest to how you made your decision to install the high efficiency ductless heat pump?

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.

96. Don't know

[IF CI1=1 FACTOR1= "your contractor's influence" AND FACTOR2= "your own research"]

[IF CI1=2 FACTOR1= "your own research" AND FACTOR2= "your contractor's influence"]

CI2. [CI1 != 96] Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Was FACTOR1 …

7. 1 - about the same as FACTOR2
8. 2

9. 3
10. 4
11. 5
12. 6 - FACTOR1 was the only important factor
96. Don't know

SELF REPORT FREE RIDERSHIP

[RESPONSES WILL BE CHECKED AGAINST CAUSAL MECHANISMS WHEN ANALYSIS IS DONE.]

FR1. If you had not participated in Efficiency Maine's program, what would you have installed?

1. Definitely would have installed a less efficient heat pump than the one you purchased
2. Probably would have installed a less efficient heat pump
3. Not sure
4. Probably would have installed a heat pump of the same or higher efficiency
5. Definitely would have installed a heat pump of the same or higher efficiency
6. Would not have installed a heat pump of any type

FR2. [IF FR1==3-5] If you had not participated in Efficiency's Maine's program, would you have installed the ductless heat pump. . .

1. At the same time
2. Within 6 months
3. Between 6 months and 1 year later
4. Over a year later
96. Don't know

BARRIERS

B1.

[IF BMONEY=1] Thinking back to before the installation, we are interested in the challenges you faced in moving ahead with installing your heat pump. Earlier you stated that you had concerns about the <BREASON>. Many homeowners also have the following concerns:

[IF BMONEY=0] Thinking back to before the installation, we are interested in the challenges you faced in moving ahead with installing your heat pump. Many homeowners have the following concerns:

- LACK OF INFORMATION - Lack of information, such as not being sure what to install, wanting to learn about environmental impacts or greenhouse gas reductions
- COST - Paying for the ductless heat pump, such as concerns about payback, whether the cost is worth it, covering the cost
- EQUIPMENT CONCERN - Concerns about reliability of the equipment, noise levels, maintenance needs, whether it will provide sufficient heat
- FINDING A CONTRACTOR - Finding a contractor you could trust
- LACK OF INTEREST OR TIME - Lack of interest in energy efficiency or lack of time to research the efficiency upgrades, hire a contractor or manage the installation

Did you experience any of these challenges prior to making the decision to install the ductless heat pump? Please select the concerns that were important to you, move them to the left column and rank them in order of importance.

If a concern was not important to you, do not add it to the list.

[RANKING][MIN:0 MAX:6]

1. LACK OF INFORMATION
2. COST
3. EQUIPMENT CONCERN
4. FINDING A CONTRACTOR
5. LACK OF INTEREST OR TIME
6. SOMETHING ELSE

B1other. [B1_1:B1_6 == 6] What is the something else?

B2. [B1_1 <= 5 AND B1_2 <=5] Comparing B1_1 to B1_2, how would you rate the importance of B1_1 in your decision to install the ductless heat pump? Was B1_1 …

1. 1 - about the same as B1_2
2. 2
3. 3
4. 4
5. 5
6. 6 - extremely more important than B1_2

96. Don’t know

B3. [B1_1 <= 5 AND B1_3 <=5] Comparing B1_1 to B1_3, how would you rate the importance of B1_1 in your decision to install the ductless heat pump? Was B1_1 …

1. 1 - about the same as B1_3
2. 2

3. 3
4. 4
5. 5
6. 6 - extremely more important than B1_3
96. Don't know

B4. [B1_2 <= 5 AND B1_3 <=5 AND (B2 != 6 OR B3 !=6)] Comparing B1_2 to B1_3, how would you rate the importance of B1_2 in your decision to install the ductless heat pump? Was B1_2 …

1. 1 - about the same as B1_3
2. 2
3. 3
4. 4
5. 5
6. 6 - extremely more important than B1_3
96. Don't know

B5. [B1_1:B1_3 == 5 AND PCMTIME=1] You mentioned that you had trouble finding time. What helped you to find the time to move ahead with the installation? [ARRAY][SUBQUESTIONS]

1. Change in personal circumstances or schedule, such as changing jobs
2. Using the Efficiency Maine registered vendor list
3. Information from Efficiency Maine through their staff, Web site or articles
4. Assistance from family, friends or acquaintance who participated in an Efficiency Maine program
5. Information provided by your contractor or home energy auditor who performed the work
6. Your previous knowledge about energy efficiency
7. Efficiency Maine package of information, contractor, equipment, and incentives.
8. Something else?

[ANSWER OPTIONS]

1. Not important at all 1
2. 2
3. 3
4. 4
5. Extremely Important 5
6. Not Applicable

B5other. [B5_8 >=3] What is the something else? ________________

B6. [B1_1:B1_3 == 3 AND PCMEQUIP=1] You mentioned that you had concerns about the equipment. Please rank these specific concerns by importance. [ARRAY]

[SUBQUESTIONS]

1. Insufficient heat
2. Noise level
3. Insufficient air conditioning
4. Reliability
5. Maintenance needs
6. High operating costs
7. Indoor air quality
8. Something else?

[ANSWER OPTIONS]

1. Not important at all 1
2. 2
3. 3
4. 4
5. Extremely Important 5

B6other. [B6_8 >=3] What is the something else? ________________

B7. [B1_1:B1_3 == 3 AND PCMEQUIP=1] What helped you to overcome your concerns about installing the ductless heat pump? [ARRAY]

[SUBQUESTIONS]

1. Your contractor who performed the work or your energy auditor
2. Information from Efficiency Maine staff, Web site or articles
3. Personal research using other sources
4. Manufacturer specifications
5. Information provided by family, friends or acquaintance who installed a ductless heat pump through an Efficiency Maine program
6. Something else?

[ANSWER OPTIONS]

1. Not important at all 1
2. 2
3. 3
4. 4
5. Extremely Important 5
6. Not Applicable

B7other. [B7_6 >=3] What is the something else? _______________

CMTIME. [EQUATION] Respondent identified causal mechanism for time barrier.

IF ((B5_2 >=3 AND !=6) OR (B5_3 >=3 AND !=6) OR (B5_4 >=3 AND !=6) OR (B5_5 >=3 AND !=6) OR (B5_7 >=3 AND !=6))

THEN CMTIME=1 ELSE CMTIME =0

CMEQUIP. [EQUATION] Respondent identified causal mechanism for equipment concerns barrier

IF ((B7_1 >=3 AND !=6) OR (B7_2 >=3 AND !=6) OR (B7_5 >=3 AND !=6))

THEN CMEQUIP=1 ELSE CMEQUIP =0

OTHERTIME. [EQUATION] Respondent identifies non-EMT sources as important

IF ((B5_1 >=3 AND !=6) OR (B5_6 >=3 AND !=6) OR (B5_8 >=3 AND !=6))

THEN OTHERTIME=1 ELSE OTHERTIME =0

OTHEREQUIP. [EQUATION] Respondent identifies non-EMT sources as important

IF ((B7_3 >=3 AND !=6) OR (B7_4 >=3 AND !=6) OR (B7_6 >=3 AND !=6))

THEN OTHEREQUIP=1 ELSE OTHEREQUIP =0

PROGRAM CONTRIBUTION

PC1. [B1_1:B1_3 == 1 AND CMINFO=1 AND OTHERINFO==1]

Information about energy efficiency upgrades is available from many sources. Let's divide the information sources into two groups:

> *Efficiency Maine sources* include Efficiency Maine's Web site, instructional videos or articles and contractors and energy auditors on Efficiency Main's list of registered vendors.
>
> *Other sources* include information from other energy auditors or contractors who are not on Efficiency Maine's list of registered vendors, Web sites other than Efficiency Maine's, your personal research or previous knowledge.

Thinking only about the information you needed to decide to install the ductless heat pump, which statement is closest to how you made your decision?

1. Efficiency Maine sources were more important than other sources of information.
2. Personal sources were more important than Efficiency Maine's sources.

96. Don't know

[IF PC1=1, THEN FACTOR1= "Efficiency Maine sources" and FACTOR2= "other sources".

IF PC1=2, THEN FACTOR2= "Efficiency Maine sources" and FACTOR1= "other sources".]

PC2. [PC1 == 1 or 2] Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 … [ROTATE ORDER 1 TO 6 THEN 6 TO 1]

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

PC3. [B1_1:B1_3 == 4 AND CMCONT=1 AND OTHERCONT==1]

The next question is about choosing your contractor.

The Home Energy Services Program requires the use of contractors who are on Efficiency Maine's lists of registered vendors.

Let's divide the sources for finding information about contractors into two groups:

> *Efficiency Maine sources* include Efficiency Main's list of registered vendors.
>
> *Other sources* include information from other energy auditors or contractors who are not on Efficiency Maine's list of registered vendors, Web sites other than Efficiency Maine's, or your personal research or previous knowledge.

Thinking only about selecting the contractor to install the ductless heat pump, which statement is closest to how you chose your contractor?

1. Efficiency Maine's lists of registered vendors were more important than other sources.
2. Other sources were more important than Efficiency Maine's lists of registered vendors.
96. Don't know

[IF PC3=1, THEN FACTOR1= "Efficiency Maine's lists of registered vendors" and FACTOR2= "other sources".

IF PC3=3, THEN FACTOR2= "Efficiency Maine's lists of registered vendors" and FACTOR1= "other sources".]

PC4. [PC3 == 1 or 2] Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 … [ROTATE ORDER 1 TO 6 THEN 6 TO 1]

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

PC5. The next question is about how you decided to pay for the ductless heat pump. Let's consider the funding sources in two groups:

Incentives are the rebates [IF EMT1_6 == "Y", ADD: "and loan"] from Efficiency Maine.

Personal sources include other funding sources that were important to your decision making process, including personal savings or other non-EMT loans, tax credits or rebates from sources other than Efficiency Maine.

Thinking only about what *tipped your decision to pay* for the high efficiency ductless heat pump, which statement is closest to how you made your decision?

1. The Efficiency Maine incentives were more important than personal sources of funding.
2. Personal sources were more important than the incentives.
96. Don't know

[IF PC5=1, THEN FACTOR1= "the Efficiency Maine incentives" and FACTOR2= "personal funding sources".

IF PC5=2, THEN FACTOR2= "the Efficiency Maine incentives" and FACTOR1= "personal funding sources".]

PC6. [PC5 == 1 or 2] Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 … [ROTATE ORDER 1 TO 6 THEN 6 TO 1]

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

PC7. [CMTIME == 1 AND OTHERTIME == 1] The next question is about the importance of Efficiency Maine in helping you to save time and move forward with the installation.

Let's consider the factors that helped you to save time and move forward with the installation in two groups:

> *Efficiency Maine services*, such as the Efficiency Maine's list of registered vendors, the Efficiency Maine Web site or staff support

Other factors include personal reasons, such as a change in your schedule. Which statement is closest to how you managed to find the time to move ahead with the efficiency upgrades?

1. Efficiency Maine's services were more important than other factors.
2. Other factors were more important than Efficiency Maine's assistance.
96. Don't know

[IF PC7=1, THEN FACTOR1= "Efficiency Maine's services" and FACTOR2= "other factors".

IF PC7=2, THEN FACTOR2= "Efficiency Maine's services" and FACTOR1= "other factors".]

PC8. [PC7 == 1 or 2] Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? 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

PC9. [B1_1:B1_3 == 3 AND CMEQUIP==1 AND OTHEREQUIP==1]

The next question is about the importance of Efficiency Maine in helping you to address your concerns about the operation of the ductless heat pump.

Let's consider the factors that helped you to address your concerns about the operation of the heat pump in two groups:

> *Efficiency Maine sources of information*, such as a contractor or energy auditor from

Efficiency Maine's list of registered vendors, Efficiency Maine's Web site or staff support.

Other factors include personal sources of information, such as your own research or a contractors no associated with Efficiency Maine.

Which statement is closest to how you addressed your concerns about the operation of the heat pump?

1. Efficiency Maine's sources of information were more important than other factors.
2. Other factors were more important than Efficiency Maine's sources of information.
96. Don't know

[IF PC9=1, THEN FACTOR1= "Efficiency Maine's sources of information" and FACTOR2= "other factors".

IF PC9=2, THEN FACTOR2= "Efficiency Maine's sources of information" and FACTOR1= "other factors".]

PC10. [PC9 == 1 or 2] Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? 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

ADDITIONAL INSTALLATIONS/INSIDE SPILLOVER

S1. Considering only the home where you installed ductless heat pump, please select all other energy efficiency upgrades you installed within the last five years without a rebate from Efficiency Maine.

[MULTRESP][EXCLUSIVE: 7;96]

1. Insulation, air sealing/sealing gaps, window replacement or window treatments
2. Efficient heating system, heat pump, space heater or air conditioner
3. ENERGY STAR appliance
4. LED light bulbs or light fixtures
5. Solar photovoltaic system or solar hot water
6. Something else?
7. None of the above

96. Don't know

[IF S1=7 OR DK, SKIP TO DEMOGRAPHICS.]

S2. [S1_1 == "Y"] What type of insulation, air sealing or window treatments did you install?

[MULTRESP][EXCLUSIVE: 7;96]

1. Attic insulation
2. Wall insulation
3. Basement or sill insulation
4. Blower-door assisted air sealing
5. ENERGY STAR triple pane replacement windows
6. Something else?
7. None of the above
96. Don't know

S3. [S1_2 == "Y"] What type of efficient heating or cooling system did you install?

[MULTRESP][EXCLUSIVE: 6;96]

1. ENERGY STAR furnace
2. ENERGY STAR boiler
3. Ductless heat pump(s)
4. ENERGY STAR room or window air conditioner
5. Something else?
6. None of the above
96. Don't know

S3A. [S3_3 == "Y"] You said you installed one or more heat pumps without receiving a rebate from Efficiency Maine. Of these heat pumps, how many are of the same or higher efficiency than the one you installed through Efficiency Maine's program?

0. 0
1. 1
2. 2
3. 3
4. 4
5. 5
96. Don't Know

S4. [S1_3 == "Y"] What type of ENERGY STAR appliance did you install?

[MULTRESP][EXCLUSIVE: 5;96]

1. ENERGY STAR clothes washing machine
2. ENERGY STAR dishwasher

3. ENERGY STAR dehumidifier
4. Something else?
5. None of the above
96. Don't know

S4A. [S1_4 == "Y"] How many of these efficient lighting products did you install? (Choose all that apply.) [MULTRESP][EXCLUSIVE: 4;96]

1. 4 or more LED bulbs
2. 4 or more LED fixtures
3. Something else?
4. None of the above
96. Don't know

S5. [IF ANY OF THE BELOW WERE SELECTED] Please tell us the year you installed the efficiency upgrade. [MULT SHORT ANSWER]

1. (S2_1 == "Y") Attic insulation
2. (S2_2 == "Y") Wall insulation
3. (S2_3 == "Y") Basement or sill insulation
4. (S2_4 == "Y") Blower-door assisted air sealing
5. (S2_5 == "Y") ENERGY STAR triple pane replacement windows
6. (S3_1 == "Y") ENERGY STAR furnace
7. (S3_2 == "Y") ENERGY STAR boiler
8. (S3_3 == "Y") Ductless heat pump
9. (S3_4 == "Y") ENERGY STAR room or window air conditioning
10. (S4_1 == "Y") ENERGY STAR clothes washing machine
11. (S4_2 == "Y") ENERGY STAR dishwasher
12. (S4_3 == "Y") ENERGY STAR dehumidifier
13. (S4A_1 == "Y") 4 or more LED bulbs
14. (S4A_2 == "Y") 4 or more LED fixtures

S6. [IF ANY OF THE BELOW WERE SELECTED] Would you have installed the efficiency upgrade <u>if you had never participated</u> in an Efficiency Maine program? [ARRAY]

[SUBQUESTIONS]

1. (S2_1 == "Y") Attic insulation
2. (S2_2 == "Y") Wall insulation
3. (S2_3 == "Y") Basement or sill insulation
4. (S2_4 == "Y") Blower-door assisted air sealing
5. (S2_5 == "Y") ENERGY STAR triple pane replacement windows
6. (S3_1 == "Y") ENERGY STAR furnace
7. (S3_2 == "Y") ENERGY STAR boiler
8. (S3_3 == "Y") Ductless heat pump
9. (S3_4 == "Y") ENERGY STAR room or window air conditioning
10. (S4_1 == "Y") ENERGY STAR clothes washing machine
11. (S4_2 == "Y") ENERGY STAR dishwasher
12. (S4_3 == "Y") ENERGY STAR dehumidifier
13. (S4A_1 == "Y") 4 or more LED bulbs
14. (S4A_2 == "Y") 4 or more LED fixtures

[ANSWER OPTIONS]

1. Definitely not
2. Probably not
3. Not sure
4. Probably would
5. Definitely would

S7. [S1_7 != "Y" AND S1_96 != "Y" AND CMBRAND==1] The next question is about how you decided to install these efficiency measures outside of the Efficiency Maine programs. Let's consider the influences that contributed to your decision in two groups:

Your previous experience with Efficiency Maine, which may have increased your awareness of energy efficiency upgrades.

Other factors, including all other influences on your decision.

What was more important to your decision to install these efficiency upgrades?

3. Your experiences with Efficiency Maine
4. Other influences
96. Don't know

[IF S7=1, THEN FACTOR1= "your experiences with Efficiency Maine" and FACTOR2= "other influences".

IF S7=2, THEN FACTOR2= "your experiences with Efficiency Maine" and FACTOR1= "other influences".

S8. [S7 == 1 or 2] Comparing FACTOR1 to FACTOR2, how would you rate the importance of

FACTOR1? 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 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 identifies 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
96. Refuse

CD2. Please include all household members who have used your home as their primary residence over the past 12 months.

1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8 or more
96. Refuse

CD3. [IF CD2 != 96] Considering the total combined income of all members of your household over the past 12 months, was your total income 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. Yes
2. No
96. Don't know
97. Refused

CD3A. [IF CD2 == 96 OR CD3==96 OR CD3 ==97] [IF SURVEY IS DONE OVER THE PHONE, STOP AS SOON AS ANYONE SAYS "YES" TO ANY RESPONSE.]

Does anyone in your household receive assistance from any of the following sources?

- Fuel Assistance through LIHEAP
- MaineCare
- TANF program through DHHS
- WIC Food assistance
- Child Care assistance program though DHHS
- Medicaid
- Food Stamps
- Medicare Part D subsidy
- Weatherization assistance from a Community Action Agency
- Assistance with energy costs through a Low Income Assistance Plan from your electric company
- Free or reduced-cost meals in a school breakfast or lunch program

2. Yes
2. No
96. Don't know
97. Refused

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

6. No High School Diploma or GED
7. High School Graduate (includes GED)
8. Associates Degree
9. Bachelors Degree (4-year degree)
10. Graduate or Professional Degree
97. Refuse

CLOSING QUESTION

C1. Is there anything else you would like to tell us about Efficiency Maine's Home Energy Savings Program?

RECORD:__________________

END OF SURVEY: 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 incentive.

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

Detailed Contractor Survey: Ductless Heat Pumps

Overview

The evaluation team plans to conduct about 40 online detailed interviews with heat pump contractors.

We will attempt to contact all contractors who installed measures for customers who participated in a ductless heat pump site visit. The contractor detailed interview guide is designed to address six objectives:

(1) Assess program influence (self-report and barrier approach)
(2) Inquire about impact-related issues
(3) Assess the percentage of heat pumps sold with and without the rebate
(4) What motivates contractors to sell high-efficiency (H-E) equipment?
(5) What factors prevent contractors from selling more high-efficiency equipment?
(6) What are contractors' perspectives on customer acceptance and the availability of high-efficiency equipment?

Table E-1: Summary of Contractor Online Survey

Section		Number of Questions	Topic Summary
Introduction	Q	2 –only if soliciting via phone	Finding the correct respondent
Defining High Efficiency Heat Pumps	SD	1	Assess common type of heat pumps being installed by contractors
Initial Information	I	4/3	Changes in the heat pump market and where applicable, why is the contractor no longer installing ductless heat pumps
Selection of Efficient Equipment	R	5/3	How do contractors work with customers? How do they make recommendations? (free- ridership questions)
Key Decision Influences	KD	2	What factors motivated the contractor to offer/install H-E heat pumps?
Causal Mechanisms	CM	2	Identify how program and non-program factors help contractors promote rebate-eligible heat pumps
Barriers	B	5/3	What are the contractor's barriers to recommending H-E heat pumps to their customers?
Availability and Market Acceptance	A	3/1	Ask contractors' perspective on customer acceptance and availability of H-E heat pumps
Program Contribution	PC	2/1	Assesss how the program supports installation of H-E heat pumps
Equipment Concerns	EQ	11/7	Contractors' perspective on equipment concerns
Unrebated Sales	US	4/3	How satisfied are contractors with the program?
Demographics	D	4/2	How many offices does the firm have and how many employees are installing ductless heat pumps in Maine?
End of Survey	ES	3	Any additional comments about experiences with the program and recommendations for improvement
Total		47 max	

Name	
Company	
Phone Number	
e-mail	
Address	
Equipment	ductless heat pump

INTRODUCTION AND FINDING CORRECT RESPONDENT

Q1. Hello, this is <INTERVIEWER NAME> calling from West Hill Energy & Computing. We are conducting market research on behalf of Efficiency Maine. This is not a sales call. May I please speak with <PROGRAM_CONTACT>?

1. No, this person no longer works here
2. No, this person is not available right now
3. Yes [GO TO SCREENER]
4. No, Other reason (specify)

Q2. Is there someone else in your company who is familiar with the Efficiency Maine Residential Heat Pump Rebate Program? IF YES: Can you connect me?

1. Yes [RECORD NAME/PHONE FOR CALLBACK]
2. No [THANK AND TERMINATE]
3. DK/ REFUSED [THANK AND TERMINATE]

Intro: Welcome and thank you for participating in the Efficiency Maine Residential Heat Pump Rebate Program Survey. This survey will cover specifics about the program's activities and rebates.

We need your feedback to determine how to improve the program. Please be sure the person completing this survey is the person who makes the decision about the ductless heat pumps offered to your customers.

DEFINING HIGH-EFFICIENCY

For the purpose of this interview, we will define high-efficiency ductless heat pumps as equipment that is eligible for a rebate from Efficiency Maine.

TABLE E-2: HIGH EFFICIENCY STANDARDS (2017 HESP HEAT PUMP ELIGIBILITY CRITERIA)

Equipment	Rebate Criteria
Ductless heat pump	Singlehead Heat Pump: HSPF of 12 or greater Multihead Heat Pump: HSPF of 10 or greater

****

INITIAL INFORMATION

I1. Does your firm currently install ductless heat pumps?

1. Yes
2. No

I2. In your opinion, how has the ductless heat pump market changed in the past 5 years?

Enter response:___________________________________

I3. When did you start installing ductless heat pumps?

1. Less than 2 years ago
2. 2 to 4 years ago
3. 5 to 7 years ago
4. 8 to 10 years ago
5. More than 11 years ago
6. Never sold ductless heat pumps
96. Don't know

[IF I3=6, THANK AND TERMINATE.]

I4. [IF I1=2] Why did you discontinue selling ductless heat pumps?

ENTER RESPONSE: __________________________________

[GO TO FIRMOGRAPHICS]

I5. For all ductless heat pumps you installed in 2017, would you say the most common type was …

1. Single-head ductless heat pump
2. Multi-head ductless heat pump
96. Don't know

SELECTION OF EFFICIENT EQUIPMENT

R1. How do you make recommendations to customers? Do you regularly offer…

1. At least one standard ductless heat pump that is not eligible for the rebate
2. Only heat pumps that are eligible for the rebate
3. Depends on the situation
4. Something else? _______________

R2. [IF R1=1 OR 3 OR 4] Using the list below, please select the situations when you offer your customers at least one standard efficiency heat pump option that is not eligible for rebates. Choose as many as apply.

1. As a regular practice on all or most bids
2. On bids for customers who seem to be price sensitive
3. On bids for customers who are not interested in energy efficiency
4. On bids for customers who request the lowest installed cost
5. Something else? ______________

R3. Did you offer ductless heat pumps before the Efficiency Maine rebates became available?

1. Yes
2. No
3. Don't know

R4. [IF R3 = 1 OR 3] Since the Efficiency Maine rebates for high-efficiency heat pumps became available, have you changed the way that you recommend heat pumps to customers? [Scale from 1 to 5; 1= much less likely to recommend rebate-eligible units, 3 = no change, 5 = much more likely to recommend rebate-eligible units]

Enter response ___________________

6. Something else?_______________

96. Not sure

R5. [IF R3=2] Has the availability of rebates from Efficiency Maine for high-efficiency heat pumps influenced the way that you recommend heat pumps to customers? [Scale from 1 to 5; 1= much less likely to recommend rebate-eligible units, 3 = no influence, 5 = much more likely to recommend rebate-eligible units]

Enter response ___________________

96. Not sure

KEY DECISION INFLUENCES

KD1. We are interested in why you sell high-efficiency ductless heat pumps. [Scale: 1 strongly disagree, 3 neither agree nor disagree, 5 strongly agree]

1. Your customers request high-efficiency heat pumps.
2. The incremental cost between standard efficiency and high efficiency heat pumps is low.
3. High-efficiency heat pumps reduce negative impacts on the environment.
4. Your customers are more satisfied with high-efficiency heat pumps than standard efficiency units.
5. Your profit margin is higher for the high-efficiency heat pumps

KD2. Are there any other reasons why you sell high-efficiency ductless heat pumps?

ENTER:___________________________________

****

CAUSAL MECHANISMS

CM1. Thinking about your efforts to sell rebate-eligible heat pumps, please indicate how important each of these sources of support were to you. [SCALE: 1 NOT AT ALL IMPORTANT TO 5 EXTREMELY IMPORTANT]

1. Appearing on the contractor list on Efficiency Maine's website
2. Marketing for Efficiency Maine's Residential Heat Pump Rebate Program
3. Your contractor network
4. Efficiency Maine's inspections of completed projects
5. Your personal research
6. Information or other support from manufacturers or distributors
7. Efficiency Maine's rebates for qualifying heat pumps
8. Rebates or discounts offered by other sources
9. Efficiency Maine Residential Registered Vendor e-Newsletter
10. Trade shows or home shows
11. Efficiency Maine Heat Pump resources (website, user tips, videos, eligible model list)
12. Contact with Efficiency Maine's staff
13. Something else? _____________

CM2. Thinking about Efficiency Maine's activities, please record whether you agree or disagree with the following statements. [Scale: 1 strongly disagree, 3 neither agree nor disagree, 5 strongly agree]

If the statement does not apply to you, mark N/A.

1. Efficiency Maine promotes awareness of the program and generates customer leads

for your business.

2. The profitability of your company has improved due to your participation in Efficiency Maine's program.

3. Efficiency Maine's registered vendor requirements, support and/or inspections have allowed your company to expand its expertise in energy efficiency.

4. Efficiency Maine rebates make the efficient heat pumps more attractive to customers and increase your close rate.

5. Efficiency Maine has helped address your concerns about the quality and reliability of heat pumps.

6. The Efficiency Maine brand makes it easier for you to sell high-efficiency heat pumps to your customers.

CAUSAL MECHANISM	CM2 RESPONSE
REDUCE FIRST COST	4
CONTRACTOR UPSELL	R4, R5
CONTRACTOR SUPPORT	1,2,3,5
EMT BRAND	6

BARRIERS

[CATEGORIES FOR BARRIER PAIRWISE QUESTIONS:]

FACTOR	WORDING
CUSTOMER DEMAND	Lack of customer demand
EQUIPMENT CONCERNS	Equipment concerns
TRUST	Lack of trust from customers
AVAILABILITY	Lack of availability of efficient heat pumps
NONE	No challenges

B1. Thinking back to when you first started selling ductless heat pumps, we are interested in the challenges you faced to increase your sales of high-efficiency heat pumps. Some contractors have mentioned the following challenges:

1. Lack of customer demand
2. Customer lack of trust in contractors
3. Lack of availability of heat pumps
4. Concerns about the quality, reliability and operation of heat pumps

Focusing on the challenges you experienced when you first started selling ductless heat pumps, please choose the ones that prevented you from increasing your sales of the rebate-eligible units and rank them in order of importance by dragging and dropping them into the column on the left.

Rank as many as apply, 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.

[DRAG AND DROP]:

1. FACTOR1 _______________
2. FACTOR2_____________
3. FACTOR3_______________

[IF FACTOR 1 IS "No Challenges" THEN SKIP TO THE NEXT SECTION] [IF FACTOR2 OR 3 is "No Challenges" THEN DROP THE FACTOR]

B2. Did you experience any other challenges to increasing your sales of high-efficiency heat pumps?

RECORD: _______________________

We would like to understand more about how these challenges influenced your efforts to increase your sales of rebate-eligible heat pumps. In the next set of questions, please compare these challenges two at a time.

[WORDING FOR FACTORS: "LACK OF DEMAND", "LACK OF TRUST", "LACK OF AVAILABILITY", "EQUIPMENT CONCERNS")

[ASK B3 IF THERE IS A FACTOR 1 AND FACTOR 2]

B3. 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 THERE IS A FACTOR 1 AND FACTOR 3]

B4. Comparing FACTOR1 to FACTOR3, how would you rate the importance of FACTOR1? 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 B5 IF THERE IS A FACTOR 3 AND FACTOR 2 AND (B3!=6 OR B4!=6)]

B5. Comparing FACTOR2 to FACTOR3, how would you rate the importance of FACTOR2? Was FACTOR2 …

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

****

AVAILABILITY AND MARKET ACCEPTANCE

A1. Has the availability of rebate-eligible heat pump models changed since 2013? Please choose the statement that is the closest to your opinion.

1. Efficiencies are higher and there is greater selection of high-efficiency models than there were in 2013.
2. The efficiencies are about the same but there is greater selection of models that meet the criteria for rebates.
3. There are fewer high-efficiency models currently available than there were in 2013.
4. The efficiency levels and selection of high-efficiency equipment are about the same as they were in 2013.
5. Something else?__________

A2. [IF A1=1 or 2] Why do you think availability has improved? Please rate the following options.

[Scale: 1 strongly disagree, 3 neither agree nor disagree, 5 strongly agree]

____

96. Don't know

[SUBSTATEMENTS]

A2a. Changes in fuel prices affect the demand for high-efficiency ductless heat pumps [NONPROGRAM]

A2b. Customers are more educated about high-efficiency equipment [NONPROGRAM]

A2c. Efficiency Maine rebates reduce costs and create additional demand [PROGRAM]

A2d. More competition among manufacturers [NONPROGRAM]

A2e. Efficiency Maine's promotions help to expand awareness of ductless heat pumps. [PROGRAM]

A2f. General increase in awareness of environmental impacts among customers, distributors and manufacturers [NONPROGRAM]

A3. In your opinion, what other factors affect the availability of rebate-eligible heat pumps?

RECORD VERBATIM: ________________

PROGRAM CONTRIBUTION

BARRIER	CAUSAL MECHANISM
LACK OF CUSTOMER DEMAND	CONTRACTOR UPSELL, REDUCE FIRST COSTS
EQUIPMENT CONCERNS	CONTRACTOR SUPPORT
LACK OF TRUST	CONTRACTOR SUPPORT
LACK OF AVAILABILITY	REDUCE FIRST COSTS

PC1. Contractors receive support for installing rebate-eligible equipment from a number of sources. We have divided these sources into two broad categories:

Efficiency Maine support, such as providing the list of registered contractors and eligible units on the EMT Web site, conducting inspections, and developing the vendor agreement

Other sources of information and support, including business networks, manufacturers, distributors, personal research, and home shows.

Thinking about the factors that motivated you to recommend and install rebate-eligible heat pumps, which of the following statements is the closest to your opinion? Choose one.

1. Contractor support from Efficiency Maine is more important than other sources of support.
2. Other sources are more important than the support from Efficiency Maine.
96. Don't know

[IF PC1=1 THEN FACTOR1='Efficiency Maine contractorf support' AND FACTOR2 = 'Other sources of support'; IF PC1=2, THEN REVERSE FACTOR1 AND FACTOR2. CHECK FOR SUBJECT/VERB AGREEMENT. IF PC1=DK, SKIP TO NEXT SECTION]

PC2. [IF A3<> DK] Comparing FACTOR1 to FACTOR2, 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

****

EQUIPMENT CONCERNS

EQ1. Do you have any of the following concerns about quality, reliability, or customer satisfaction of the ductless heat pumps? Choose as many as apply.

1. Frequent callbacks
2. Inadequate heating or cooling over a range of temperatures
3. Inadequate heating at very low temperatures
4. Availability of replacement parts
5. Response time to reach the setpoint is longer
6. Increased maintenance
7. Customers do not understand how to operate ductless heat pumps
8. Concerns about the performance of new technologies
9. Concerns about the cost of operation for ductless heat pumps
10. Something else?___________
11. None of the above

EQ2. [IF EQ1=1 AND/OR 5] Please explain the most common reasons for the [IF EQ1=1:] 'callbacks'] [IF EQ1=6:] and 'increased maintenance'.

RECORD RESPONSE: ________________________________

EQ3. Please estimate what percentage of your customers plan to use their heat pumps for cooling, heating or both? [Optional if respondent cannot estimate] [Percentages should add to 100%]

1. Cooling _____%
2. Heating ___%
3. Both cooling and heating ____%

EQ4. When a customer is planning to use the ductless heat pump for both heating and cooling, how do you size the heat pump?

1. For cooling
2. For heating
3. For the larger of the heating or cooling load
4. Something else? _______________

EQ5. Please explain why you size the rebate-eligible heat pumps for [IF EQ4=1 enter "cooling", IF EQ4=2 enter "heating"]

RECORD RESPONSE: ________________________________

EQ6. How important are the following factors in locating the ductless heat pump within the home? [SCALE: 1 (NOT IMPORTANT AT ALL, TO 5 VERY IMPORTANT; ADD NOT APPLICABLE AS AN OPTION]

1. Location of the thermostat of the central heating system
2. Floor plan/air movement
3. Inadequate heating/cooling in specific areas
4. Space constraints
5. Arrangement of the central heating system zones
6. Aesthetics/customer preference

EQ7. Are there any other important factors?

ENTER RESPONSE: ______________________________

EQ8. What advice or tips would you offer other installers for optimum installation location?

ENTER RESPONSE: ______________________________

EQ9. What advice do you give to your customers about how to operate their ductless heat pumps? Choose all that apply.

1. Set the thermostat at one temperature and leave it alone
2. Set the thermosat at a higher temperature than the central heat thermostat in the winter
3. Turn off the heat pump when it is cold out
4. Turn off the heat pump when the outdoor temperature is <u>below a certain level</u>
5. Set the thermostat at a lower temperature than the central heat thermostat
6. Turn off the central heat
7. Turn off the central heat when the outdoor temperature is <u>above a certain level</u>
8. Something else? ______________________

EQ10. [IF EQ9=4] What is the lowest outdoor temperature that you recommend for operating the heat pump?

Enter: ______________________________

EQ11. [IF EQ9=7] At what outdoor temperature do you recommend turning off the central heating?

Enter: ______________________________

EQ12. How do you estimate Energy Savings

UNREBATED SALES

The next questions are about the ductless heat pumps you sold in 2017.

US1. For all ductless heat pumps purchased in 2017 **without the rebate**, would you say that the most common HSPF was …

1. the federal minimum with an HSPF of 8.2
2. 8.3 to 9.9 HSPF
3. 10 to 11.9 HSPF
4. 12 HSFP or above

96. Don't know

US2. For all ductless heat pumps purchased in 2017 **without the rebate**, what were the three most common models that you installed? Please rank the models in order of installation frequency.

1. [RECORD FIRST RANKED MODEL]
2. [RECORD SECOND RANKED MODEL]
3. [RECORD THIRD RANKED MODEL]

US3. For all ductless heat pumps that you installed in Maine in 2017, approximately what percentage was ….

Description	Percentage (should add to 100%)
A. Heat pumps **not eligible** for Efficiency Maine rebate	
B. Heat pumps **eligible** for a rebate and **received a rebate**	
C. Heat pumps **eligible** for a rebate but **did not receive a rebate**	

Your best estimate is fine.

96. Don't know

US4. [IF US3.C>0] Why do you sell eligible heat pumps without the rebate?

[OPEN END]:____

FIRMOGRAPHICS

D1. How many staffed offices does your firm have in the state of Maine?
ENTER: ___________

D2. How many full-time employees does your firm have in the state of Maine?
ENTER: ___________

D3. [IF I1=1] Approximately how many of your full-time Maine employees primarily install ductless heat pumps?
ENTER: ___________

D4. [IF I3 >= 3 (INSTALLING DHPs FOR 5 YEARS OR MORE)] Compared to five years ago, has the percentage of your Maine employees primarily engaged in installing ductless heat pumps increased, decreased, or stayed about the same?

1. Increased
2. Stayed about the same
3. Decreased
96. Don't know

END OF SURVEY

ES1. What is the most valuable aspect of Efficiency Maine Residential Heat Pump Rebate Program?

RECORD: ____

ES2. In closing, is there anything else you would like to tell us about your experiences with Efficiency Maine Residential Heat Pump Rebate Program (such as unexpected benefits or challenges)?

[RECORD OPEN END]

ES3. Do you have any recommendations for how to improve the Efficiency Maine Residential Heat Pump Rebate Program?

[RECORD OPEN END]

That completes the survey. On behalf of Efficiency Maine, thank you very much for your time and thoughtful answers today.

Detailed Customer Survey: Unregulated Fuels

Section	Purpose	Evaluation Component	Questions
Measure Installations	Verify installation of program measures	Billing analysis & NTG	M1; loop through measures
Heating system and fuel use information	Identify and assess level of secondary fuels	BA	HS0-HS4 (min 2/max 5)
Fuel dealer and delivery	Fuel delivery schedule	BA	FD1-FD2 (2)
Thermostat settings	Thermostat use and changes over time	BA	T1-T4 (4)
Water heater	Water heating fuel	BA	WH1-WH2 (2)
EE Interest & Knowledge	Gauge interest/knowledge in EE prior to EMT interactions	NTG	E1-E3 (2)
EMT	Identify specific actions taken with EMT	NTG	EMT1-EMT2 (min 1/ max 2)
Key Motivations	Assess reasons for installing measures	NTG	KD1 (1)
Causal Mechanisms	Assess program- and nonprogram-related sources of info	NTG	CM1-CM6 (min 2/ max 4)
Contractor Influence	Assess relative influence of customer/contractor on installation	NTG	CI1-CI2 (2)
Free Riders	Self report free rider questions	NTG	FR1-FR2 (min 1/ max 2)
Barriers	Identify barriers, calculate Barrier Score	NTG	B1-B7; min 1/max 7
Program Contribution	Assess program contribution, calculate PC score	NTG	PC1-PC10 (min 2/ max 8)
Nonprogram Measures	Identify measures installed outside of EMT programs & timing; self report spillover & pairwise spillover	BA & NTG	S1-S8 (min 1/max 8)
Occupancy changes	Changes in occupancy	BA	OCC1-OCC2 (min 1/ max 2)
Demographic information:	Demographics	BA & NTG	CD1-CD5 (5)
Closing	Any other comments about EMT program	None	C1 (1)
Total			Min 32/ Max 60

NAME:	EVALUATION ID:
ADDRESS:	
MEASURE1: [WHEC NOTE – MEASURE1 = Air sealing, insulation or air sealing and insulation]	DATE INSTALLED:
MEASURE2:	DATE INSTALLED:
MEASURE3:	DATE INSTALLED:
ASHP:	[1/0 if minisplit heat pump was an installed measure]
FUELCONVERSION:	[1/0 if used a bulk fuel in the pre period and natural gas in the post period]
FUELNUM:	[Number of fuels listed on the BF form]
FUEL1:	[Fuel types listed on the BF form] [WHEC NOTE: ADD "heat" to end for wording of HS2.]
FUEL2:	
FUEL3:	
REBATEAMOUNT:	[Rebate amount for MEASURE1 to try to jog recall for respondents who do not indicate they received a rebate]

INSTALLED MEASURES

M1. Our records show that you installed <MEASURE1> 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
5. Something else? _____________________

[IF MORE THAN 1 MEASURE, LOOP THROUGH M1 FOR EACH MEASURE.]

HEATING SYSTEM & FUEL USE INFORMATION

Variable	Definition	Initial State	Comment
FUELNUM	Number of fuels used	From sample frame	Increment if more fuels selected in HS1; Questions H2-H4 need to be asked for all fuels, including ones ID'ed in HS1
FUEL(i)	Array of fuel types; for homes with multiple fuels, i is the index	From sample frame	Add fuels ID'ed in HS1
i	Fuel number index	FUELNUM from sample frame	Increment for each fuel type selected in HS1

HS1. The form you submitted indicates that you used <FUELTYPE1> [IF NEEDED: <FUELTYPE2> AND <FUELTYPE3>] to heat your home since 2013. Thinking about these fuels, what type of heating system or systems have you used from 2013 to present?

1. Central boiler or furnace
2. Room heater such as Monitor or Rinnai
3. Gas-fired stove or fireplace
4. Kerosene space heater
5. Something else?

HS2. Did you use any other heating fuels or systems?

1. Cord wood (for wood stove, boiler or furnace) [FUEL(i)="wood heat"]
2. Wood pellets [FUEL(i)="wood pellet heat"]
3. Electric space heater [FUEL(i)="electric space heater"]
4. Minisplit or ductless heat pump [FUEL(i)="heat pump"]
5. Something else? _______________
6. None of the above

[INCREMENT FUELNUM BY THE NUMBER OF HS1 OPTIONS SELECTED AND FILL IN FUELTYPE(i) FROM THE HS1 RESPONSES.]

[HEATING SYSTEM LOOP i=1 TO FUELNUM FOR HS3 TO HS5.]

HS3. Which of the following best describes how you used the FUEL(i) after the efficiency upgrades were completed?

7. Throughout the entire heating season from September to May
8. Only during the coldest months from December to February
9. Only in the Spring and Fall
10. Only on the coldest days
11. Rarely
12. Not at all
7. Something else? ___________________
96. Don't know

HS4. [IF HS2 <> 6] Approximately what percent of your living space is heated by the FUEL(i)?

1. 100%
2. 81 to 99%
3. 61 to 80%
4. 41 to 60%
5. 21 to 40%
6. Less than 20%

96 Don't know

HS5. Comparing the winter after you installed <MEASURE1> [ADD IF NEEDED: <MEASURE2> AND <MEASURE3>] to the winter before the work, did you change the way you use your FUEL(i)? Choose one option.

1. You used FUEL(i) a lot more after the work was completed
2. Somewhat more
3. About the same
4. Somewhat less
5. A lot less
6. Did not use the <FUEL(i)> at all after the work was completed
7. Did not use the <FUEL(i)> at all before the work was completed
8. Something else?

FUEL DEALER QUESTIONS

FD1. Approximately how often do you (did you) receive fuel deliveries during the winter months of December through March. Do you receive deliveries …

1. Once a month or more often
2. Once every two months
3. Once or twice a year
4. When needed
5. Something else? _____________

FD2. When you receive(d) fuel deliveries, does the fuel dealer fill the tank to capacity?.

1. Every time
2. Most of the time
3. Some of the time
4. Rarely
5. Never

96. Don't know

THERMOSTAT USE

T1. How do you set the thermostat for heating in the room you use the most?

1. Set at one temperature and leave it
2. Set back with programmable thermostat
3. Change temperature setting remotely (WiFi or phone app)
4. Use Smart Thermostat to automatically adjust temperature
5. Manually adjust as needed
6. Combination of setback methods (manual, programmed, remote)
7. Something else? ______________________________

T2. What are your thermostat settings for heating in the room you use the most?

Daytime temperature setting: _______________

Nighttime temperature: _________

T3. After installing the <MEASURE1> [ADD IF NEEDED: <MEASURE2> AND <MEASURE3>], did you change your thermostat setting(s)?

1. Turned the thermostat up less than 5°F
2. Turned up more than 5°F
3. Turned down less than 5°F
4. Turned down more than 5°F
5. Did not change thermostat settings
6. Something else?_______

96. Don't know

T4. Are your fuel bills higher, lower or the same since you installed <MEASURE1> [IF NEEDED: <MEASURE2> AND <MEASURE3>]?

1. Higher
2. The same
3. Lower

96. Don't know

WATER HEATING

WH1. What fuel do you use to heat your water?

1. Natural gas (not propane)
2. Electric (not heat pump)
3. Heat pump/hybrid electric
4. Propane
5. Fuel oil
6. Kerosene
7. Solar with electric back up
8. Solar with propane or natural gas back up
9. Something else? _____________

WH2. What fuel did you use to heat your water prior to installing <MEASURE1> [ADD IF NEEDED: <MEASURE2> AND <MEASURE3>]?

1. Natural gas (not propane)
2. Electric (not heat pump)
3. Heat pump/hybrid electric
4. Propane
5. Fuel oil
6. Kerosene
7. Solar with electric back up
8. Solar with propane or natural gas back up
9. Something else? _____________

EE INTEREST & KNOWLEDGE

[QUESTIONS WILL BE SET UP WITH SCALE ACROSS TOP & RADIO BUTTONS.]

E1. Prior to learning about Efficiency Maine's programs, how would you describe your knowledge about energy efficiency?

[SCALE FOR E1& E2: 1 to 5 scale 1 is not interested at all and 5 is very interested]

E2. Prior to learning about Efficiency Maine's programs, how interested were you in energy efficiency?

E3. Following your interactions with Efficiency Maine, how would you rate your interest in energy efficiency?

[SCALE E3: 1 to 5 -1 is not knowledgeable at all and 5 is very knowledgeable.]

EFFICIENCY MAINE

[DEFINE VARIABLES]

Variable	Definition	Initial State	Comment
PCMTIME	Potential causal mechanism for time barrier	0	EMT may help save time through providing information or through the list of registered vendors
PCMEQUIP	Potential causal mechanism for equipment concerns barrier	0	EMT may help address equipment concerns through providing information or the expertise of registered vendors

EMT1. Have you taken advantage of any of these offerings from Efficiency Maine? Choose as many as apply. **Please consider your answer carefully as other questions are based on your responses.**

1. Instructional videos by Efficiency Maine, such as those available on YouTube or the Efficiency Maine Web site
2. Home energy audit from a contractor registered with Efficiency Maine
3. Efficiency Maine booth at an event
4. Efficiency Maine Newsletter
5. Efficiency Maine's Web site
6. Reading articles by Efficiency Maine in newspapers, magazines or Web sites
7. Efficiency Maine's trained staff, available by phone or e-mail
8. Efficiency Maine's list of registered vendors
9. Follow Efficiency Maine on social media
10. Rebate from Efficiency Maine for installing energy upgrades
11. Energy Loan through Efficiency Maine
12. Something else? _____________
13. None of the above

EMT2. [IF EMT1 <> 10] Our records show that you received a rebate of <REBATEAMOUNT> for <MEASURE1>. Do you recall receiving the rebate?

1. Yes
2. No

97. Don't know

[UPDATE VARIABLES]

Variable	Initial State	Condition	Final State	Comments

PCMTIME	0	EMT1.1=9 >=3 (any options less than 10) ; otw, no change	1	If select any option that could save time, set to 1
PCMEQUIP	0	EMT1<10 (any options less than 10) ; otw, no change	1	If select any option that could address equipment concerns, set to 1

[IF MORE THAN ONE MEASURE INSTALLED:] For the remainder of this survey, please focus on <MEASURE1> only.

KEY MOTIVATIONS

KD1. Thinking back to before you installed <MEASURE1>, please rate the following factors in motivating you to improve the efficiency of your home. [SCALE: NOT IMPORTANT AT ALL, SLIGHTLY IMPORTANT, MODERATELY, STRONGLY OR EXTREMELY IMPORTANT.]

1. To save energy or lower your heating bills
2. To address concerns about health issues, such as air quality
3. To improve the environment, reduce carbon footprint
4. You were better able to pay for the project
5. To improve the comfort of your home
6. You had recently purchased or remodeled your home and wanted to make it more efficient
7. [IF ASHP=1] To add efficient air conditioning or improve the air conditioning in your home with your minisplit heat pump
8. Something else? [DESCRIPTION]

CAUSAL MECHANISMS

[DEFINE AND INITIALIZE VARIABLES]

Variable	Definition	Initial State	Comment
CMINFO	Respondent identified causal mechanism for information barrier	0	Set to 0, change if respondent indicated EMT services were useful
CMTIME	Respondent identified causal mechanism for time barrier; toggled in B5-B7	0	Same as above
CMEQUIP	Respondent identified causal mechanism for equipment concerns barrier; toggled in B5-B7	0	Same as above
CMCONT	Respondent identified causal mechanism for contractor barrier	1	CMCONT starts as 1 since program requires a registered contractor be used
CMBRAND	Respondent identified causal mechanism relating to EMT brand	0	EMT brand may make participants more open to additional efficiency investments; used for pairwise spillover
BMONEY	Money could be a barrier	0	Back up if respondent does not select money barrier (B1) but still lists money-related concerns in CM2
BREASON	CM2 response identifying money concern	Empty	Provides text for prompt if money barrier is not selected and BMONEY=1
OTHERINFO	Respondent identifies non-EMT sources as important	0	If both EMT and non-EMT sources are selected, then need pairwise for program contribution; otw, skip pairwise;
OTHERTIME	Same as above	0	Same as above
OTHEREQUIP	Same as above	0	Same as above
OTHERCONT	Same as above	0	PCMCONT starts as 1 since program requires a registered contractor be used; other sources for choosing a contractor must be selected

CM1. Thinking about the installation of the <MEASURE1>, please rate the importance of the following sources of information in deciding the specifics of what to install. [SCALE: 1 TO 5, NOT AT ALL IMPORTANT TO EXTREMELY IMPORTANT, ADD NOT APPLICABLE AS AN OPTION.]

1. Your contractor who completed the installation
2. A different contractor
3. Home energy audit from an auditor who was on Efficiency Maine's list of registered vendors
4. Home energy audit from an auditor who was not on Efficiency Maine's list of registered vendors
5. Personal research or previous knowledge
6. Instructional videos or articles by Efficiency Maine

7. Instructional videos or articles from sources other than Efficiency Maine
8. Assistance from family, friend or acquaintance who participated in one or more Efficiency Maine programs
9. Assistance from family, friend or acquaintance who had not participated in an Efficiency Maine program
10. Efficiency Maine Web site
11. Manufacturer or other Web site
12. Contact with Efficiency Maine's trained staff
13. Home improvement store
14. Something else? [DESCRIPTION]

CM2. Many customers have concerns about paying the costs for the energy savings and achieving savings. Please record your response to the following statements. [SCALE: STRONGLY DISAGREE, SOMEWHAT DISAGREE, NEITHER AGREE NOR DISAGREE, SOMEWHAT AGREE OR STRONGLY AGREE.]

1. You were concerned about covering the upfront costs of the <MEASURE1>.
2. You needed financing to pay for the <MEASURE1>.
3. You were uncertain whether you would see the expected savings in your energy bills.
4. You had concerns about the payback or return on investment.

CM3. How did you select the contractor who installed the <MEASURE1>? Please rate the following sources by importance to you. [SCALE: 1 TO 5, NOT AT ALL IMPORTANT TO EXTREMELY IMPORTANT.]

1. A contractor you had used in the past
2. Efficiency Maine's list of registered vendors
3. Assistance from your fuel dealer
4. Personal research
5. Assistance from a home energy auditor who was on Efficiency Maine's list of registered vendors
6. Assistance from a home energy auditor not registered with Efficiency Maine
7. Referral from family, friend or acquaintance who participated in an Efficiency Maine program
8. Referral from family, friend or acquaintance who had not participated in an Efficiency Maine program
9. Something else?___________________

CM4. Please rate each of the following statements. [SCALE: strongly disagree, somewhat disagree, neither, somewhat agree or strongly agree.]

1. Using an energy auditor and/or contractor who was on Efficiency Maine's list of registered vendors made it easier for you to move ahead with installing <MEASURE1>.
2. You would have preferred to use a different contractor who was not on Efficiency Maine's list of registered vendors to do the work.

CM5. Please rate each of the following statements. [SCALE: strongly disagree, somewhat disagree, neither, somewhat agree or strongly agree.]

1. Efficiency Maine is a trusted source of information about energy efficiency.
2. Your experience with Efficiency Maine has made you more willing to invest in improving the efficiency of your home.
3. Efficiency Maine makes investing in efficiency easier by packaging the efficient equipment, qualified contractors, incentives and relevant information.

CM6. Please rate how likely you are to take these actions: [SCALE: 1 TO 5, VERY UNLIKELY, SOMEWHAT UNLIKELY, NEITHER, SOMEWHAT LIKELY, VERY LIKELY]

1. Recommend EMT to a friend
2. Take advantage of EMT services in the future

[UPDATE VARIABLES]

Variable	Initial State	Condition	Updated State	Comments
CMINFO	0	CM1.1 OR CM1.3 OR CM1.6 OR CM1.10 OR CM1.12 >=3	1	If identified EMT information source as important, change to 1
CMCONT	1	(CM3.2 AND CM3.5<3) OR CM4.2>3	0	If did not identify an EMT source of contractors as important or would have preferred to use non-EMT contractor, change to 0
CMBRAND	0	(CM5.1OR CM5.2 OR CM5.3 >3) OR (CM6.1 OR CM6.2 > 3)	1	If agreed with brand questions or likely to recommend to others, change to 1
BMONEY	0	CM2.1 OR CM2.2 OR CM2.3 OR CM2.4 > 3	1	If agreed with one or more of the money questions, change to 1
BREASON	Empty	CM2.1>3	'upfront costs'	If identified a money-related issue, change to issue to use as prompt in B1A, if needed; if more than one selected, BREASON is filled in with the first selection in the series of 4
		CM2.2>3	'finding financing'	
		CM2.3>3	'uncertainty of savings'	
		CM2.4>3	'payback or return on investment'	
OTHERINFO	0	CM1.2 OR CM1.4 OR CM1.5 OR CM1.7 OR CM1.8 OR OR CM1.11 OR CM1.13 >=3	1	If identified a non-EMT information source as important, change to 1
OTHERCONT	0	(CM3.1 OR CM3.3 OR CM3.4 OR CM3.6 OR CM3.7 OR CM3.8 >=3) OR CM4.2<3	1	If identified a non-EMT source of contractors as important or would prefer to use a non-EMT contractor, change to 1

CONTRACTOR INFLUENCE

CI1. Which statement is closest to how you made your decision to install the <MEASURE1>?

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.

[IF CI1=1 FACTOR1= "your contractor's influence" AND FACTOR2= "your own research"]

[IF CI1=2 FACTOR1= "your own research" AND FACTOR2= "your contractor's influence"]

CI2. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Was FACTOR1 …

1. about the same as FACTOR2
2. slightly more important than FACTOR2
3. moderately more important than FACTOR2
4. strongly more important than FACTOR2

5. extremely more important than FACTOR2
6. FACTOR1 was the only important factor

CI3. How satisfied were you with your <MEASURE1> contractor? [SCALE 1 TO 5, NOT AT ALL TO VERY SATISFIED]

Record: ____________________

Comment: ___________________________________

SELF REPORT FREE RIDERSHIP

[RESPONSES WILL BE CHECKED AGAINST CAUSAL MECHANISMS WHEN ANALYSIS IS DONE.]

FR1. Would you have installed the same level of <MEASURE1> if you have not participated in Efficiency Maine's program? [ROTATE RESPONSES 1 TO 5, THEN 5 TO 1.]

1. Definitely would not have installed the same level of <MEASURE1>
2. Probably would not
3. Not sure
4. Probably would
5. Definitely would have installed the same level of <MEASURE1>

FR2. [IF FR1=NOT SURE OR PROBABLY OR DEFINITELY WOULD:] If you had not participated in Efficiency's Maine's program, would you have installed the <MEASURE1>. . .

1. At the same time
2. Within 6 months
3. Between 6 months and 1 year later
4. Over a year later

96. Don't know

BARRIERS

B1. [IF BMONEY=1] Thinking back to before the installation and how you decided to install the <MEASURE1>, we are interested in the challenges you faced in moving ahead with the project. Earlier you stated that you had concerns about BREASON. Many homeowners also have the following concerns:

[IF BMONEY=0] Thinking back to before the installation and how you decided to install the <MEASURE1>, we are interested in the challenges you faced in moving ahead with the project. Many homeowners have the following concerns:

- INFORMATION - Lack of information, i.e. not sure what to install, want to learn about environmental impacts or greenhouse gas reductions

- COSTS - Paying for the <MEASURE1>, such as concerns about payback, whether the cost is worth it, covering the cost
- INSTALLATION/MATERIALS - Concerns about the installation process, the safety of the insulation or sealing materials or indoor air quality
- CONTRACTOR - Finding a contractor you could trust
- INTEREST/TIME - Lack of interest in energy efficiency or lack of time to research the efficiency upgrades, hire a contractor or manage the installation

Did you experience any of these challenges prior to making the decision to install the <MEASURE1>? Please select the concerns that were important to you, move them to the left column and rank them in order of importance. If a concern was not important to you, do not add it to the list. HIGHLIGHT IN YELLOW IF NOT DONE ALREADY

BARRIER 1: ___________

BARRIER 2: ___________

BARRIER 3: ___________

BARRIER 4: ___________

Something else? ________________

[IF NO BARRIERS OR SOMETHING ELSE, SKIP TO NEXT SECTION.

IF ONLY ONE BARRIER WAS SELECTED AND …

a) IF EQUIPMENT CONCERNS, SKIP TO B6;
b) IF TIME, SKIP TO B5;
c) OTHERWISE, GO TO NEXT SECTION.]

B2. Comparing <BARRIER1> to <BARRIER2>, how would you rate the importance of <BARRIER1> in your decision to install <MEASURE1>? Was BARRIER1 …

1. about the same as BARRIER2
2. slightly more important than BARRIER2
3. moderately more important than BARRIER2
4. strongly more important than BARRIER2
5. extremely more important than BARRIER2

[IF 3 BARRIERS, CONTINUE; OTW, SKIP TO NEXT SECTION.]

B3. Comparing <BARRIER1> to <BARRIER3>, how would you rate the importance of <BARRIER1> in your decision to install <MEASURE1>? Was BARRIER1 …

1. about the same as BARRIER3
2. slightly more important than BARRIER3

3. moderately more important than BARRIER3
4. strongly more important than BARRIER3
5. extremely more important than BARRIER3

B4. Comparing <BARRIER2> to <BARRIER3>, how would you rate the importance of <BARRIER2> in your decision to install <MEASURE1>? Was BARRIER2 …

1. about the same as BARRIER3
2. slightly more important than BARRIER3
3. moderately more important than BARRIER3
4. strongly more important than BARRIER3
5. extremely more important than BARRIER3

B5. [IF TIME IS A BARRIER IN THE TOP 3 AND PCMTIME=1] You mentioned that you had trouble finding time. What helped you to find the time to move ahead with the installation? [SCALE: 1 to 5 not at all important to extremely important, & not applicable.]

1. Change in personal circumstances or schedule, such as changing jobs
2. Using the Efficiency Maine registered vendor list
3. Previous relationship with your contractor
4. Information from Efficiency Maine staff, Web site or articles
5. Assistance from family, friends or acquaintance who participated in an Efficiency Maine program
6. Assistance from family, friends or acquaintance who had not participated in an Efficiency Maine program
7. Information provided by your contractor or home energy auditor who performed the work
8. Information provided by a contractor or home energy auditor who did not perform the work
9. Your previous knowledge about energy efficiency
10. Efficiency Maine package of information, contractor, equipment, and incentives.
11. Something else? _______________
12. None of the above

B6. [IF INSTALLATION/MATERIALS CONCERNS ARE A BARRIER IN THE TOP 3 AND PCMEQUIP=1] You mentioned that you had concerns about the installation process or safety of the materials. Please rank these specific concerns by importance. [SCALE: 1 to 5 not at all important to extremely important.]

1. Household disruption during the installation process
2. Safety of insulation or sealing materials
3. Savings may not be achieved
4. Indoor air quality
5. Something else? _______________

B7. What helped you to overcome your concerns about installing the <MEASURE1>? [SCALE: 1 to 5 not at all important to extremely important, not applicable.]

1. Your contractor who performed the work or your energy auditor
2. A contractor or home energy auditor who did not perform the work
3. Information from Efficiency Maine staff, Web site or articles
4. Personal research using other sources
5. Manufacturer specifications
6. Information provided by family, friends or acquaintance who installed a insulation and/or air sealing through an Efficiency Maine program
7. Information provided by family, friends or acquaintance who not had used an Efficiency Maine program to install insulation and/or air sealing
8. Something else? _______________
9. None of the above

[UPDATE VARIABLES]

Variable	Initial State	Condition	Updated State	Comments
CMTIME	0	B5.2, 4, 7 OR 10 >=3	1	If identified EMT as important to saving time, change to 1
CMEQUIP	0	B7.1 OR 3 >=3	1	If identified EMT as important to addressing installation/material concerns, change to 1
OTHERTIME	0	B5.1,3,5,6,8 OR 9 >= 3	1	If identified non-EMT sources as important to saving time, change to 1
OTHEREQUIP	0	B7.2,4, 5, 6 OR 7 >= 3	1	If identified non-EMT sources as important to addressing equipment concerns, change to 1

PROGRAM CONTRIBUTION

PC1. [ASK PC1 ONLY IF INFORMATION IS IN TOP 3 BARRIERS AND CMINFO=1 AND OTHERINFO=1]

INFORMATION

Information about energy efficiency upgrades is available from many sources. Let's divide the information sources into two groups:

> *Efficiency Maine sources* include Efficiency Maine's Web site, instructional videos or articles and contractors and energy auditors on Efficiency Main's list of registered vendors.
>
> *Other sources* include information from other energy auditors or contractors who are not on Efficiency Maine's list of registered vendors, Web sites other than Efficiency Maine's, your personal research or previous knowledge.

Thinking only about the information you needed to decide to install the <MEASURE1>, which statement is closest to how you made your decision?

1. Efficiency Maine sources were more important than other sources of information.
2. Personal sources were more important than Efficiency Maine's sources.

[IF PC1=1, THEN FACTOR1= "Efficiency Maine sources" and FACTOR2= "other sources". IF PC1=2, THEN FACTOR2= "Efficiency Maine sources" and FACTOR1= "other sources".]

PC2. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 … [ROTATE ORDER 1 TO 6 THEN 6 TO 1]

1. about the same as FACTOR2
2. slightly more important than FACTOR2
3. moderately more important than FACTOR2
4. strongly more important than FACTOR2
5. extremely more important than FACTOR2
6. FACTOR1 were the only important factor

PC3. [ASK PC3 ONLY IF CONTRACTOR BARRIER IS IN TOP 3 BARRIERS AND CMCONT=1 AND OTHERCONT=1]

CONTRACTOR

The next question is about choosing your contractor.

The Home Energy Savings Program requires the use of contractors who are on Efficiency Maine's lists of registered vendors.

Let's divide the information sources into two groups:

Efficiency Maine sources include Efficiency Maine's Web site, instructional videos or articles and contractors and energy auditors on Efficiency Main's list of registered vendors.

Other sources include information from other energy auditors or contractors who are not on Efficiency Maine's list of registered vendors, Web sites other than Efficiency Maine's, your personal research or previous knowledge.

Thinking only about selecting the contractor to install the <MEASURE1>, which statement is closest to how you chose your contractor?

1. Efficiency Maine's lists of registered vendors were more important than other sources.
2. Other sources were more important than Efficiency Maine's lists of registered vendors.

[IF PC3=1, THEN FACTOR1= "Efficiency Maine's lists of registered vendors" and FACTOR2= "other sources". IF PC5=3, THEN FACTOR2= "Efficiency Maine's lists of registered vendors" and FACTOR1= "other sources".]

PC4. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 … [ROTATE ORDER 1 TO 6 THEN 6 TO 1]

1. about the same as FACTOR2
2. slightly more important than FACTOR2
3. moderately more important than FACTOR2
4. strongly more important than FACTOR2
5. extremely more important than FACTOR2
6. FACTOR1 were the only important factor

[COSTS BARRIER]

PC5. COSTS

The next question is about how you decided to pay for the <MEASURE1>. Let's consider the funding sources in two groups:

Incentives are the rebates [IF EMT1=11, ADD: "and loan"] from Efficiency Maine.

Personal sources include other funding sources that were important to your decision making process, including personal savings or other non-EMT loans, tax credits or rebates from sources other than Efficiency Maine.

Thinking only about what *tipped your decision to pay* for the <MEASURE1>, which statement is closest to how you made your decision?

1. The Efficiency Maine incentives were more important than personal sources of funding.
2. Personal sources were more important than the incentives.

[IF PC5=1, THEN FACTOR1= "the Efficiency Maine incentives" and FACTOR2= "personal funding sources". IF PC5=2, THEN FACTOR2= "the Efficiency Maine incentives" and FACTOR1= "personal funding sources".]

PC6. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 … [ROTATE ORDER 1 TO 6 THEN 6 TO 1]

1. about the same as FACTOR2
2. slightly more important than FACTOR2
3. moderately more important than FACTOR2
4. strongly more important than FACTOR2
5. extremely more important than FACTOR2
6. FACTOR1 were the only important factor

PC7. [TIME BARRIER; ASK PC7 ONLY IF CMTIME=1 AND OTHERTIME=1]

TIME

The next question is about the importance of Efficiency Maine in helping you to save time and move forward with the installation.

Let's consider the factors that helped you to save time and move forward with the installation in two groups:

> *Efficiency Maine services*, such as the Efficiency Maine's list of registered vendors, the Efficiency Maine Web site or staff support

Other factors include personal reasons, such as a change in your schedule.Which statement is closest to how you managed to find the time to move ahead with the efficiency upgrades?

1. Efficiency Maine's services were more important than other factors.
2. Other factors were more important than Efficiency Maine's assistance.

[IF PC7=1, THEN FACTOR1= "Efficiency Maine's services" and FACTOR2= "other factors". IF PC7=2, THEN FACTOR2= "Efficiency Maine's services" and FACTOR1= "other factors".]

PC8. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 …

1. about the same as FACTOR2
2. slightly more important than FACTOR2
3. moderately more important than FACTOR2
4. strongly more important than FACTOR2
5. extremely more important than FACTOR2
6. FACTOR1 were the only important factor

PC9. [ASK PC9 ONLY IF EQUIPMENT BARRIER IS IN TOP 3 BARRIERS, CMEQUIP=1 AND OTHEREQUIP=1]

CONCERNS ABOUT THE INSTALLATION OR MATERIALS

The next question is about the importance of Efficiency Maine in helping you to address your concerns about the installation or safety of the insulation or sealing materials.

Let's consider the factors that helped you to address your concerns about the installation or safety of the materials and move forward with the installation in two groups:

> *Efficiency Maine sources of information*, such as a contractor or energy auditor from Efficiency Maine's list of registered vendors, Efficiency Maine's Web site or staff support.

Other factors include personal sources of information, such as your own research or a contractors no associated with Efficiency Maine.Which statement is closest to how you addressed your concerns about the installation or safety of materials and decided to move ahead with the efficiency upgrades?

1. Efficiency Maine's sources of information were more important than other factors.
2. Other factors were more important than Efficiency Maine's sources of information.

[IF PC9=1, THEN FACTOR1= "Efficiency Maine's sources of information" and FACTOR2= "other factors". IF PC9=2, THEN FACTOR2= "Efficiency Maine's sources of information" and FACTOR1= "other factors".]

PC10. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 …

1. about the same as FACTOR2
2. slightly more important than FACTOR2
3. moderately more important than FACTOR2
4. strongly more important than FACTOR2
5. extremely more important than FACTOR2
6. FACTOR1 was the only important factor

ADDITIONAL INSTALLATIONS/INSIDE SPILLOVER

S1. Considering only the home where you installed <MEASURE1>, please select all other energy efficiency upgrades you installed within the last five years without a rebate from Efficiency Maine. Choose as many as apply. HIGHLIGHT ADDED PHRASE IN YELLOW.

1. Insulation, air sealing/sealing gaps, window replacement or window treatments
2. Efficient heating system, space heater or air conditioner
3. ENERGY STAR appliance
4. LED or CFL light bulbs or light fixtures
5. Solar photovoltaic system or solar hot water
6. Something else?
7. None of the above

[IF S1=7, SKIP TO DEMOGRAPHICS.]

S2. [IF S1=1] What type of insulation, air sealing or window treatments did you install?

1. Attic insulation
2. Wall insulation
3. Basement or sill insulation
4. Blower-door assisted air sealing
5. Caulking, weather stripping, or spray foam in gaps
6. ENERGY STAR double pane replacement windows
7. ENERGY STAR triple pane replacement windows
8. Added new storm windows
9. Added new window inserts
10. Installed plastic film over windows
11. Something else?
12. None of the above

S3. [IF S1=2] What type of efficient heating system did you install?

1. ENERGY STAR furnace
2. ENERGY STAR boiler
3. ENERGY STAR Minisplit heat pump
4. Geothermal heat pump
5. ENERGY STAR room or window air conditioner
6. ENERGY STAR central air conditioner
7. Something else?
8. None of the above

S4. [IF S1=3] What type of ENERGY STAR appliance did you install?

1. ENERGY STAR clothes washing machine
2. ENERGY STAR dishwasher
3. ENERGY STAR dehumidifier
4. ENERGY STAR air purifier
5. Something else?
6. None of the above

S4A. [IF S1=4] How many of these efficient lighting products did you install? (Choose all that apply.)

1. Less than 4 CFL bulbs (individual bulbs, not packages)
2. 4 or more CFL bulbs
3. Less than 4 LED bulbs
4. 4 or more LED bulbs
5. Less than 4 CFL or LED fixtures
6. 4 or more LED fixture
7. Something else?
8. None of the above

S5. [IF ONE OR MORE MEASURE GROUPS SELECTED IN S1] Please tell us the year you installed the efficiency upgrade.

[DROP IN MEASURES SELECTED ABOVE]

Measure	Description	Year of Installation	Received Rebate from Efficiency Maine
S5a	[DROP-IN]		Yes/No/Not sure
S5b	[DROP-IN]		Yes/No/Not sure
S5c	[DROP-IN]		Yes/No/Not sure
S5d	[DROP-IN]		Yes/No/Not sure
S5e	[DROP-IN]		Yes/No/Not sure
S5f	[DROP-IN]		Yes/No/Not sure

[ELIMINATE MEASURES THAT RECEIVED AN EMT REBATE/IF "Yes" TO REBATE DROP MEASURE FROM LIST. NOTE – ONLY REBATED MEASURES SHOULD BE ON LIST.]

S6. Would you have installed the efficiency upgrade if you had never participated in an Efficiency Maine program?

Measure	Description	Definitely not	Probably not	Not sure	Probably would	Definitely would
S6a	[DROP-IN]	○	○	○	○	○
S6b	[DROP-IN]	○	○	○	○	○
S6c	[DROP-IN]	○	○	○	○	○
S6d	[DROP-IN]	○	○	○	○	○

S7. [IF CMBRAND=1] The next question is about how you decided to install these efficiency measures outside of the Efficiency Maine programs. Let's consider the influences that contributed to your decision in two groups:

Your previous experience with Efficiency Maine, which may have increased your awareness of energy efficiency upgrades.

Other factors, including all other influences on your decision.

What was more important to your decision to install these efficiency upgrades?

1. Your experiences with Efficiency Maine
2. Other influences

[IF S7=1, THEN FACTOR1= "your experiences with Efficiency Maine" and FACTOR2= "other influences". IF S7=2, THEN FACTOR2= "your experiences with Efficiency Maine" and FACTOR1= "other influences".]

S8. Comparing FACTOR1 to FACTOR2, how would you rate the importance of FACTOR1? Were FACTOR1 …

1. about the same as FACTOR2
2. slightly more important than FACTOR2

3. moderately more important than FACTOR2
4. strongly more important than FACTOR2
5. extremely more important than FACTOR2
6. FACTOR1 was the only important factor

OCCUPANCY

OCC1. How many weeks is your home occupied during a typical year?

1. Year round, from 48 to 52 weeks
2. Less than 48 weeks

OCC2. [IF OCC1=2] How many weeks is 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)

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 identifies 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

96. Refuse

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

1. 1
2. 2
3. 3
4. 4
5. 5

6. 6
7. 7
8. 8 or more
96. Refuse

CD3. [IF CD2 != 96] Considering the total combined income of all members of your household over the past 12 months, was your total income 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. Yes
2. No
96. Don't know
97. Refused

CD3A. [IF CD2 == 96 OR CD3==96 OR CD3 ==97] [IF SURVEY IS DONE OVER THE PHONE, STOP AS SOON AS ANYONE SAYS "YES" TO ANY RESPONSE.]

Does anyone in your household receive assistance from any of the following sources?

- Fuel Assistance through LIHEAP
- MaineCare
- TANF program through DHHS
- WIC Food assistance
- Child Care assistance program though DHHS
- Medicaid
- Food Stamps
- Medicare Part D subsidy
- Weatherization assistance from a Community Action Agency
- Assistance with energy costs through a Low Income Assistance Plan from your electric company
- Free or reduced-cost meals in a school breakfast or lunch program

1. Yes
2. No
96. Don't know
97. Refused

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. Bachelors Degree (4-year degree)
5. Graduate or Professional Degree
98. Refuse

CLOSING QUESTION

C1. Is there anything else you would like to tell us about Efficiency Maine's Home Energy Savings Program?

RECORD:___________________

****

END OF SURVEY: 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 $25 incentive.

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

Appendix F

Unregulated Fuels Customer Survey Findings

Appendix F: Unregulated Fuels Customer Survey Findings

This appendix presents findings from the participant survey which was conducted to collect information about household characteristics useful for interpreting and refining the unregulated fuels billing analysis. The survey was primarily conducted over the Internet, with an option to complete the survey over the phone upon request.

Advance letters with survey links were sent to a random sample of 938 participants who were identified in the program database as using an unregulated fuel. A $25 check was provided to participants who mailed back a signed consent form and completed the online survey. The disposition is provided in Table F-1 below.

TABLE F-1: SURVEY DISPOSITION

	Total Sent	Total Returned	Total Surveys Completed
Consent Forms with Survey Link	938	463	299
Total Billing Data Requests to Fuel Dealers	456	289	-

The unregulated fuel survey questions were mainly concerned with current and past use of primary and secondary heat, and the method and frequency of fuel deliveries. In addition to the 299 completed surveys, twenty-five (25) respondents completed some questions but did not make it to the end of the survey, giving a total of 324 responses for some questions.

Despite extensive efforts to obtain completed surveys for all homes included in the billing analysis, twenty-one (21) respondents did not complete the survey. Ninety-six (96) participants were included in the final billing model and seventy-five (75) of those respondents completed the survey.

The results of the survey are summarized below for all 324 partial and completed respondents, and separately for respondents who were included in the billing model. The following sections cover the heating fuel types, use of wood heat, fuel deliveries, heating system controls, demographics and a summary of the key findings.

F-1 Heating Fuel Types

The table below provides a summary of primary heating fuels reported by all survey respondents and also for those respondents who were included in the billing model. As shown in Table F-2, over three quarters of the survey respondents used oil, propane and wood as heating fuels during the analysis period. About twenty-five percent (25%) of the respondents used electricity and natural gas.

TABLE F-2: PRIMARY HEATING FUELS USED DURING THE ANALYSIS PERIOD

Primary Heating Fuel	All Survey Respondents (n=324)	Percent of All Survey Respondents[1]	Respondents in Billing Model (n=75)[1]	Percent of All Respondents in Billing Model[2]
Oil	239	74%	64	85%
Propane	43	13%	9	12%
Kerosene	8	2%	1	1%
Wood	13	4%	0	0%
Electric[3]	13	4%	1	1%
Natural gas[4]	4	1%	0	0%
Multifuels, no primary	4	1%		

[1] Multiple responses were allowed so percentages add to more than 100%.

[2] Participants using electricity, wood or pellet stoves as a primary heating source who also identified an unregulated fossil fuel as secondary heating source were included in the billing model.

[3] Electric space heaters and heat pumps

[4] Fuel switches to or from natural gas

Of the 324 survey respondents, 232 (72%) reported using a secondary heat source.[1] A variety of fuels were used for supplemental heat, with wood and electric heat pumps the most common.

TABLE F-3: SECONDARY HEATING FUELS DURING ANALYSIS PERIOD

Secondary Heating Fuel	All Survey Respondents (n=324)[1]	Percent of All Survey Respondents[2]	Respondents in Billing Model (n=75)	Percent of All Respondents in Billing Model[4]
No secondary heat	193	60%	68	91%
Wood	34	10%	7	9%
Electric[3]	35	11%	6	8%
Propane[4]	12	4%	2	3%
Oil	9	3%	0	0%
Kerosene	6	2%	0	0%
Natural gas	2	1%	0	0%
Natural gas	2	1%	0	0%

[1] Multiple responses were allowed and responses reflect all secondary heat use even if it is infrequent or is only used in small area.

[2] Multiple responses were allowed, so percentages of the respondents add to more than 100%

[3] Electric space heaters (1) and heat pumps (34)

[4] Propane space heaters, stoves and fireplaces

F-2 Wood Heat

The customer survey covered questions about the extent of wood heat usage during the pre- and post-installation periods. Changes in the use of secondary wood heat are important to

[1] Fuels that were used minimally, *i.e.*, that were used in 20% of the area of the home or less or used only occasionally, were not included.

consider when estimating changes in usage of delivered fuels because an increase or decrease in reliance on wood during the post-installation period can be mistaken for efficiency savings or lack of efficiency savings.

About nine percent (9%) of homes in the billing analysis model and twenty percent (20%) in the broader customer survey sample use wood as either their primary or secondary source of heat.

As shown below in Table F-4, most respondents (80%) either did not use wood heat at all or did not have substantial wood heat. For all respondents, seven percent (7%) reported no change in their secondary wood heat use compared to the pre-installation period, and only two percent (2%) reported using their wood heat more in the post-installation period. Of the seven (7) respondents in the billing model who used wood heat, four (4) reported using wood heat the same in the pre- and post-periods and three (3) said they used the wood heat less in the post-period; using less in the pre-period may simply indicate that they noticed the reduction in energy use.

TABLE F-4: COMPARISON OF CHANGES IN WOOD HEATING

	All Survey Respondents	Percent of All Survey Respondents[1]	Respondents in Billing Model	Percent of All Respondents in Billing Model
No or minimal wood heat	259	80%	68	91%
Used wood heat the same	24	7%	4	5%
Used wood heat more in post-installation period	7	2%	0	0%
Used wood heat less in post-installation period	30	9%	3	4%
Did not use heat before EE upgrade	4	1%	0	0%

[1] Percentages do not add to 100% due to rounding

F-3 Delivery Methods

The billing analysis uses the timing and volume of fuel deliveries to estimate customer consumption levels over a given time period. As shown below in Table F-5, about three quarters of the survey respondents receive regular deliveries, and twenty-four percent (24%) receive deliveries as needed.

TABLE F-5: DELIVERY FREQUENCY

	All Survey Respondents (n=324)	Percent of All Survey Respondents[2]	Respondents in Billing Model (n=75)	Percent of All Respondents in Billing Model
Once a month or more often	110	34%	43	57%
Once every two months	70	22%	16	21%
Once every three to four months	3	1%	0	0%
Once or twice a year	50	15%	2	3%
When needed	77	24%	14	19%
Invalid responses[1]	14	5%	0	0%

[1] Twelve respondents mentioned not using the fuel anymore and two respondents provided invalid responses

[2] Percentages add to more than 100% due to rounding

Survey respondents were also asked how often their tank was filled to capacity when deliveries were made, as opposed to having a set quantity of fuel delivered, *e.g.*, 100 gallons. As shown in Table F-6, eighty-six percent (86%) of all survey respondents and ninety-two percent (92%) of respondents in the billing model reported that the fuel tanks were filled to capacity every time or most of the time.

TABLE F-6: DELIVERY METHODS

Fuel tank is filled …	All Survey Respondents (n=324)	Percent of All Survey Respondents[1]	Respondents in Billing Model (n=75)	Percent of All Respondents in Billing Model
Every time	232	72%	64	85%
Most of the time	46	14%	5	7%
Some of the time	15	5%	1	1%
Rarely	4	1%	0	0%
Never	12	4%	0	0%
Don't know	15	5%	5	7%

[1] Percentages add to more than 100% because of rounding

F-4 Heating System Controls

Substantial changes in the thermostat setting between the pre- and post-periods could introduce additional error into the billing analysis. A direct relationship between heating degree days and energy consumption is more easily observed when the thermostat is set at a consistent temperature and left alone or consistently set back. As shown in Table F-7 below, over half the respondents reported setting the thermostat at one temperature or setting back their thermostat by using a programmable or smart thermostat.

TABLE F-7: HEATING SYSTEM CONTROLS

Heating System Controls	All Survey Respondents (n=324)	Percent of All Survey Respondents[1]	Respondents in Billing Model (n=75)	Percent of All Respondents in Billing Model
Manually adjust as needed	122	38%	26	35%
Set at one temperature and leave it	101	31%	23	31%
Set back with programmable thermostat	74	23%	19	25%
Combination of setback methods (manual, programmed, remote)	15	5%	4	5%
Use a smart thermostat to automatically adjust temperature	10	3%	3	4%
Change temperature setting remotely (Wi-Fi or phone app)	1	0%	0	0%
Invalid response	1	0%	0	0%

[1] Percentages add to more than 100% due to rounding

Snap back occurs if a participant decides to increase the indoor temperature after the installation, and "takes back" some the energy savings in the form of enhanced comfort. As shown in Table F-8, a large majority of respondents (82%) reported no change in how they set their thermostats between the pre- and post-period and only one percent (1%) of all respondents reported turning the thermostat up by 5°F or more, suggesting that snap back is unlikely to be affecting the billing analysis results.

TABLE F-8: CHANGES IN THERMOSTAT SETTINGS FROM PRE- TO POST-INSTALLATION PERIOD

Thermostat setting	All Survey Respondents (n=324)[1]	Percent of All Survey Respondents	Respondents in Billing Model (n=75)	Percent of All Respondents in Billing Model
Did not change thermostat settings	266	82%	62	83%
Turned down less than 5°F	24	7%	7	9%
Turned the thermostat up less than 5°F	13	4%	1	1%
Turned down more than 5°F	14	4%	4	5%
Turned up more than 5°F	2	1%	0	0%
Don't know	4	1%	1	1%

[1] One respondent did not answer the question

The comparison of all respondents to respondents included in the billing model suggests that the two groups are quite similar with respect to changes in thermostat settings from pre- to post-periods.

F-5 Demographics

Survey participants were asked several demographic questions pertaining to the number of occupants in their home, annual income and education levels. Out of 298 respondents who answered the occupancy question, all but three participants live year-round in their homes and more than three quarters of the residences had three or fewer occupants.

The sample population proved to be highly educated compared to the Maine population, with seventy percent (70%) of surveyed participants having attained at least a college degree. About thirty-nine percent (39%) of participant's survey reported a post graduate degree as the highest level of education completed by the homeowner. 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% and 10.9% have a post graduate degree.[2] About eighty-seven percent (87%) of the respondents had total household income above the LIHEAP income eligibility threshold.[3]

F-6 Key Findings

The unregulated fuels survey was designed to provide additional information to interpret the billing analysis. The key findings are summarized in Table F-9.

TABLE F-9: KEY FINDINGS FOR RESPONDENTS IN THE BILLING ANALYSIS

Topic	Issue	Survey Findings for Homes in the Billing Model
Secondary Fuel Use	Multiple fuels make it more difficult to estimate the unregulated fuel savings.	91% of the homes in the billing model did not use a secondary fuel.
Changes in Use of Wood Heat	Wood heat use is difficult to quantify and changes in the use of wood heat use could introduce bias to the unregulated fuel savings	Three homes (3%) indicated a change in their wood heat use.
Fuel Deliveries	Filling the tank to capacity makes it easier to determine how much fuel was used during the period between deliveries	92% of respondents reported that the fuel tank is filled to capacity all or most of the time
Changes in thermostat settings	Snap back occurs if participants increase the thermostat setting in the post period and "take back" some savings as enhanced comfort	No homes raised the thermostat setting by 5°F or more, and only one home reported increasing the thermostat setting by less than 5°F, suggesting that snap back is not an issue

[2] 2013-2017 American Community Survey 5-Year Estimates https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

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

Appendix G

Ductless Heat Pump Customer Survey Findings

Appendix G: Ductless Heat Pump Customer Survey Findings

The ductless heat pump survey was divided into two parts. The first part of the survey focused on ductless heat pump operational issues and the second part focused on net-to-gross (NTG) and program influence. This appendix presents findings from the first part of the participant survey which was conducted to collect information on ductless heat pump operation and secondary heating systems and fuel use. This information was useful in understanding how program participants are operating their heat pumps. There were 288 respondents who participated in the survey. Of the total respondents, eleven (11) did not complete the survey. The results are summarized below for all respondents who answered questions in each section.

G-1 Sampling

Stratification was conducted to ensure that the survey respondents represented a range of program participants. An email blast with the survey link was sent out to a random sample of 1,979 participants who had installed a ductless heat pump through the HESP program. The online survey was designed to allow respondents to take the survey on heat pump operational issues until the stratification quotas were met. Once a quota was met in any of the strata, participants were automatically redirected to the NTG survey. A $15 check incentive was provided to participants who completed the survey.

The stratification requirements were to complete forty (40) surveys (to meet 80/10) in each of the substrata presented in Table G-1. The strata were not mutually exclusive, as one respondent could be in more than one category. As shown Table G-1 below, the quotas for all strata were met except for multifamily and mobile home.

TABLE G-1: STRATIFICATION REQUIREMENTS

Strata Description	Quota	Survey Respondents (n=288)	Percentage of Survey Respondents[1]
Installed for one winter	40	47	16%
Installed for 2 winters	40	100	35%
Installed for 3 winters	40	141	49%
Installed in mobile homes	40	6	2%
Installed in multi-family buildings	40	24	8%
Installed in single-family homes with less than 2000 square feet	40	154	53%
Installed in single-family homes with more than 2000 square feet	40	84	29%

[1]Percentages add to more than 100% because one respondent could be in more than one category. The percentage reported is based on the 288 respondents who answered the question.

Figure G-1 below shows that eighty-five (85%) of the 288 respondents installed the ductless heat pump in an existing home. About fourteen percent (14%) installed ductless heat pumps either in a new home or in an addition to an existing home. As shown in Figure G-1 below, the most common type of ductless heat pump being installed was a single indoor unit heat pump.

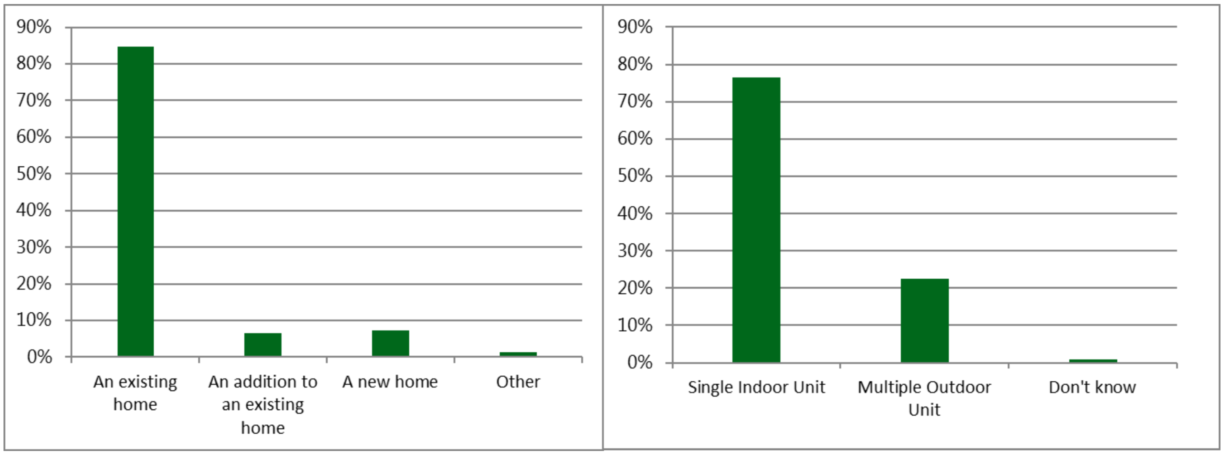

FIGURE G-1: TYPES OF HOME WHERE HEAT PUMP WAS INSTALLED AND TYPES OF HEAT PUMP INSTALLED[1]

G-2 Reasons for Heat Pump Installation

Respondents who installed the ductless heat pump in an existing home were asked about their reasons for installation and the mode of operation throughout the year.

[1]"Other" category has a total of seven respondents and five cited "condo" and one cited "apartment" as the building where the heat pump is installed. One respondent reported that the heat pump is installed in a semi-attached apartment to a single-family home

Table G-2: Reasons for Installing The Heat Pump

Install Reason[1]	Survey Responses (n=244)[1]	Percentage of Survey Responses[1]
Heat previously unheated space	43	18%
Previous heating equipment was insufficient or needed replacing	67	27%
Add air conditioning[2]	155	64%
Previous air conditioner was insufficient or needed replacing[2]	50	20%
Improve energy efficiency	238	98%
Save heating costs	226	93%
Save cooling costs	99	41%
Other[3]	26	11%
None of the above	2	1%

[1] Survey question was only asked to customers that installed heat pumps in existing homes (n=244). Respondents were allowed to cite multiple reasons. Percentages add to more than 100% because multiple responses were allowed.
[2] Sixteen (16) respondents selected both the adding air conditioner and previous air conditioner was insufficient or needed replacing options. The total number of respondents choosing one or the other of the air conditioning options was 189 (77%).
[3] Most often-cited "other" reasons were environmental and convenience concerns.

A summary of the reasons for installation are provided in Table G-2. Almost all of the respondents reported installing the heat pump to improve energy efficiency and save heating costs. Over two-thirds (64%) reported that they wanted to add air conditioning or replace an existing air conditioner.

Survey respondents were asked which modes they use their ductless heat pump during each month of the year. Homeowners are likely to be using a combination of different modes during any particular month, so multiple responses were allowed. Almost all respondents (95%) reported using the heating mode during winter months. As shown in Figure G-2 below, majority of the respondents either used the cooling mode or turned off their heat pump during summer months. Less than five percent (5%) of the respondents reported using the dehumidification or fan only mode during the summer months.

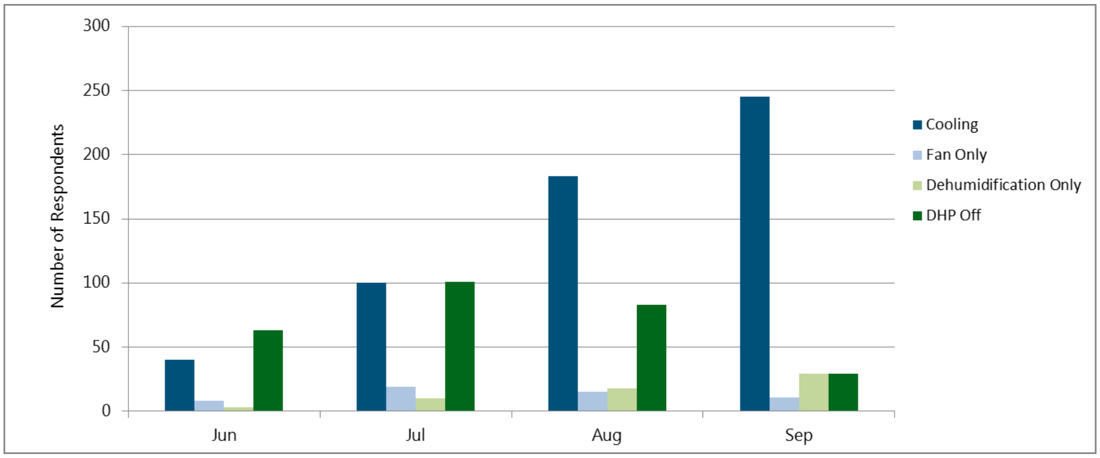

FIGURE G-2: HEAT PUMP USE DURING SUMMER MONTHS

Respondents were asked how often they clean the ductless heat pump filter. As shown in Figure G-3 below, about a third of the 288 respondents said they clean the filter once a month and about five percent (5%) of the survey respondents cited never cleaning the filter.

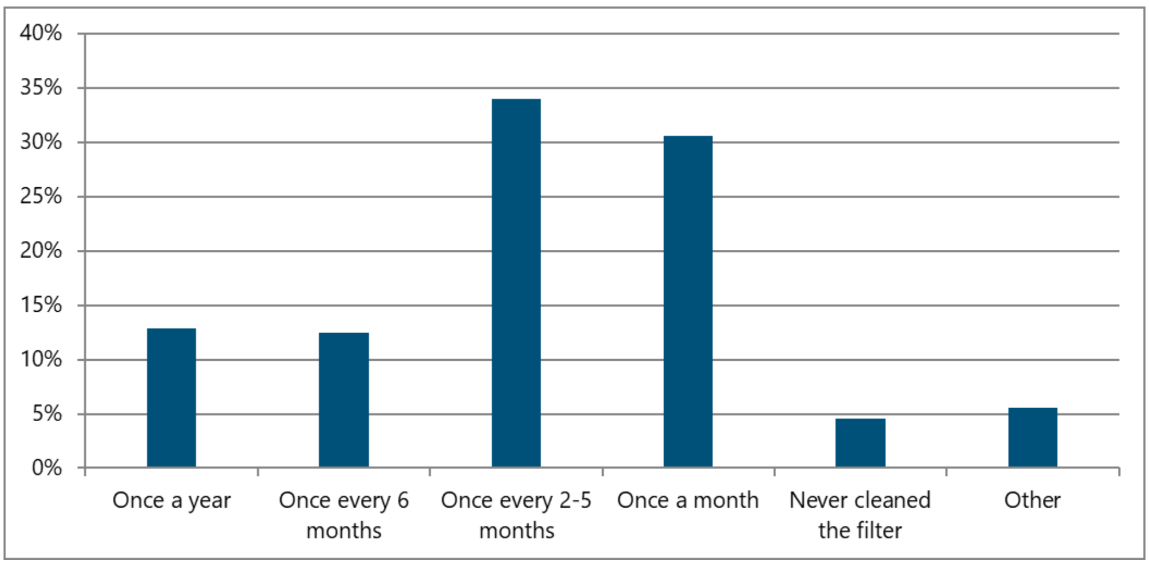

FIGURE G-3: HEAT PUMP FILTER CLEANING

G-3 Ductless Heat Pump Operation

Another area of interest was how customers operate their ductless heat pumps based on outside temperature. Survey respondents were asked if they turn off their heat pumps below a certain temperature in the heating and cooling seasons.

About thirty-nine percent (39%)[2] of 286 respondents who answered the question reported turning the heat pump off at low winter temperatures. A small percentage (5%) of the respondents reported not using the heat pump during the heating season.

During the winter season, some homeowners turn their heat pump off in response to the outdoor temperature. Respondents were asked if they turn off the heat pump when the outdoor temperature falls below or goes above a certain temperature[3]. Out of 286 respondents who answered the question, forty percent (40%) mentioned turning off the heat pump when it gets warm outside. A summary of the distribution of the responses is shown in Figure G-4 below.

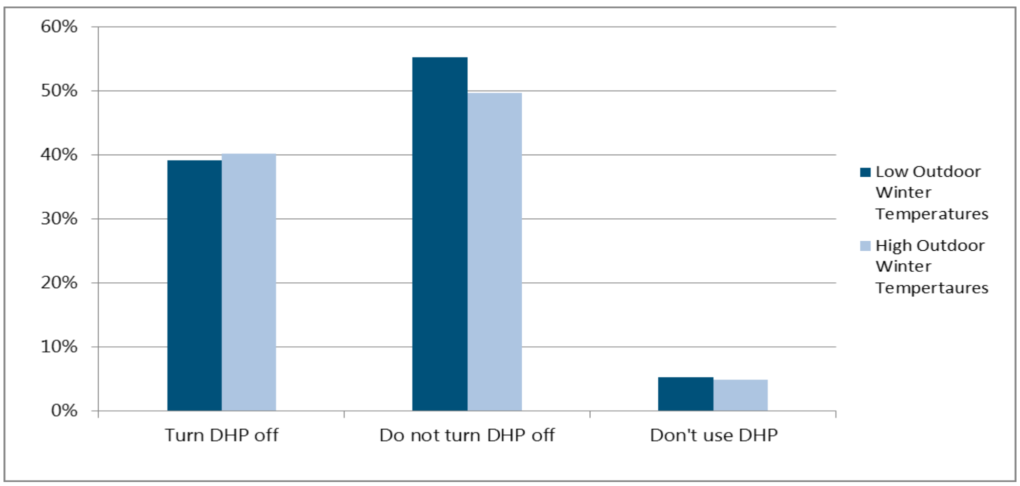

FIGURE G-4: HEAT PUMP OPERATION DURING THE HEATING SEASON

A summary of the responses is shown in Table G-3 and Table G-4 below. Figure G-5 provides the temperatures at which respondents reported turning off their heat pumps during low winter outdoor temperatures.

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[2] One respondent said "Don't know"

[3] A summary of the temperatures respondents reported turning off their heat pumps is provided in this appendix in Table G-3, Figure G-5 and Table G-4.

Table G-3: Heat Pump Operation At Low Winter Outdoor Temperatures

Heat Pump is turned off during the winter when the temperature drops below [1] ….	Survey Respondents (n=285)[2]	Percentage of Survey Respondents[3]
0 degrees	31	11%
Below 20 degrees	54	19%
Below 40 degrees	24	8%
Do not turn off heat pump at very cold temperatures	158	55%
Do not use heat pump during the winter	15	5%
Invalid responses[4]	3	1%

[1]Responses were numerical values and the evaluation team grouped the responses into bins for reporting
[2]One respondent said, "Don't know" and was removed from the total count
[3]Percentages add to 99% and not 100% because of rounding
[4]These respondents cited turning off their heat pump at temperatures above 70 degrees, suggesting they did not understand the question

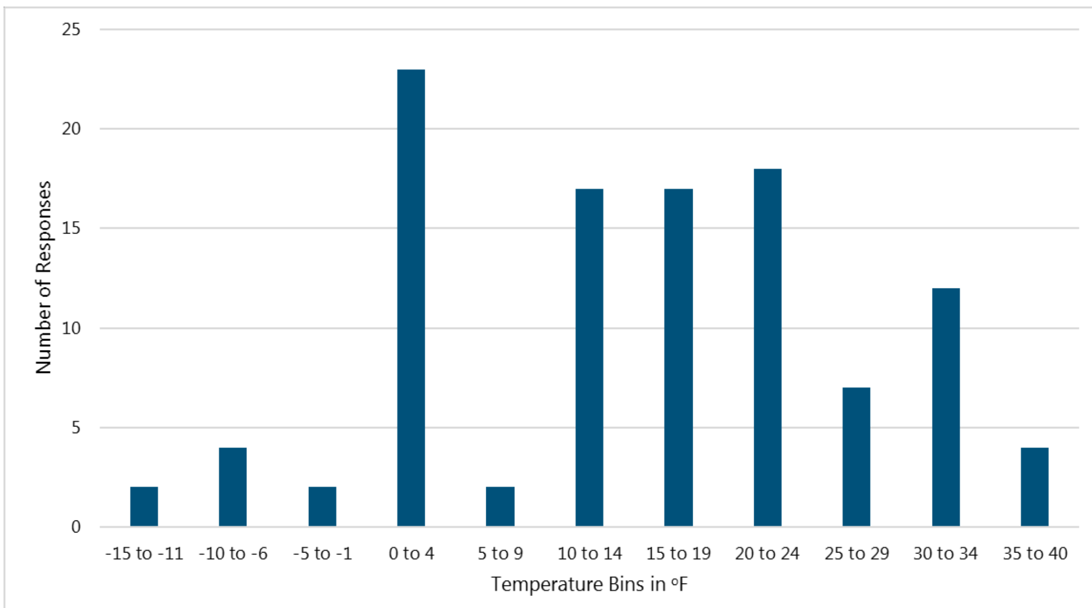

Figure G-5: Heat Pump Operation At Low Winter Outdoor Temperatures – Temperature Below Which The Heat Pump is Turned Off

Table G-4: Heat Pump Operation At High Winter Outdoor Temperatures

Heat pump is turned off during the winter when the temperature goes above[1]....	All Survey Respondents (n=269)[3]	Percent of All Survey Respondents
41 degrees	53	20%
60 degrees	38	14%
Do turn off heat pump at high outdoor temperatures	142	53%
Do not use heat pump during the winter	14	5%
Invalid responses[2]	22	8%

[1]Responses were numerical values and the evaluation team grouped the responses into bins for reporting
[2]These respondents did not understand the question and reported turning off the heat pump when temperatures are below 40 degrees
[3] Two (2) respondents said, "Don't know" and 15 respondents who provided invalid responses on their heat pump operation at warm outdoor temperatures were not asked to specify the temperatures at which they turn off their heat pump when it gets warm outside during the winter. These 17 respondents were removed from the total count.

During the cooling season, some homeowners turn off their heat pumps in response to the outdoor temperature instead of allowing the heat pump to automatically shut off when temperatures fall below the setpoint. Survey respondents (285) were asked if they turn off the heat pump during the cooling season and 49% said they turn off the heat pump when it gets cool outside. About 38% (107) said they do not turn off their heat pump and 10% (27) mentioned not using their heat pump during the summer. Table 5 below provides a summary of the responses related to cooling season heat pump operation.

TABLE G-5: HEAT PUMP OPERATION DURING THE COOLING SEASON

Heat pump is turned off during the summer when the temperature is below[1]....	Respondents (n=275)[2]	Percent of All Survey Respondents
40 degrees	14	5%
60 degrees	30	11%
80 degrees	94	34%
Do turn off heat pump during the summer	107	39%
Do not use heat pump during the summer	27	10%
Invalid responses[3]	3	1%

[1] Responses were numerical values and the evaluation team grouped the responses into bins for reporting
[2]Ten (10) respondents said, "Don't know" and were removed from the total count
[3] These respondents reported turning off the heat pump above 80 degrees, which suggests they did not understand the question.

G-4 Heating Fuels

Respondents in existing homes were asked to identify other heating systems that they have used in the past 4 years. As shown in Table G-6 below, about 89% of the survey respondents used delivered fuels, i.e. oil, propane or kerosene as heating fuels during the analysis period. As mentioned in Section G-2, almost all respondents (95%) mentioned using the heat pump for heating.

TABLE G-6: HEATING SYSTEMS DURING ANALYSIS PERIOD

Heating Fuel	Survey Responses (n=288)[1]	Percentage of All Survey Respondents
Delivered fuels	255	89%
Wood	101	35%
Electric resistance heat[2]	56	19%
Natural Gas	6	2%
Other[3]	8	3%

[1] Multiple responses were allowed and responses reflect all heating fuels use both primary and secondary. There were 44 (15%) respondents who did not answer this question because they installed the ductless heat pump in a new home or in an addition to an existing home
[2] Electric baseboard and space heaters
[3] Geothermal heat pumps, wood fireplace/stove, electric radiant and solar

About 35% of the respondents used wood and 19% used electricity. About 71% of the homes with electric resistance heat also had a boiler or furnace[4] and 23% reported having propane or kerosene space heaters.

Respondents were also asked if they changed their heating fuel use after installing the ductless heat pump. As shown below in Table G-7, 76% of the survey respondents reported either using less or not using delivered fuels after installing the ductless heat pump. About 68% of the respondents reported using less or not using any wood during the post-installation period. A small minority of respondents mentioned using more of the wood heat after the ductless heat pump was installed.

TABLE G-7: COMPARISON OF REPORTED CHANGES IN HEATING FUEL USE

Reported Change in fuel usage	Delivered Fuels (n=246)[1]		Natural Gas (n=6)[1]		Wood (n=92)[1]		Electric Resistance (n=48)[1]	
	Count	%	Count	%	Count	%[2]	Count	%[2]
Did not use after heat pump was installed	10	4%	0	0%	3	3%	2	4%
Used less after the work was completed	176	72%	4	67%	60	65%	29	60%
Used the same	45	18%	2	33%	26	28%	17	35%
Used more in post-installation period	15	6%	0	0%	3	3%	0	0%

[1] Respondents who did not answer the questions and who said "don't know" were removed from the total count.
[2]Totals do not add to 100% due to rounding

G-5 Heating System Controls

Another household characteristic that is an important factor in estimating energy savings is how customers operate their heating systems through thermostats and other equipment controls. Changes in thermostat-setting behavior between the periods before and after an efficiency measure is installed could account for a portion of the measured change in energy consumption that would not necessarily be attributable to the efficiency measure itself. As shown in Table G-8 below, 51% of respondents reported setting the thermostat at one temperature and leaving it. About 10% of the respondents said they set back their thermostat, either manually or by using a programmable thermostat.

[4] 55% of the respondents had an oil boiler of furnace. The rest reported having a propane or kerosene boiler.

TABLE G-8: DUCTLESS HEAT PUMP THERMOSTAT USE

Heating System Controls	Respondents (n=283)[1]	Percent of Survey Respondents[2]
Set at one temperature and leave it	145	51%
Manually adjust (including use of the heat pump remote control)	105	37%
Combination of setback methods (manual, programmed, remote)	20	7%
Set back with programmable thermostat	9	3%
Change temperature setting remotely with Wi-Fi or phone app	4	1%

[1]One respondent cited "Don't know" and was removed from the total count
[2]Totals do not add to 100% due to rounding

Additional questions were asked about how respondents control their central heating system that heats the same area as the ductless heat pump. Out of 284 respondents, 166 (58%) reported having a central heating system in the same area as the heat pump. Of these 166 respondents, 34% had one central heat thermostat and 65% had two or more thermostats. A summary of how survey respondents control their central heat thermostat during the coldest months of the year is provided in Table G-9 below.

TABLE G-9: CENTRAL HEATING SYSTEM CONTROLS DURING THE COLDEST MONTHS

Central Heating System Controls	Respondents (n=161)[1]	Percent of Respondents
Set at a lower temperature than the heat pump thermostat	93	58%
Set at the same temperature as the heat pump thermostat	27	17%
Manually adjust the thermostat on the central heating system based on indoor temperature	19	12%
Turn central heat off unless needed	10	6%
Turn heat pump off in coldest months	7	4%
Set at a higher temperature than the heat pump thermostat	5	3%

[1]Five (5) respondents said, "Don't know" and were removed from the total count

G-6 Air Conditioning Use

Survey respondents were asked questions related to their air conditioning use before and after the heat pump was installed. Out of 282 respondents, 64% (181) had central, window or room AC before installing the heat pump.[5] Table G-10 below provides a summary of the responses.

TABLE G-10: COOLING SYSTEM IN PLACE BEFORE INSTALLING THE HEAT PUMP

Cooling Equipment Type	Respondents (n=282)[1]	Percent of Respondents[2]
Central air conditioning	4	1%
Window or room air conditioning	178	63%
No air conditioning	100	35%

[1] Five respondents said, "Don't know" and one respondent had missing data. Window or room air conditioning
[2]Percentages do not add to 100% due to rounding

The next question was how AC use changed after installing the ductless heat pump. A summary of the responses is provided in Table G-11 below. The majority of the respondents reported that they no longer use their window or central air conditioning system.

TABLE G 11: AC USE AFTER HEAT PUMP INSTALLATION

After installing your heat pump, do you use your window or central AC	Respondents (n=181)[1]	Percent of Respondents
No longer use window or central AC	141	78%
Less[2]	31	17%
About the same	7	4%
A lot more	2	1%

[1] One respondent had missing data and was removed from the total count
[2] Twelve percent (12%) said a lot less and five percent (5%) said somewhat less

[5] Only 1% of the respondents had central air conditioning

G-7 Experiences with Contractors

To participate in HESP, homeowners are required to use a contractor registered with Efficiency Maine. As shown in Table G-12 below, out of 281 respondents who were asked their level of satisfaction on a scale 1 to 5, about 94% gave a high score (a score of 4 and 5).

TABLE G-12: CONTRACTOR SATISFACTION

Level of Contractor Satisfaction	Respondents (n=281)	Percent of Respondents
1 – Not all satisfied	6	2%
2	2	1%
3	9	3%
4	18	6%
5 Very satisfied	246	88%

Participating homeowners receive training on how to operate the ductless heat pump from various sources. Out of 279 respondents, 94% (261) reported that they received training or advice on how to use their heat pump. As shown in Figure G-6 below, the majority of the respondents (255) reported that they received advice from their contractor. Other sources of advice were Efficiency Maine website, staff, friends or family and fuel dealers.

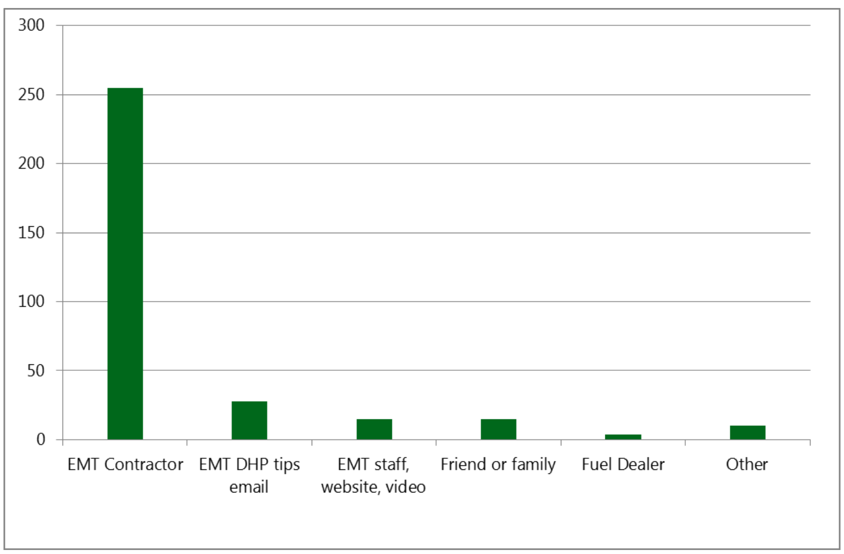

FIGURE G-6: SOURCES OF HEAT PUMP OPERATION ADVICE

Survey respondents were also asked what topics were covered as part of the training or advice. The table below provides a distribution of the responses. Multiple responses were allowed for this question.

TABLE G-13: ADVICE ON HOW TO OPERATE HEAT PUMP

Heat Pump Topics Covered in Advice	Responses (n=261)[1]	Percent of Responses[2]
How to use the remote control	249	95%
How to adjust vane/air-flow direction for heating and cooling	226	87%
How to clean the filter	235	90%
How to use the mode settings (fan, heating, cooling or dehumidification)	230	88%
Recommended temperature setting for heat pump	145	56%
Recommended temperature setting for central heating system	87	33%
How to operate your heat pump in very cold outdoor temperatures	133	51%

[1] The total responses (n=261) is the number of respondents who said they received advice on how to use their heat pump
[2] Multiple responses were allowed, so percentages add to over 100%

Survey respondents were asked an open-end question on what they were told about how to operate their heat pump when it gets really cold. The open-end question was not mandatory and 104 respondents provided valid responses. Table G-14 below provides a summary of the verbatim responses.

TABLE G-14: VERBATIM RESPONSES ON HOW TO OPERATE THE HEAT PUMP DURING THE COLDEST DAYS

Advice on How to Operate the Heat Pump During the Coldest Days	Respondents (n=104)	Percent of Respondents[2]
Turn off heat pump below 5 degrees	7	7%
Turn off heat pump below 20 degrees	13	13%
Turn heat pump off [1]	11	11%
Leave heat pump as it is	28	27%
Heat pump is not efficient at low temperatures[1]	32	31%
Increase the heat pump's thermostat setting	8	8%
Supplement with another heating source	5	5%

[1] These respondents did not specify the temperature at which they were advised to turn the heat pump off or the temperature at which the heat pump is no longer efficient.
[2] Percentages do not add to 100% due to rounding

G-8 Key Findings

The key findings from the ductless heat pump survey are as follows:

- Almost all of the survey respondents reported installing the heat pump to improve energy efficiency (98%) and save heating costs (93%). Over two-thirds (64%) reported that they wanted to add air conditioning or replace an existing air conditioner.
- About 55% of the survey respondents reported that they do not turn off their heat pump at low outdoor winter temperatures
- A majority (89%) reported using delivered fuels during the past 4 years and 90% reported using delivered fuels less after installing the ductless heat pump
- About 64% had air conditioning before installing the heat pump and 78% reported not using their air conditioners after installing the heat pump. Approximately 17% reported using the AC less after upgrading to a heat pump.
- Survey respondents reported receiving advice on how to operate the heat pump at low temperatures. Of the 104[6] respondents who provided verbatim responses of the advice they received, 27% reported that they were told to leave the heat pump as it is at low temperatures. Approximately 31% reported being told that the heat pump is less efficient at low temperatures.

[6] About 7% and 13% reported they were told to turn off their heat pump at 5 degrees and 20 degrees respectively.

Appendix H
Contractor Ductless Heat Pump Survey Findings

Table of Contents

H-1	Ductless Heat Pumps Marketing	1
H-2	Rebate-Eligible vs. Non-Rebate-Eligible Heat Pumps	2
H-3	Motivations	5
H-4	Barriers	5
H-5	Program Influence and Causal Mechanisms	6
H-6	Installation Practices	10
H-7	Program Value and Recommendations	12
H-8	Firmographics	13
H-9	Key Findings	15

Appendix H: Contractor Ductless Heat Pump Survey Findings

The following sections present findings from the contractor ductless heat pump survey. The contractor survey had questions related to how long contractors have been selling ductless heat pumps, issues surrounding whether and when contractors offer rebate-eligible models and sources of support both within and outside of the program. The survey also covered topics such as how contractors communicate program offerings to their customers, the sources of motivation for contractors selling heat pumps, contractor practices regarding equipment location and operation, contractors' perspectives on the availability of rebate-eligible models, and contractor experiences and satisfaction with the program.

An email blast was sent out to 312 contractors with the goal of getting 40 completed surveys. A $75 check incentive was provided to contractors who completed the survey. All contractors who installed more than five ductless heat pumps during the analysis period were included in the survey sample. A summary of the disposition is provided in Table H-1 below.

TABLE H-1: SURVEY DISPOSITION

	Count	Percentage of Population
Contractor in population	495	
Contractors with < 5 installations	85	17%
Contractors with > 5 installations	410	83%
Contractors with > 5 installations and valid e-mail information	312	63%
Survey completes[1]	41	8%

[1]These are respondents who completed the entire survey. There were an additional 8 respondents who answered some questions but did not finish the survey.

As shown in the table above, there were 41 respondents who completed the survey. Eight (8) respondents did not complete the survey all the way through. Results are presented for all respondents who answered questions in each section.

H-1 Ductless Heat Pumps Marketing

Respondents were asked how long they have been selling heat pumps and if they began selling heat pumps prior to HESP. There were 49 responses; Figures H-1 and H-2 depict the responses to these questions.

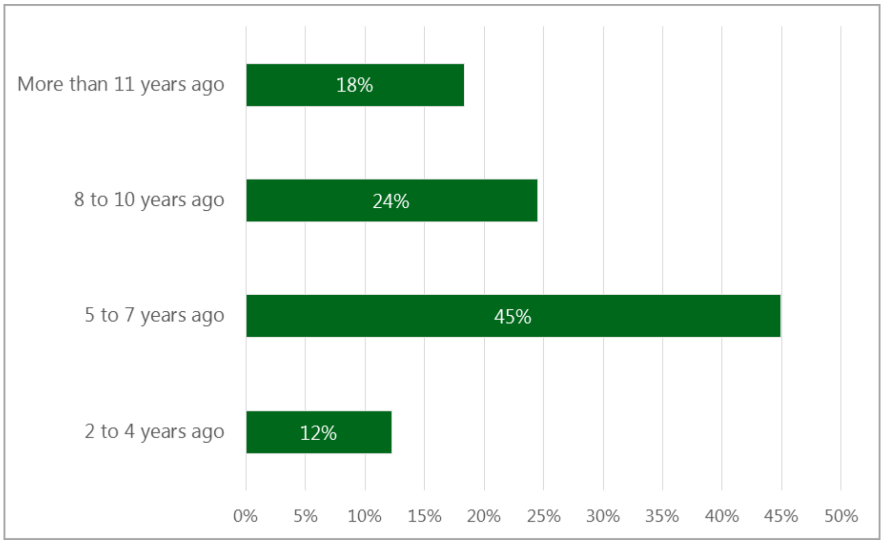

FIGURE H-1: LENGTH OF TIME SELLING HEAT PUMPS (n=49)

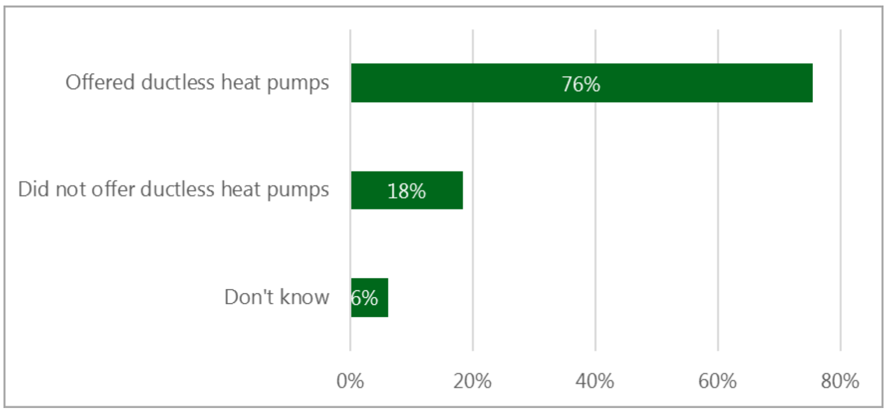

FIGURE H-2: HEAT PUMP OFFERING BEFORE THE PROGRAM (n=49)

As shown in the figures above, 87% of respondents have been selling this equipment for 5 or more years, and 76% of respondents offered heat pumps prior to the HESP rebates.

H-2 Rebate-Eligible vs. Non-Rebate-Eligible Heat Pumps

Contractors who offer non-rebate-eligible heat pumps were asked when they offer the standard efficiency heat pumps. Figure H-3 and Figure H-4 show the responses to these questions. Figure H-3 indicates that price sensitivity is the most common circumstance, with 61% responding that they offer the non-eligible heat pumps either to price sensitive customers or customers requesting the lowest price. Multiple responses were allowed to this question and many contractors provided additional comments under the "other" category. Sixteen contractors chose this option and most of them mentioned that customers sometimes request larger units or cooling-only options that are not eligible for the HESP rebate.

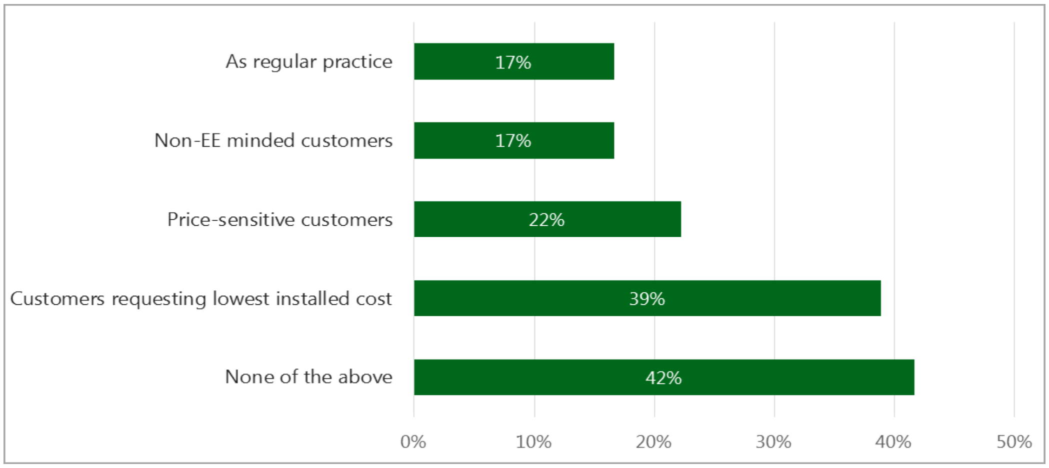

FIGURE H-3: CIRCUMSTANCES FOR OFFERING NON-ELIGIBLE HEAT PUMPS (n=36)

Figure H-4 describes how the respondents characterized the rebate-eligibility of the heat pumps they sold in 2017. The responses were put into three categories:

1. Low level: contractors who reported that less than 30% of the heat pumps they sold were in the category (dark green)
2. Moderate level: between 30% and 75% of the heat pumps sold were in the category (grey)
3. High level: over 75% of the heat pumps sold were in the category (light green)

Ninety-six percent (96%) of respondents responded that fewer than 30% of the eligible heat pumps units they sold did not receive a rebate. See Section H-7 for more contractor feedback.

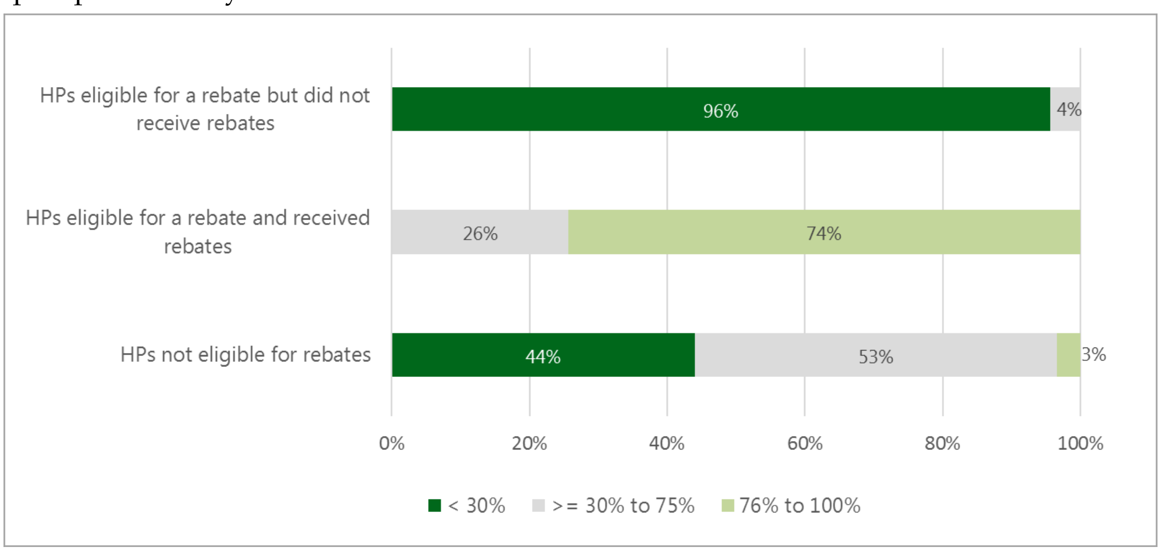

FIGURE H-4: DUCTLESS HEAT PUMP 2017 SALES COMPARISON (n=42)

Contractors were asked about the efficiency ratings of heat pumps sold without rebates, whether they were single-unit or multi-unit heat pumps, and why they sold heat pumps without rebates.

Figure H-5 shows contractor responses when asked what were the most common HSPF ratings for heat pumps they sold in 2017 without rebates.

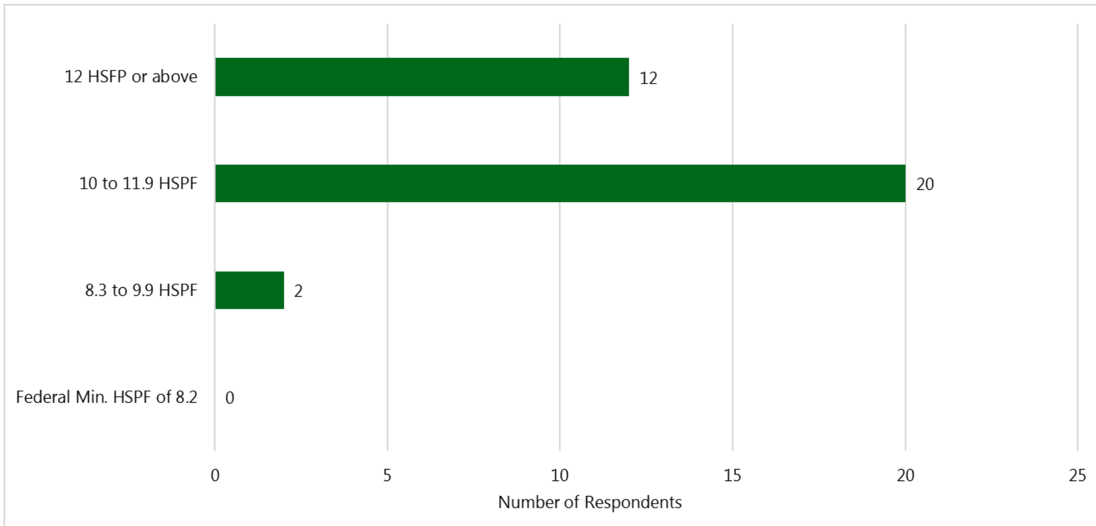

FIGURE H-5: MOST COMMON HSPF FOR HEAT PUMPS SOLD IN 2017 WITHOUT A REBATE (N=38)[1]

Ten contractors selling heat pumps that did not receive a rebate in 2017 were asked an open-ended question to explain why they sell eligible heat pumps without a rebate .[2] Eight of the responses to the question indicated that the main reason was an ineligible location. Six of these respondents reported that their homes were vacation, non-resident or commercially used homes. Two contractors said that some customers want the heat pump to be installed in a garage or other ineligible location.

[1] Eight (8) respondents reported "Don't know" and were removed from the total count.
[2] Two of the contractors who answered this question provided an unrelated response to the question that was asked.

H-3 Motivations

Contractors were asked about why they sell high-efficiency heat pumps. The following summarizes the contractor responses:

- Almost 80% of the contractors strongly or somewhat agreed that their customers request high efficiency equipment.
- The second most common motivation was reducing negative impacts on the environment, which was cited by 64% of contractors.
- More than half (54%) of the contractors agreed that the incremental cost of the high efficiency heat pumps is low.
- Contractors were least likely to say that they were motivated to sell high-efficiency equipment because of a higher profit margin.

The motivations are summarized in Figure H-6.

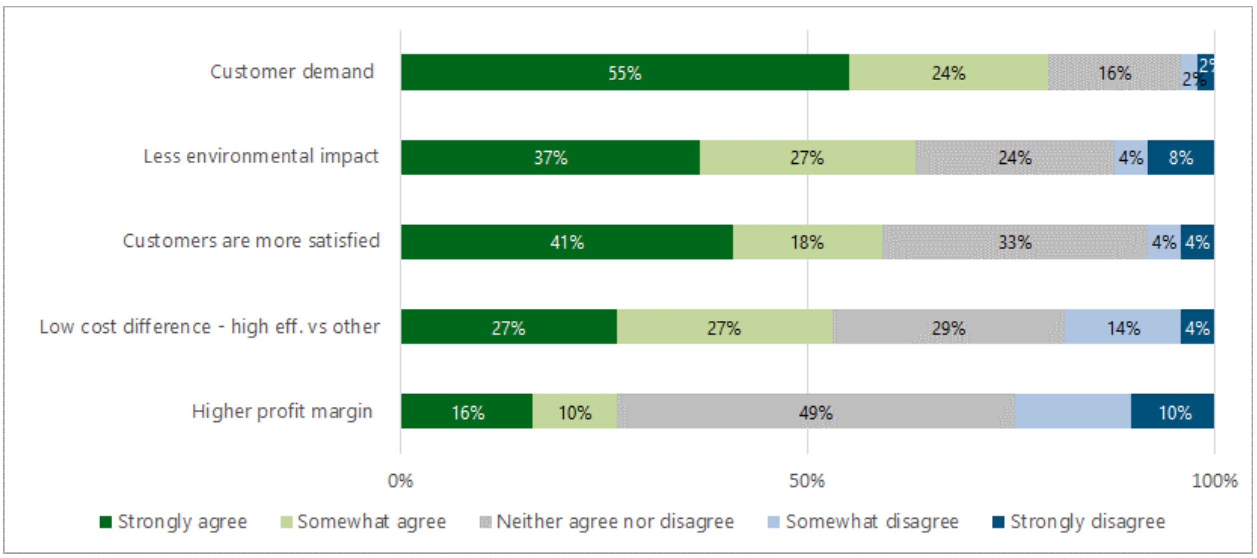

FIGURE H-6: MOTIVATION FOR SELLING HIGH-EFFICIENCY (REBATE-ELIGIBLE) HEAT PUMPS (n=49)

H-4 Barriers

Contractors were asked about the challenges that prevented them from selling more high-efficiency equipment *when they first started selling heat pumps* by ranking the challenges in order of importance. Respondents were allowed to indicate that they did not perceive any barriers and to select only the barriers that they experienced. Thirty three percent (33%) of the respondents indicated they had no challenges. Figure H-6 illustrates the responses.

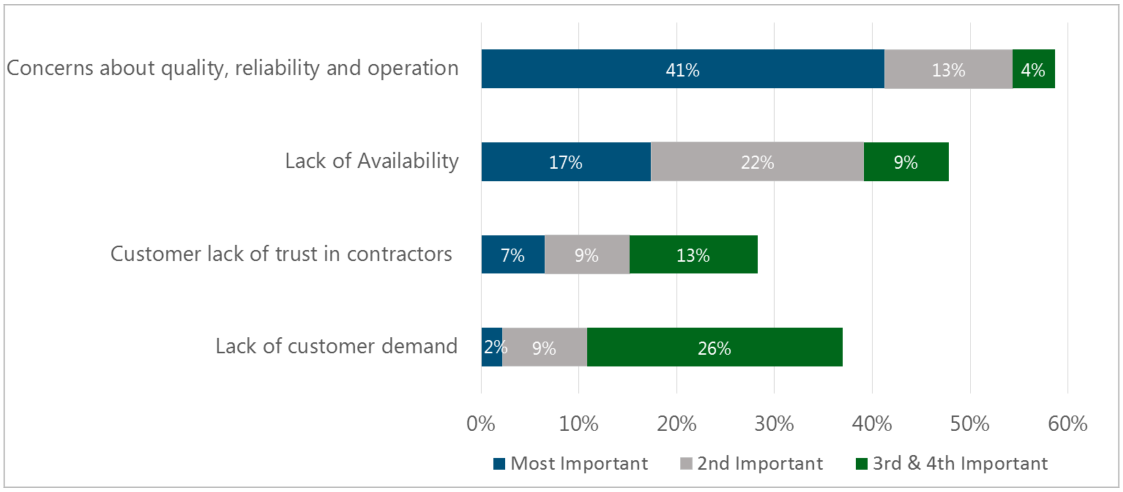

FIGURE H-7: CONTRACTOR PERSPECTIVE ON BARRIERS (n=46)

About 67% of the respondents listed one or more barriers. The most commonly cited barrier was concerns about the quality, reliability and operation of the heat pumps. About 59% of respondents reported this was a barrier and 41% listed as the most important barrier. While 48% of respondents listed customer demand as a barrier, only a small minority (17%) identified it as the most important barrier. Lack of availability and lack of trust in contractors were selected less frequently.

Some contractors identified other challenges to increasing their sales of high efficiency heat pumps when they first started selling them. These included finding quality employees, finding the right equipment, lack of customer confidence or knowledge of how the equipment operates, and competition.

H-5 Program Influence and Causal Mechanisms

These questions were designed to assess the influence of the program in promoting efficient heat pumps, how the respondents perceive the EMT program activities and how the activities support contractors. Some of the findings are discussed summarize below.

1. Efficiency has increased and selection of heat pump models is better since the HESP rebates started (67% of respondents).
2. Two-thirds of respondents reported that they are more likely to recommend high efficiency units due to the HESP rebates.
3. Over 80% of the contractors attributed some level of support from EMT in motivating them to recommend and install high efficiency heat pumps, and about 42% reported that EMT's support was more important than other sources of support.
4. Eighty percent (80%) of respondents listed at least one of EMT's activities as a strongly or extremely important source of support in their efforts to sell and install high efficiency heat pumps.
5. Respondents reported that the EMT brand makes it easier to sell high efficiency heat pumps (70%) and EMT program participant has increased their profitability (68%)

The responses to the specific questions are provided in more detail below.

Contractors were asked about change in availability of energy efficiency equipment since the program's inception in 2013. As shown in Figure H-7, about 67% of respondents felt that efficiencies are higher and there is a greater selection of rebate-eligible heat pumps than in 2013.

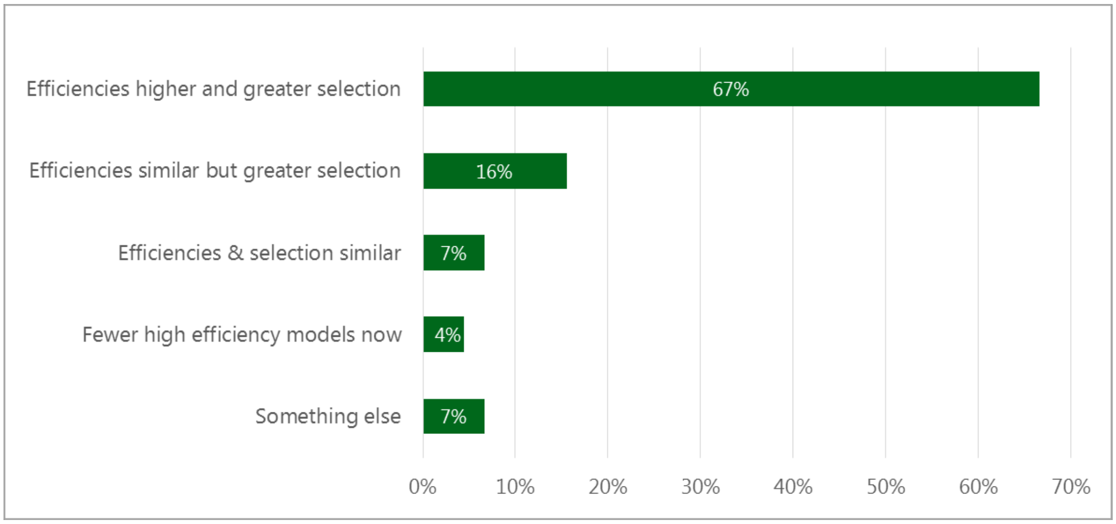

FIGURE H-8: CHANGES IN AVAILABILITY OF REBATE-ELIGIBLE HEAT PUMPS (n=45)

The contractors who stated the availability of high efficiency heat pumps had improved were also asked their perspective about the reasons behind the increase in availability. EMT rebates and promotions were listed as important factors to the increased availability of heat pumps. The top three choices were competition among manufacturers, customer awareness and EMT rebates.

The survey included questions about whether contractors have changed how likely they are to recommend high efficiency heat pumps. The wording of the question depended on how long the contractors had been installing heat pumps, as given below.

1. Contractors who have been installing heat pumps for more than five 5 years (before HESP rebates were offered):

   Since the Efficiency Maine rebates for high-efficiency heat pumps became available, have you changed the way that you recommend heat pumps to customers?

2. Contractors who ***have not*** been installing heat pumps for more than five (5) years:

   Has the availability of rebates from Efficiency Maine for high-efficiency heat pumps influenced the way that you recommend heat pumps to customers?

Figure H-9 shows responses from both groups of contractors. These responses suggest that the rebates have been successful in incentivizing both sets of contractors to offer rebate-eligible heat pumps to their customers. About two-thirds of contractors reported that the rebates made them more likely to recommend high efficiency heat pumps.

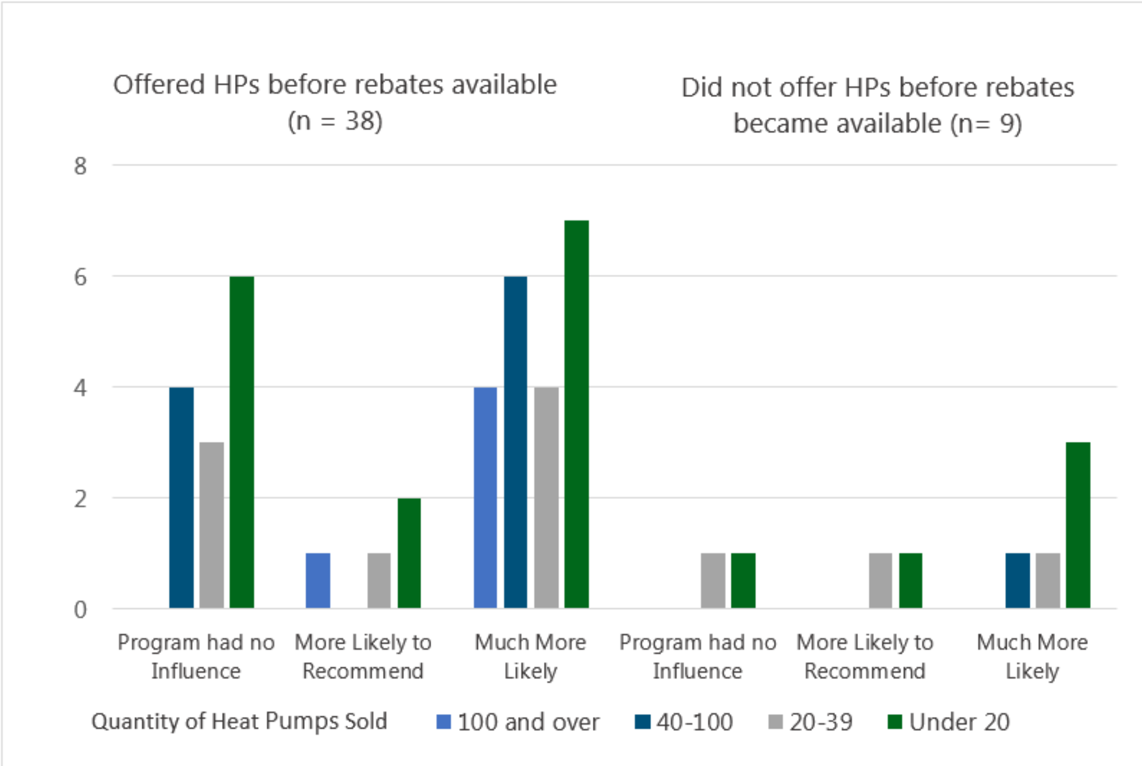

FIGURE H-9: CHANGES IN HEAT PUMP RECOMMENDATIONS DUE TO REBATES, AS A FUNCTION OF SALES[3]

Contractors were asked to compare EMT contractor support to other non-EMT sources in motivating them to recommend and install high efficiency heat pumps. Over 80% of the contractors attributed some level of support from EMT in motivating them to recommend and install high efficiency heat pumps. A summary of the responses is provided Figure H-10 below. The respondents were evenly divided between whether the EMT or other sources of support was more important.

[3] The quantity of heat pumps sold is a sum of the quantity of heat pumps recorded in effRT for FY2014-FY2016.

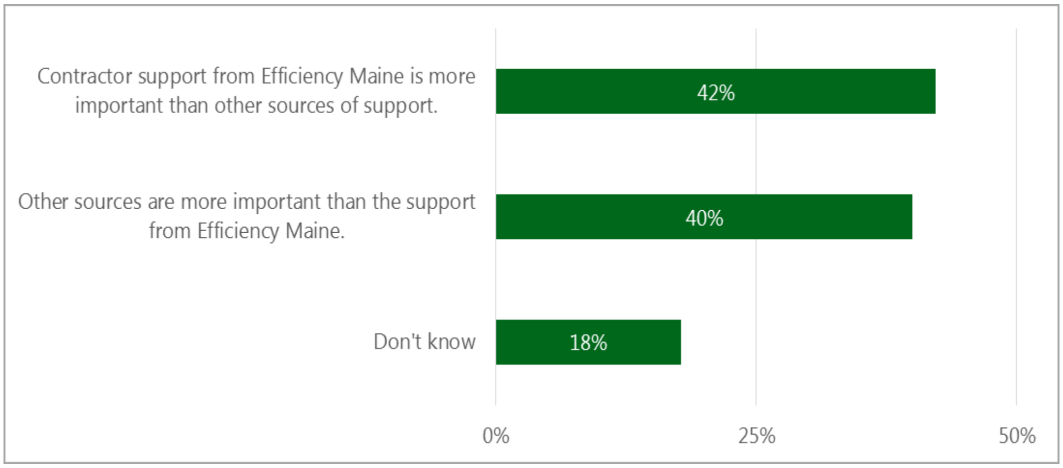

Figure H-10: Sources of Support to Recommend and Install Efficient Heat Pumps (n=45)

Contractors were also asked to rate EMT's activities by level of importance in supporting high efficiency heat pumps. The rebate was rated by 78% of respondents as strongly or extremely important, followed by the contractor list (71%) and EMT resources, such as the Web site, user tips, videos and eligible model list, with 61%.

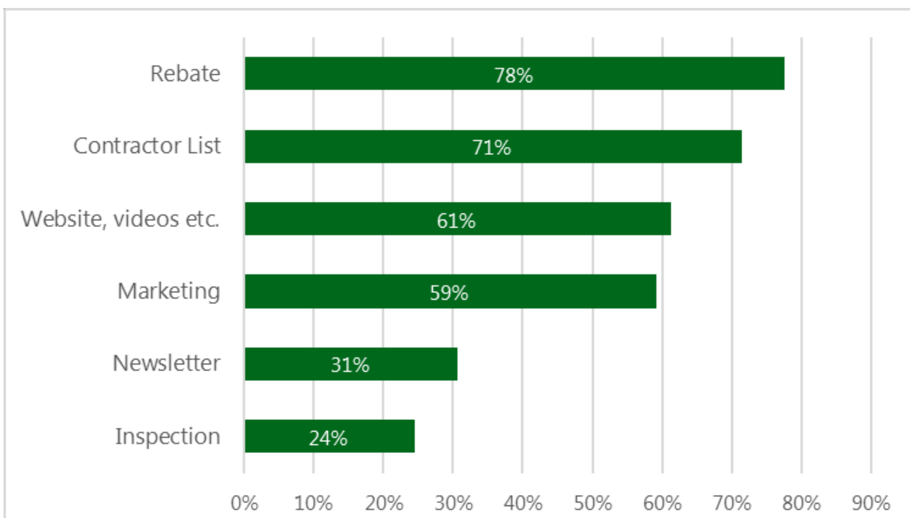

Figure H-11: EMT Activities Ranked by Importance

Contractors were also asked to agree or disagree with statements to understand better how EMT's program is supporting contractors. A substantial majority of respondents agreed with the following:

- EMT brand makes it easier to sell high efficiency heat pumps (70%)
- Rebates make the efficient heat pumps more attractive to customers and increase the close rate (77%)
- EMT program participant has increased their profitability (68%)

- EMT promotes program awareness and generates customer leads (68%)

The range of responses is illustrated in Figure H-12.

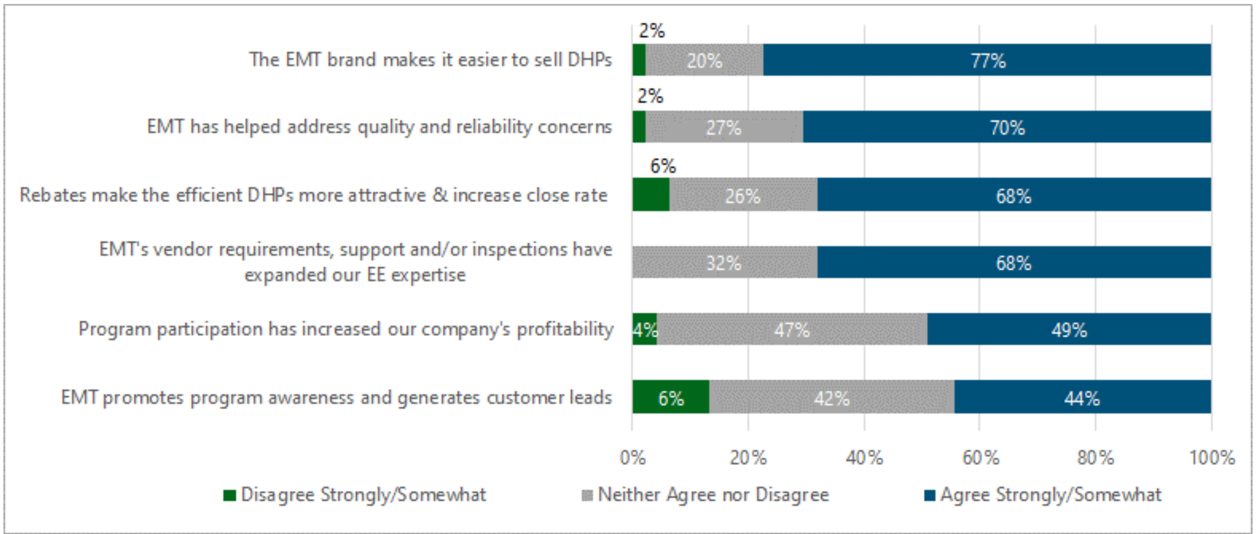

FIGURE H-12[4]: –HOW EMT'S ACTIVITIES SUPPORT CONTRACTORS (n=47)

H-6 Installation Practices

This section began by asking respondents to estimate how their previous year's heat pump sales broke down in terms of desired customer function (heating, cooling or both). Sixty-three percent (63%) estimated that over three-quarters of their heat pump installations were intended to provide both heating and cooling. In contrast, only four percent (4%) said that over three-quarters of their sales were for heating-only, and no respondents reported that such a large majority of installations were for cooling-only.

When a customer planned to use a heat pump for both heating and cooling, the respondents reported sizing the heat pump as follows:

- 47% sized the equipment for the larger of the two loads
- 39% used the maximum heating load
- 14% used the cooling load

There was a range of opinions on this point, with several contractors simply stating that in Maine, the heating load would always be larger than the cooling load.

Contractors were asked how important several factors were in locating the heat pumps within customer's homes. Figure H-13 describes their responses, showing that a majority of respondents listed all six factors as strongly or extremely important.

[4] Percentages do not add up to 100% due to rounding

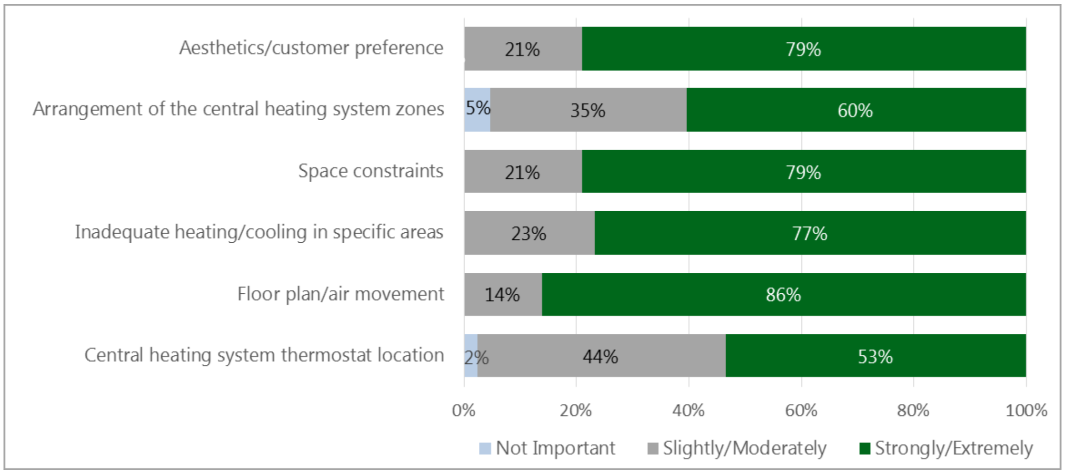

FIGURE H-13: LOCATING THE HEAT PUMP WITHIN THE HOME (n=43)

Respondents were asked to identify other important factors related to heat pump installation and 15 contractors provided additional detail. Seven respondents referred to optimizing refrigerant line routing to minimize runs while locating the outdoor unit to avoid prevailing winds, snowdrifts, and overhanging trees and roof icicles, code setback requirements vis-à-vis nearby combustion vents and balancing all of these needs with the owners' desires to minimize visual impact. The remainder of comments included customer education on operation and maintenance, being sure to check a home's total electric load, and insulation or air sealing opportunities that could be pursued as another upgrade element.

Contractors were asked about the advice or tips would they offer to other installers for optimum system location. The most cited comments fell into the following 3 categories:

- Twenty-five (25) respondents cited optimizing the location of the indoor units(s) as an important piece of advice
- Eight (8) respondents reported optimizing the location of the outdoor unit to avoid damage, minimize exposure sun, wind or snow
- The need to balance comfort needs, efficiency and aesthetics was cited by 3 respondents

Contractors were also asked what advice they give to customers about how to operate their ductless heat pumps. Six contractors responded to this open-ended question and reported providing the following advice:

- Turn off heat pumps during a storm
- Do not use auto mode, try out different settings to reach a good comfort level
- Reduce the thermostat setting on the central heating system, run the heat pump when you are home, set back the existing heating system and heat only the room you are in
- Turn down the thermostat on the heat pump by 5°F when you are not home and turn up to the desired temperature when you are home

- Set the thermostat on the heat pump where you are comfortable
- Use the heat pump as the primary heat source with pre-existing heat source as back up
- Give the units time to react and don't keep pushing buttons

Figure H-14 describes concerns that respondents perceive related to heat pumps. Fourteen contractors did not select any of the options. About 20% of the contractors cited being concerned that their customers do not know how to operate the heat pumps. Fourteen (14%) of the contractors were concerned about the ductless heat pumps' inadequate heating at very low temperatures and 12% were concerned about the cost of operation.

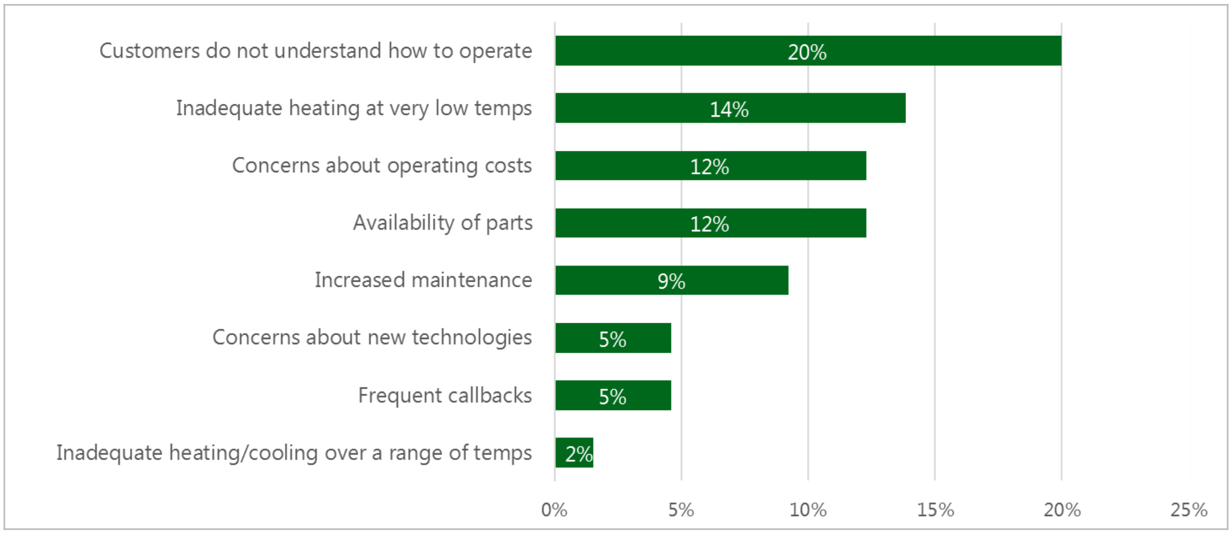

FIGURE H-14: CONCERNS ABOUT HEAT PUMP PERFORMANCE (n=31)

Contractors were asked whether they provide energy estimate savings to their customers. Of 40 responses, 28 said no and 12 said yes. Half of those who do offer savings estimates said they use the EMT calculator.

H-7 Program Value and Recommendations

Contractors were asked about the most valuable aspect of the HESP program and recommendations for improvements to the program. Responses are summarized in the table below.

Table H-2: Contractors Comments on Program

Topic	Number of Responses	Comments
Most Valuable Aspect of HESP	41	Rebate (30) Quick turn around on the rebate EMT marketing, contractor list EMT lends legitimacy Customer education with focus on being "green" and reducing oil use HESP weatherization complements heat pump rebates
Suggestions for Improvements	18	Inadequate lead time regarding vendor requirement changes such as training More communication in advance regarding insurance/license renewals and other program paperwork requirements Move rebates to distributor level ("instant") Faster rebate check turnaround ("4-6 weeks is way too long") Wider heat pump eligibility (part-time residences, outbuildings, camps, garages) Larger rebates for multi-head installations Reduce paperwork /online form that customer can start Give out best performing and most reliable information on different brands More customer videos and media promotions showing the success and *cost reduction* of heating and cooling a home done in conjunction with air sealing and insulating Confirmation of receipt of rebate form More installation inspections on all aspects; insulation, air sealing, heat pumps

One contractor mentioned a concern for the future: "Not sure if it is valuable but it props up the heat pump market allowing it to be an option in place of central heating equipment which in my opinion is bad in the long run for the consumers."

H-8 Firmographics

Several questions were asked to assess the overall size and program-related activities of the contractors who responded to the survey.

Table H-3: Number of Staffed Offices In Maine

Number of Staffed Offices	Number of Responses (n=41)	% of Total
0	7	17%
1	32	78%
2	2	5%

Table H-4: Number of Employees Installing Heat Pumps

Number of Employees Primarily Installing Heat Pumps	Number of Responses (n=40)	Percentage of Total
0	5	13%
1	15	38%
2	10	25%
3 to 5	6	15%
6 and above	4	10%

Table H-5: Changes in Employees Installing Heat Pumps in the Previous Five Years

Description	Number of Responses (n=39)	Percentage of Total
Increased	17	46%
Stayed about the same	18	49%
Decreased	2	5%

H-9 Key Findings

Key findings from this survey are as follows:

- Efficiency has increased and selection of heat pump models is better since the HESP rebates started (67% of respondents)
- Two-thirds of respondents reported that they more likely to recommend high efficiency units due to the HESP rebates
- Over 80% of the contractors attributed some level of support from EMT in motivating them to recommend and install high efficiency heat pumps, and about 42% reported that EMT's support was more important than other sources of support
- Eighty percent (80%) of respondents listed at least one of EMT's activities as a strongly or extremely important source of support in their efforts to sell and install high efficiency heat pumps
- Respondents reported that EMT brand makes it easier to sell high efficiency heat pumps (70%) and an EMT program participant has increased their profitability (68%)
- Some eligible heat pump units are sold without the rebate, mostly due to applications that are not eligible (seasonal homes, garages, large units)
- Respondents most common concern about heat pumps is that customers do not understand how to operate them (20%), followed by inadequate heating at low temperatures (14%), operating costs (12%) and availability of parts (12%)
- Contractors would like to see stability in the rebate amounts, less paperwork, more lead time for recertifications/changes, and an easier rebate process for commercial sales

Overall, contractors' view of the heat pump program is positive ("It gives the industry credibility", "Efficiency Maine is doing a great job", and "Efficiency Maine is a great program, making the earth greener and saving customers' money").

Appendix I

Ductless Heat Pump Analysis Details

Appendix I: Ductless Heat Pump Analysis Details

This section provides additional detail on how the ductless heat pumps gross evaluated savings were calculated.

I-1 Estimating Heat Pump Savings

Savings from the ductless heat pumps were estimated from the metered data collected on-site. The recorded measurements are shown in the Table I-1 below.

Table I-1: Measurements and Inputs

Meter	Metric	Equation Input	Measurement	Purpose
Dent Elite-Pro	kW	$kW_{metered}$	Heat pump kW and Power Factor	Provides input power and kWh of heat pump
Hobo UX120-006M	Inlet air temperature	ΔT_{air}	Inlet air temperature	Calculate the temperature difference (how much the air is heated)
	Outlet air temperature		Heat pump output air temperature	
	Air velocity	None	Air velocity (feet/minute)	Measure air velocity to determine fan speed
Hobo Pendant	Ambient Air		Room temperature	Provides temperature set point
TSI AccuBalance Balometer	Airflow	m = flow rate for fan speed (ft^3/min) x run time (at fan speed)	Airflow spot measurement (cubic feet/minute)	Measure cfm at each fan speed and one auto cycle
Other Input	None	c_p	Specific heat of air at the temperature range (Btu/lbm °F)	Btu/lbm °FConversion variable, depends on air temperature
Other Input	None	ρ	Density of air at the temperature range (lbm/ft^3)	Conversion variable, depends on air temperature
Other Input	None	OAT	Outdoor ambient air temperature	From NOAA – use to normalize results

While on-site, West Hill Energy technicians used a Balometer flow hood to take spot measurements of the air flow (cubic feet per minute) at each fan speed. Typically, there are four or five fan speeds, ranging from low to high. The Balometer was used to measure CFM at all sites. Additionally, at 19 sites an air flow meter was installed on the outlet grill to measure air velocity near the center of the grill throughout the metering period.

The fan speed coupled with the change in temperature between the inlet and outlet provides a means of calculating the heat delivered to the space from the unit. The heat delivered to the space and the metered energy of the unit allowed us to calculate the coefficient of performance (COP) of the unit at outdoor air temperature ranges. In homes without an air velocity meter, an average airflow value was assumed.

The meter data was combined with hourly outdoor air temperature from the nearest NOAA weather station using the following process:

1. The hourly temperature data was grouped into 5-degree temperature bins for the analysis.
2. The average kW usage and percent of time when the heat pump is on were calculated for each temperature bin and identified as cooling or heating usage.
3. This usage by temperature bin was normalized to an annual kWh, peak summer kW and peak winter kW using the averages of five years of temperature data from 2012 to 2016.

The results from the analysis of metered data were compared to a baseline heat pump using the same baseline Heating Season Performance Factor (HSPF) and Seasonal Energy Efficiency Ratio (SEER) as in the Technical Reference Manual (TRM). As no metered HSPF and SEER were available for the baseline units, the manufacturer's HSPF and SEER were used for the efficient case units for a consistent comparison between the baseline and efficient case to maintain consistency. The baseline usage was calculated using the ratio of the efficient to baseline HSPF (for heating) and SEER (for cooling) and the metered usage of efficient units. The difference between the two usage values is the savings. This calculation does not include the measured COP, but the baseline unit would likely have a similar change in COP based on outdoor temperature. Because of this the ratio of the manufacturer's reported HSPF should be approximately equivalent to the ratio of the actual COP based on metering.

I-2 Comparison to AMI Data

A comparison was done between the metering results and the AMI data that was available for metered participants. The goal was to determine if the metering data could be supplemented with homes using only AMI data, possibly with an adjustment factor.

The AMI data were combined with the NOAA outdoor air temperature and the same process of binning the AMI data by 5°F to determine temperature-dependent use was conducted. A regression of temperature on kWh use was then performed to identify homes with temperature dependent use.

As the AMI data includes all of the electricity usage in the home, there is noise in the data that adds uncertainty when determining the heat pump run time and kWh usage. The heat pump use would represent only a portion of the household, temperature-dependent use. The adjustment factor reflects the percent of the temperature-dependent use that is due to the heat pump.

For homes that did not show temperature dependent use, this approach cannot be effective and there is no alternative strategy for separating the heat pump use from the overall household energy use.

Homes with temperature dependent use were identified as homes where the temperature dependent regression had an R^2 greater than 0.7, this was true for 16 of the 22 homes included in the analysis. The calculation was done using a base of both 60°F and 65°F to check the impacts of different set points. The results of this analysis showed a large amount of variation in the ratio between the meter data results and the AMI data results. The results are summarized in Table I-2. As can be seen from the results, there is a high amount of variability in the results, resulting in low confidence in the calculated average ratio.

TABLE I-2: AMI ANALYSIS RESULTS

Variable	Mean	Standard Deviation	Relative Precision	Min	Max
AMI kWh at 60°F	3,369	2,479	30%	1,160	10,078
AMI kWh at 65°F	3,904	2,899	31%	1,341	11,681
Meter kWh	2,435	1,562	26%	307	6,013
Meter to AMI ratio at 60°F	0.895	0.681	31%	0.194	2.771
Meter to AMI ratio at 65°F	0.786	0.612	32%	0.167	2.452
Closest Match ratio[1]	0.853	0.600	29%	0.194	2.452

[1]This uses the result of the AMI regression closest to the meter results.

I-3 Total Household Heating Energy Use

For homes with metering, we collected permission to request the bulk fuel billing records and included these participants in our requests to the fuel dealers. We collected bills for fossil fuels for about half of the metered sites. Due to the limited billing data collected from the sites only one of the homes had sufficient data for a good pre/post comparison. The site showed a comparable reduction in oil usage due to the heating provided by the heat pump.

I-4 Baseline Definition

Typically, energy efficiency baselines are determined based on whether the installation is a retrofit (baseline is pre-install condition) or market opportunity (baseline is a standard efficiency unit). Heat pumps tend to blur this distinction as they are often installed in existing homes (suggesting retrofit) but the participant may have decided to install a heat pump prior to selecting the efficient model (market opportunity).

Some circumstances, where new heating or cooling is added, are clearly market opportunity and the baseline is a standard efficiency new heater and/or air conditioner. Other cases are not as obvious. If a heat pump is installed to enhance the capacity of existing heating and/or cooling systems, the actual load displaced would be from the previous system. However, if the homeowner made the decision to install a heat pump prior to considering the available models and investigating the efficiency, the load was removed even if they had installed a standard efficiency heat pump.

Rather than trying to distinguish between retrofit and market opportunity, our approach investigates the motivations for installing the heat pumps and the range of alternatives considered by the homeowner, as shown in Table I-3.

Table I-3: Baseline Definitions

	Motivating Factor	Baseline Equipment
Heating	Existing System did not provide enough heat or had failed	Standard efficiency heat pump
	New installation (no existing heat in area with heat pump)	Standard efficiency heat pump
	Existing system provided sufficient heat; previous system kept in place and heat pump added to improve efficiency	Blended baseline based on the alternatives considered by the homeowner
Cooling	Heat pump purchased for both heating and cooling, primarily for cooling or home had existing A/C	Standard efficiency heat pump
	Heat pump purchased for heating only and no previous A/C or plans to install A/C	Cooling (if any) is additional use; baseline is no air conditioner

The detailed customer survey included questions to determine the percent of homes in each of these categories and the questions are presented in Table I-4.

Table I-4: Heat Pump Baseline Survey Responses for Heating

Category		% of Survey Respondents	Baseline
New homes, additions or had insufficient heat		39%	Standard efficiency heat pump
Existing home with sufficient heat	Did not consider other options	47%	Standard efficiency heat pump
	Did consider other options	14%	Blended baseline based on the alter-natives considered by the homeowner

For the respondents who said they did not consider an alternative for heating, a standard efficiency heat pump is a reasonable baseline. Thus, the standard efficiency baseline is appropriate for 86% based on the heating use (39%+47%). Based on the customer survey results 85% of the homes should have a standard efficiency heat pump as the cooling baseline.

Because both the heating and cooling have an 85%+ with a standard efficiency baseline, the current TRM baseline of a standard efficiency heat pump was considered appropriate.

I-5 Comparison of Costs of Heat Pumps and Oil Heat

A study was performed to assess the cost to heat with a ductless heat pump compared with fuel oil over a range of outside temperatures. The costs are based on the six-month averages taken in the summer of 2018. The metered heat pump efficiency results by temperature bin from the meter results were used to calculate the heat pump cost. The results of this study are shown in the table below. Based on this analysis the heat pump use is less expensive down to approximately 5 °F. One thing that is important to note with these results is that only about 2% of the total annual hours in Maine are less than 5°F[1], so for most of the time the heat pump will be lower cost.

TABLE I-5: COST TO HEAT COMPARISON BY OUTSIDE TEMPERATURE

Outside Temperature (°F)	Heat Pump COP[1]	Cost to heat Ductless Heat Pump[2]	Cost to heat Oil[3,4]	% Reduction in Cost
60	3.1	$15.22	$24.60	42%
55	3.3	$14.09	$24.60	47%
50	3.3	$14.31	$24.60	46%
45	3.2	$14.97	$24.60	43%
40	3.0	$14.69	$24.60	40%
35	2.7	$16.02	$24.60	35%
30	2.5	$17.69	$24.60	28%
25	2.4	$18.63	$24.60	24%
20	2.2	$19.93	$24.60	19%
15	2.1	$21.21	$24.60	14%
10	1.9	$22.88	$24.60	7%
5	1.8	$24.60	$24.60	0%
0	1.6	$27.76	$24.60	-13%
-5	1.4	$31.65	$24.60	-29%
-10	1.1	$38.73	$24.60	-57%

[1] Heat pump efficiencies based on the findings in this report
[2] Assumes $0.15/kWh of electricity, Six Month Average from Maine Governor's Office, Taken Summer 2018
[3] Assumes $2.73/gallon of Oil, Six Month Average from Maine Governor's Office, Taken Summer 2018
[4] Assumes an average operating efficiency of 80%

[1] Based on an average of 21 weather stations throughout Maine between 2012 and 2016, not weighted to population.

Appendix J

Net-to-Gross Causal Mechanisms

Appendix J: Net-to-Gross Causal Mechanisms

MEMORANDUM

TO:	Laura Martel, Efficiency Maine Trust
FROM:	Kathryn Parlin and Jenna Bagnall-Reilly, West Hill Energy
	Lori Lewis, Analytical Evaluation Consultants
DATE:	March 2, 2017
RE:	Causal Mechanisms for HESP

A key part of preparing for the net-to-gross analysis of HESP is to understand the causal mechanisms that are intended to change market behavior. For this reason, we requested a discussion with program staff to learn about how the program works. This memo summarizes our conclusions about the causal mechanisms based on our conversation of February 3, 2017 with HESP staff.

J-1 Overview

Causal mechanisms reflect the program logic and its theory, i.e., the theoretical construct that underpins the program activities and expected outcomes. For example, if a program is focused on market transformation, then program activities should target specific market actors and produce specific outputs that are expected to lead to defined and sustainable market outcomes. Through our discussion with program staff, we believe the goal of HESP is to increase the uptake of energy efficiency (EE) measures (i.e., market penetration).

From a net-to-gross (NTG) perspective, understanding the causal mechanisms is important as we will want to verify that the causal mechanisms have been engaged and have had or are expected to lead to the desired outcomes (impacts). This approach incorporates a feedback loop to the program for improving program delivery.

In addition, the Barriers Approach will provide a deeper understanding of the market barriers to the installation of EE measures facing customers and contractors. The causal mechanisms represent the way in which the program is designed to overcome these barriers.

Our approach to defining the causal mechanisms is as follows:

1. Discuss program activities and features with the program staff to understand how and why the program is expected to work
2. Match the program activities with the intended outcomes
3. Identify the causal mechanisms, and assess the program activities associated with the causal mechanisms and outcomes
4. Review the causal mechanisms in the context of the barriers they are intended to overcome

This analysis provides the foundation for the NTG research.

This memo describes the results of our analysis and provides the opportunity for feedback from EMT. The discussion with program staff was conducted on February 3, 2017, and was recorded. Each of the remaining steps are discussed in more detail below.

J-2 Program Activities and Outcomes

Table J-1 shows the program activities and outcomes as we understand them from the discussion with program staff.

TABLE J-1: PROGRAM ACTIVITIES AND OUTCOMES

Program Activity	Outcome	Comments
Rebate	Increase interest and follow through with EE measures, mitigate first cost barrier	Rebates cover about 17% of incremental costs on average
Contractor List	**Customers:** Simplify finding a contractor for customers	Many customers look for reliable contractors – can be a barrier
	Contractors: Build contractor infrastructure with more leads	As contractors have more work, they are more willing to invest time and resources into EE
Vendor Agreement/ Inspections	High quality of work with contractors from list	Addresses customer's concerns about quality of work and trust
Marketing	Increase interest in measures and generate leads	Includes Pandora Radio, Google Ads, Hulu, events and magazine ads
Instructional Videos	Education on efficient heat pump and marketing to increase interest in heat pumps	Videos are available on YouTube, Hulu and the EMT website.
E-mail newsletter on HP to customers & contractors	Improve operation of heat pumps	Customer and contractor education
Scholarships for Heat Pump Training	Contractors improve expertise in heat pumps	Encourages training in heat pumps and increases the number of qualified installers
EMT Loan	Mitigate first costs barrier	Loan fund from ARRA grant; about 5-8% of participants finance through the loan; seen as "enabler", no savings
EMT Branding	Generate trust	Leverages other program activities to increase program impacts

J-3 Program Activities, Causal Mechanisms and Outcomes

Table J-2 reflects our understanding of the program activities, causal mechanisms and the intended outcomes. We defined six causal mechanisms, as discussed below. Some causal mechanisms affect only customers or only contractors.

1. Rebate/loan (customer): The rebate and loans are intended to partially defray the upfront cost of the measures, to generate interest in EE and to make it easier for customers to move forward with the installation of the measures
2. Customer education (customers): An energy audit provides a clear description of what needs to be done to make the house more energy efficient and can help customers to develop an actionable plan; although audits are only utilized by some HESP participants, it may be an important causal mechanism for those participants. In addition, EMT offers instructional videos on heat pump installation and use.
3. Vetting contractors (customers): EMT's contractor list provides customers with a pre-selected list of contractors, which simplifies the process; EMT's role as a trusted advisor and also conducting inspections as a regular part of program delivery may allay customers' concerns about the quality of the work, the reliability of the contractor, and the performance of the equipment.
4. Supporting EE contractor infrastructure (contractors): A number of the program activities are designed to try to build the contractor infrastructure, including the contractor list and marketing to increase leads, the scholarships for heat pump training, inspections to provide feedback on quality of work, newsletters, etc. This support may make contractors more willing to make investments in equipment and devote more of their time and resources to EE installations.
5. Upselling EE equipment (contractors): As a result of the program and the infrastructure support, contractors may find EE measures more profitable and be more willing to encourage the installation of EE equipment more actively, both inside and outside of the program.
6. EMT branding (both customers and contractors): Program staff indicated that they see the EMT brand as a key factor in the success of the programs as it leverages the program activities beyond the actual impact of specific actions. For example, the rebates are 17% of the incremental costs on average, which is a relatively small proportion, but the EMT brand helps to encourage customers and contractors to pursue the EMT-supported EE options.

These casual mechanisms are tied to the program activities and outcomes in Table J-2 below.

TABLE J-2: CAUSAL MECHANISMS AND OUTCOMES

Program Activity	Causal Mechanism	Outcomes	
		Customers	**Contractors**
Rebate/Loan	Reduce first costs	Generate buzz, encourage follow through, mitigate first costs	Provides hook to start conversation about EE, increases closure rates
Marketing	Support contractor infrastructure	Generate interest in program and installing EE measures	Promotes awareness of the program and generates leads
Energy Audit/ Email Newsletter/ Instructional Videos	Customer education	Provides road map for EE upgrades, customer education on heat pumps, easier to move forward with EE measures	
Contractor List	Provide customers with vetted contractors	Simplify process, increase trust and credibility, improve quality of work and customer satisfaction	
Vendor Agreement/Inspections, Marketing, and Training Scholarships	Support contractor infrastructure		Improve profitability, increase time and resources on EE, gain expertise, more worthwhile to do EE
Rebate, contractor list and contractor support	Contractors upsell equipment		Contractor recommend EE equipment more frequently or actively due to program support and rebates
EMT Branding	EMT branding	Generates trust, customers and contractors are more likely to engage in program activities	

The table above maps the causal mechanisms to specific program activities and outcomes for customers and contractors. This step is an important part of establishing causality between the program and changes in the market. As part of the NTG approach, we will investigate how the causal mechanisms changed behavior (outcomes) for customers and contractors.

J-4 Causal Mechanisms and Barriers

The final step is to make the connection between the causal mechanisms and the barriers. For the Barriers Approach, this connection is the underlying support for program influence. The surveys will use the causal mechanisms, along with other nonprogram-related factors, to assess how HESP is overcoming the barriers to the installation of EE measures.

Barriers to installation of EE measures are different for customers and contractors. We have worded the barriers as they are understood by customers and contractors. Key barriers for contractors fall into the following categories:

1. Lack of demand/customer acceptance
2. Lack of trust in contractors
3. Lack of availability of EE equipment
4. Equipment concerns (performance uncertainty)

For customers, the most common barriers are as follows:

1. Lack of information, e.g., they do not understand the savings potential or are not sure what to install
2. Lack of trust in contractors
3. Money, e.g., upfront costs or concerns about payback or return on investment
4. Equipment concerns

Table J-3 matches up the causal mechanisms to the barriers for contractors and customers, respectively.

Table J-3: Causal Mechanisms and Barriers for Customers and Contractors

Causal Mechanism	Contractor Barrier	Customer Barrier
Reduce first costs	Lack of demand	Money
Customer Education	Lack of demand/customer acceptance	Information, Equipment Concerns (performance uncertainty)
Vet contractors	Lack of trust	Lack of trust
Support contractor infrastructure	Lack of trust, lack of demand	Lack of trust, information
Upsell equipment	Lack of availability, lack of demand	Information
EMT branding	All	All

J-5 Conclusions

The discussion above explains how the program activities relate to the causal mechanisms and intended outcomes. The use of the causal mechanism is different for the two NTG approaches.

- **Enhanced Self Report:** The enhanced self-report involves asking one or more key participant decision-makers a series of closed and open-ended questions about whether they would have installed the same EE equipment in the absence of the program (the counterfactual world), whether they found out about the program before or after they decided to install the efficient equipment (temporal sequence), as well as questions regarding the influence of both program and nonprogram factors. Verifying the causal mechanisms allows us to be confident that the changes are related to specific program activities.
- **Barriers Approach:** This approach has two stages – first, determining the relative importance of the barriers (Barriers score) and then assessing the role of the program in overcoming each barrier (Program Contribution score). The second stage calls for assessing both the nonprogram and program influences to overcome the barriers. The causal mechanism defines the program influences.

This analysis of causal mechanisms will be used to develop the NTG algorithms and survey instruments for customers and contractors.

We are looking forward to feedback from EMT HESP program staff.

Appendix K

Memo on Cognitive Interview Results

Appendix K: Memo on Cognitive Interview Results

MEMORANDUM

TO:	Laura Martel, Efficiency Maine Trust
FROM:	Kathryn Parlin and Jenna Bagnall-Reilly, West Hill Energy
	Lori Lewis, Analytical Evaluation Consultants
DATE:	May 17, 2017
RE:	Summary of Cognitive Interview Results

The customer cognitive interviews were designed to test HESP causal mechanisms, i.e., how the program is intended to promote and encourage the installation of energy efficiency (EE) measures.[1] Testing causal mechanisms requires determining if EMT's services, outreach or educational offerings were instrumental in encouraging participants to move forward with the energy efficiency installations. The cognitive interviews also helped us to understand the decision-making process in a more nuanced way. There are two stages to this process:

1. Identifying the specific EMT offerings used by the participant
2. Investigating how these offerings assisted the participant

The HESP program is designed to approach customers from multiple directions, and to provide multiple channels to meet participants' needs. These interviews were designed to try to identify the variety of specific EMT offerings that are most commonly used by program participants. These results will inform the design of the customer survey instruments.

Ten (10) interviews were completed between March 29, 2017, and April 12, 2017. Interviewees were contacted by phone and by e-mail. These interviews were not intended to be representative of the entire program population; rather, our goal was to talk with participants who could describe how they were affected by the program. Several of the respondents participated in the surveys because of their positive interactions with EMT. Since we were trying to confirm that we fully understand how EMT influences customers to install efficiency measures, it is beneficial to have respondents who are enthusiastic about EMT. However, the responses shown below should be interpreted in that light.

HESP casual mechanisms and intended outcomes for customers are copied below from the causal mechanism memo, for context.

[1] See the memo on causal mechanisms, dated March 2, 2017.

TABLE K-1: CAUSAL MECHANISMS AND OUTCOMES

Causal Mechanism	Customer Outcomes
Reduce first costs	Generate buzz, encourage follow through, mitigate first costs
Customer education	Provides road map for EE upgrades, customer education on heat pumps, easier to move forward with EE measures
Provide customers with vetted contractors	Simplify process, increase trust and credibility, improve quality of work and customer satisfaction
EMT branding	Generates trust, customers and contractors are more likely to engage in program activities

Summary of Results

Overall, the results of the interviews indicate that the causal mechanisms are working for these survey respondents. As would be expected, specific EMT offerings work better for some respondents than others.

TABLE K-2: CAUSAL MECHANISMS AND RESPONSES

Causal Mechanism	EMT Offerings	Importance to Respondents[1]
Reduce first costs	Rebates	Moderate
Customer education	Website	Moderate
	Energy audit	Moderate/High
	Savings calculators	Possible
	Case studies	Possible
	Newspaper/magazine articles	Possible
	Instructional videos	Low
	Booth at events	Moderate
	Electric meter loan	Low
EMT Branding	Trusted source of EE information	High
	Help to figure out what to install	High
	More willing to invest in EE	High
	Increased interest in EE	Mixed
Provide customers with vetted contractors	Contractor list	Moderate
	Post installation inspection	High (Insulation/Air Sealing) Low (Heat Pumps)

[1] Note that the cognitive interview respondents are not expected to be representative of all HESP program participants.

K-1 First Costs

From previous experience, we have found that responses to questions about the cost barrier can be inconsistent. For example, some respondents may say that cost was not a barrier and then later respond that the rebate was important in their decision to install the efficiency equipment.

For this reason, we tried a different approach. We first asked the barrier question, and four of the ten respondents listed money as a barrier. We then asked follow-up questions about funding. Respondents were asked to agree or disagree with statements regarding four aspects of concerns about money:

1. Covering the upfront costs
2. Needing financing
3. Concerns that savings are uncertain
4. Concerns about payback or return on investment

Three respondents were asked this series (two identified money as a barrier and one who did not). All three of them either strongly or somewhat agreed with at least one of these statements, even the one respondent who did not list money as a barrier, suggesting that this approach may also produce inconsistent responses. At the end of the survey, we asked this participant whether the wording of the questions about the cost barrier worked; he did not provide a direct response.

We have to acknowledge that the cost barrier is complex and likely to vary by measure. One respondent who installed a heat pump volunteered that the difference in price between the standard and efficient model is not very large.

Due to these results, we made changes to the survey instrument to try to obtain more consistent responses by assessing the cost barrier in three ways:

1. By asking for agreement/disagreement with the four statements about costs
2. By offering costs as an option under the barriers question
3. Prompting the respondent to add the cost barrier if they agreed with one or more of the initial four statement but did not select the cost barrier
4. By asking the program contribution for the rebate for all respondents, whether or not they listed cost as a barrier as a check on consistency.

We will try to monitor the responses to the full-scale survey for consistency.

K-2 Customer Education

Nine of the respondents were asked about customer education. Of the 9 respondents, 7 listed both EMT and non-EMT sources of information that were important to their decision to install the measure. Two listed only EMT sources of information. This is consistent with our past research, indicating that customers obtain information from a variety of sources.

As energy audits are required for air sealing and insulation work, two of the three respondents had an audit by an EMT-registered energy auditor and the third was not sure if the auditor was EMT-registered or not. Two of the seven respondents with efficient heating equipment had an audit through EMT. All five respondents rated the audit highly for "…providing … a reliable estimate of energy or dollar savings" and "encouraging you to take action to improve the efficiency of your home."

K-3 EMT Branding

Prior to contact with EMT, the cognitive interview respondents rated themselves as very interested and moderately to very knowledgeable in EE. Following their interactions with EMT, they reported the following changes in their level of interest:

- All three of the interviewees who installed insulation reported that they were a lot more interested in EE.
- Of the four interviewees who installed a boiler (1) or heat pump (3) and were asked the question, 2 indicated their interested in EE was higher and 2 said it was the same.

While none of these respondents indicated that lack of interest in EE was a barrier for them, these responses suggest that direct interaction with EMT does generate additional interest.

We asked about the EE actions taken prior to participation in EMT's programs, and most of the respondents had taken a wide range of EE actions, including insulation, air sealing (a couple with blower door tests), high efficiency heating systems, Energy Star appliance, new windows, efficient lighting and other behavioral actions. One respondent specifically tied these actions to their frugality.

EMT staff suggested that the case studies, engaging customers on social media and encouraging word of mouth are approaches they use to try to overcome lack of interest in EE. Many of these interviewees were older and were not necessarily inclined toward using social media. Some relevant responses are provided below:

- Two respondents mentioned the importance of their rental or apartment associations in learning about EMT.
- One respondent discussed how he personally spreads the word about EMT.
- One respondent mentioned reading the case studies on the EMT website.
- One respondent clearly remembered seeing ads for EMT on an Internet site such as Pandora or Hulu

We did not explicitly ask whether they follow EMT on Facebook or Twitter; this option could be included in the final survey.

All of the respondents strongly agreed that EMT is a "trusted source of information about energy efficiency," suggesting that EMT endorsement increases creditability and trust. Almost all of the respondents somewhat or strongly agreed that their "experience with Efficiency Maine has made [them] more willing to invest in improving the efficiency of [their] home[s]."As these respondents had already installed EE measures prior to participating in the program, this reflects the portion of the population that had a high preexisting awareness of EE.

A few respondents volunteered that they had previously participated in EMT programs, although the survey responses suggest that barriers for specific measures persist even for prior participants, i.e., installing one measure through EMT's programs does not mean that the participant is knowledgeable about, and ready to install, other measures that may be appropriate for their home. Thus, prior participation could increase interest in energy efficiency but not necessarily result in the installation of other measures without additional EMT intervention and support.

One respondent gave an eloquent description of his discovery of EMT. He went into a Home Depot about ten years ago and saw a promotion for CFL's by EMT. Then the "lights turned on" and he began noticing EMT advertisements elsewhere. EMT "opened their eyes, raised awareness of how easy it is, what you can do on your own," and how you can achieve big savings with EE.

K-4 Contractors

The cognitive interviews suggest that contractors are key in the decision-making process. Of the eight respondents who were asked questions on this topic, all reported that their contractor was strongly or extremely important in providing the information needed for them to move forward with the installation. Three respondents used the EMT -registered vendors listed on the website and one respondent referenced the list but then selected a different EMT-registered contractor.

One respondent focused on the key role of the contractor and expressed the opinion that the contractor's ability to close the sale and the customer's trust in the contractor are critical components of the program. Three respondents used a contractor they knew and had previously used. One respondent selected a contractor from the EMT list and then discovered it was the relative of a friend. He clearly stated that finding out about the personal connection "cemented [the contractor's] credibility."

For the heating systems (boiler and heat pumps), three of the five responses identified the contractor's influence as the only important or most important influence on the decision to install. For air sealing and insulation, the respondents placed their own knowledge as equal to or more important than the contractor's influence.

As we have found in other, similar research, respondents were primarily motivated to install the EE measures by saving energy or reducing energy bills and improving the comfort of their homes. For the heat pumps, respondents overwhelmingly (5 out of 6) reported that adding air conditioning was strongly or extremely important motivation.

K-5 Feedback on Survey Questions

At the end of the survey, we asked respondents if they found it difficult to answer the questions. The comments from the four respondents who identified issues are provided below:

- Hard to answer question on my level of research and judging the reduction in consumption

- Yes, I had to think
- Time barrier question was difficult (mentioned by two respondents, question has been reworded)
- A little wordy, hard to remember when there was series of five responses; may be easier on the web but the response rate may be lower

In response to our other follow-up questions, one respondent noted that the relative importance questions were difficult for her, another mentioned the overall length and one expressed concern about the questions on "financial status." We can add a "Don't know" or refused option for those questions so no one has to answer them if they feel uncomfortable with it.

K-6 Conclusions

The cognitive interviews confirmed the HESP causal mechanisms outlined in Table K-1: Causal Mechanisms and Outcomes, which we can now be incorporated into the NTG questions for both the self-reports and barrier approaches. The strategy for each NTG approach is described below.

- **Self-reports**
  - Inquire about all causal mechanisms
  - Ask about program influence if respondent identifies at least one causal mechanism as important
- **Barrier Approach**
  - Inquire about all causal mechanisms
  - Identify the barriers experienced by the respondent
  - Define program activities that overcame the barriers based on causal mechanisms identified by the respondent

Questions will be worded to ask respondents to rate the importance of causal mechanisms on their decision to install the EE measure(s). The following table shows our approach to confirming the causal mechanisms.

Table K-3: Confirmation of Causal Mechanisms

Causal Mechanism	Confirmation of Causal Mechanism
Reduce first costs	Importance of incentives/rebate on decision to install
Customer education	Information from EMT was important for moving forward with the installation
Vetting contractors	EMT contractor list was important in deciding who to hire
EMT Branding	Questions will measure knowledge gained and increase in willingness to make EE investment based on familiarity with EMT

Appendix L

Net-to-Gross Method and Approach

Appendix L: Net-to-Gross Method and Approach

This section provides a detailed description of how the net-to-gross (NTG) calculations were made. The first section covers the free rider (FR) calculations and the second describes the process for estimating spillover (SO). The net-to-gross ratio (NTGR) was estimated for air sealing and insulation measures and for ductless heat pumps.

L-1 FR Approach

The method for estimating FR required combining the self-report and program influence methods. Two customer detail surveys were used to estimate the NTGR for the evaluated measures:

1. Unregulated fuels survey for air sealing and insulation
2. Heat pump NTG/Program Influence survey

The survey instruments can be found in Appendix E and the survey dispositions are presented in Appendices F and G. This section describes these two methods and how the estimates were combined to obtain an adjusted FR.

L-1.1 FR Self-Report Approach

The foundation of the self-report method is to inquire about what the participants would have done in the absence of the upstream rebates. Standard self-report questions were used.

Table L-1: Customer Self-Report Free Rider Questions and Scoring for Heat Pumps

Question	Response	Free Rider Rate
If you had not participated in Efficiency Maine's program, what would you have installed?[1]	Definitely would have installed a less efficient heat pump	FR = 0%
	Probably would have	FR = 25%
	Not sure	FR = 50%[2]
	Probably would have installed a heat pump of the same or higher efficiency	Initial FR = 75%, continue
	Definitely would have	Initial FR = 100%, continue
	Would not have installed a heat pump of any type	FR = 0%
If you had not participated in Efficiency's Maine's program, would you have installed the ductless heat pump. . .	Within 6 months	Adjusted FR = Initial FR x 100%
	6 months to one year	Adjusted FR= Initial FR x 50%
	Over one year	Adjusted FR=0%
	Don't know	Adjusted FR= Initial FR x 50%

[1] This example is from the heat pump survey. The first question was omitted from the survey for the insulation and air sealing measures and the wording and rebate amounts were adjusted as appropriate.
[2] A sensitivity analysis was conducted by removing the "not sure" responses and the FR rate was very close with and without these responses.

L-1.2 Estimate Program Influence

Program influence was estimated for each survey respondent via a two-step process:

1. Determine how program affected the participant (causal mechanisms)
2. Quantify the contribution of the program in comparison to other influences

If the participant did not identify any causal mechanisms that they used, then the program influence was assumed to be zero.

Five main causal mechanisms for the program to promote the energy efficiency upgrade were identified:

1. Reduce first cost through rebates
2. Offer a list of registered contractors to assist customers
3. Provide key information about the measure and installation
4. Address customers' concerns about the equipment or installation
5. Reduce the amount of time required for the participant to install the efficiency upgrade

All participants received the rebate, so the program influence question about the rebate was asked of all participants. In addition, all participants were required to select from the EMT list of registered contractors. However, participants did not necessarily have to use the list to select a contractor, *e.g.*, they may have a previous relationship with a registered contractor and decide to use them without use of EMT's list. The causal mechanisms are discussed in more detail in Appendices J and K.

To assess how the program influenced participants, the following process was used:

1. Determine the specific HESP offerings recognized and used by the respondents
2. Assess whether the respondent was influenced by both program and nonprogram factors related to the identified causal mechanism(s)
3. Quantify the HESP influence in comparison to nonprogram influences for each of the identified causal mechanism(s) through pairwise questions

The initial survey question simply asked whether the participant had taken advantage of any of these HESP offerings: 1) home energy audit, 2) EMT's website, 3) EMT articles in newspapers, magazines or websites, 4) EMT's list of registered contractors, 5) the HESP rebates and/or 6) an EMT energy loan. Based on the responses to this question, the causal mechanisms that could have been used by each participant were identified. The EMT offerings were matched to the causal mechanisms in Table L-2.

TABLE L-2: HESP OFFERINGS MATCHED TO CAUSAL MECHANISMS

HESP Offerings	Causal Mechanisms: Reduce First Cost	Finding a Contractor	Information Source	Equipment Concerns	Saving Time
Energy Audit		✓	✓	✓	✓
Website		✓	✓	✓	✓
Informational Articles			✓	✓	✓
Contractor List		✓		✓	✓
Rebate	✓				
EMT Energy Loan	✓				

The program influence questions were only asked for causal mechanisms that were linked to the specific HESP offerings identified by the respondent, with one exception: the program influence question for the rebate was asked of all respondents, even if initially they did not recall receiving it.[1] In both of the HESP surveys, almost all of the respondents recalled receiving the rebate.

An example of the two questions used to quantify program influence is given below.

> *The next question is about how you decided to pay for the ductless heat pump. Let's consider the funding sources in two groups:*
>
> > **Incentives** *are the rebates [IF EMT1_6 == "Y", ADD: "and loan"] from Efficiency Maine.*
> >
> > **Personal sources** *include other funding sources that were important to your decision-making process, including personal savings or other non-EMT loans, tax credits or rebates from sources other than Efficiency Maine.*
>
> *Thinking only about what* **tipped your decision to pay** *for the high efficiency ductless heat pump, which statement is closest to how you made your decision?*
>
> 1. *The Efficiency Maine incentives were more important than personal sources of funding.*
> 2. *Personal sources were more important than the incentives.*
>
> 96. *Don't know*
>
> *[The words in green were highlighted for emphasis in the web survey.]*

[1] This decision was made based on previous experience suggesting that respondents may not initially recall the rebate but will later identify the rebate as a key part of their decision-making process. This is more of an issue in upstream programs where the discount may not be as obvious to the customer.

[Assume option 1 was selected.] Comparing the Efficiency Maine incentives to personal funding sources, how would you rate the importance of the Efficiency Maine incentives? Were the Efficiency Maine incentives . . .

1. *1 - about the same as personal funding sources*
2. *2*
3. *3*
4. *4*
5. *5*
6. *6 - Efficiency Maine incentives were the only important factor*

Table L-3 below shows how the program influence score was calculated.[2]

TABLE L-3: CALCULATION OF THE PROGRAM INFLUENCE SCORE FOR DUCTLESS HEAT PUMPS

	Program Influence Score (1-FR)	
	Incentives more important	**Other influences more important**
1 - About the same importance	50%	50%
2	60%	40%
3	70%	30%
4	80%	20%
5	90%	10%
6 - Only one factor was important	100% (selected)	0% (not selected)

The final program influence score for each respondent was the maximum value of the program influence scores over all the causal mechanisms selected by the respondent.

[2] In the ductless heat pump survey, a numerical scale was selected to match the balanced scale. The air sealing/insulation survey described the categories in words: "about the same, slightly more important, moderately more, extremely more" and "the only important factor." In a previous study, we tested the wording using a balanced scale and an alternative, non-linear scale giving less weight to "slightly" and "moderately" and more weight to "strongly" and "extremely" and the change in scale had little effect on the NTGR's (less than 1%).

L-1.3 Combining Self-Report Free Ridership and Program Influence

The self-report NTGR (1-FR, excluding spillover) and program influence score (reflecting the contribution of the program to the decision) were combined for each survey respondent using the following rules:

1. If both the self-report and program influence questions were answered by the respondent, the responses were averaged
2. If only the self-report questions were answered, the self-report NTG was used

The self-report questions were answered for all respondents, so no additional adjustments were necessary. The combined NTGR was used for the final estimate.

L-2 Spillover

There are several types of spillover (SO) generated by energy efficiency programs:

- Inside spillover: participants install more energy efficiency measures outside of the program due to their positive experience in the program
- Outside spillover: participating contractors and vendors recommend and install efficiency measures outside of the program due to their experiences with the program
- Nonparticipant spillover: nonparticipants hear about efficiency measures indirectly as a result of energy efficiency programs and decide to install efficiency upgrades on their own

In this evaluation, only participant inside SO was estimated. SO was determined from participant surveys. As with FR, the final estimate combined self-reports and program influence. The approach involved several steps:

1. Determine whether additional energy-savings measures were installed after the program reported measure(s)
2. Assess whether the measure was installed outside of an EMT program, including comparing installations to HESP program records to remove measures installed through the program
3. Adjust for the contribution of the program to the installation using self-report and program influence
4. Estimate the energy savings per home for the additional measures based on program reported savings (where applicable), the Maine TRM or other TRM's and/or other relevant evaluations
5. Aggregate the SO savings by measure and for the program

As with FR, both self-report and program influence approaches were used to estimate the EMT influence.[3] The wording of the self-report likelihood question was similar to the FR question and was asked for each spillover measure installed. The program influence question was asked for all spillover installations as a group and was only asked if the respondent indicated that they had positive interactions with EMT.[4] These steps are described in more detail below.

L-2.1 SO Measures Installed

The measures identified as having SO potential are listed below with the type of savings and source in Table L-4.

TABLE L-4: SO MEASURES, SAVINGS AND SOURCES

Measure	kWh	Winter Peak kW	Summer Peak kW	MMBtu	Source of Savings Estimate
Attic Insulation	✓		✓	✓	HESP Program Installed Average x 45%
Wall Insulation	✓		✓	✓	HESP Program Installed Average x 45%
Basement Insulation	✓		✓	✓	HESP Program Installed Average x 45%
Blower-Door Assisted Air Sealing	✓		✓	✓	HESP Program Installed Average x 45%
ES Furnace[1]				✓	HESP Program Installed Average
ES Boiler[1]				✓	HESP Program Installed Average
Minisplit Heat Pump	✓	✓	✓		HESP Program Installed Average
ES Room A/C[2]	Savings too small		✓		EMT TRM
ES Clotheswasher[2]	✓	✓	✓		EMT TRM
ES Dishwasher[2]	Savings too small	✓	✓		EMT TRM
ES Dehumidifier[2]	✓		✓		EMT TRM

[1] Based on the results of a recent study conducted for NYSERDA, indicating that insulation measures installed outside of the program save about 45% of measures installed through the program. See Section 12, References in the main report.
[2] ES = ENERGY STAR®

In the air sealing/insulation survey, respondents were asked to identify all measures installed, when the measure was installed and whether a rebate from EMT was received. In the heat

[3] The self-report questions were asked for each measure; the program influence questions were asked for all additional measures as a group due to survey length.
[4] Positive interactions included stating that their experiences with EMT made them more likely to install energy efficiency equipment, they consider EMT a trusted source of information about energy efficiency and/or they are likely to take advantage of EMT services in the future. A large majority of respondents agreed with one or more of these statements.

pump survey, this set of questions was modified to reduce survey length; respondents were asked to identify only measures that were not rebated and were then asked when the measure was installed.

SO measures were restricted to those measures installed after participation in HESP based on the dates provided by the survey respondents. In addition, all claimed installations were compared to the HESP program participation data and removed if the measure had been installed through the program. This process covered both Steps 1 and 2 in the list in L-2 above.

L-2.2 SO Program Influence

Both self-report and program influence approaches were used to estimate the EMT influence.

Self-Report

The wording of the self-report likelihood question was similar to the FR question and was asked for each spillover measure installed:

> *Would you have installed the efficiency upgrade if you had never participated in an Efficiency Maine program? [Emphasis in the original]*
>
> 1. *Definitely not*
> 2. *Probably not*
> 3. *Not sure*
> 4. *Probably would*
> 5. *Definitely would*

The self-report calculation was done as shown in the first question of Table L-1.

Program Influence

The program influence questions were asked for all measures as a group to avoid excessive survey length. The wording of the program influence questions is provided below.

> *The next question is about how you decided to install these efficiency measures outside of the Efficiency Maine programs. Let's consider the influences that contributed to your decision in two groups:*
>
> *Your previous experience with Efficiency Maine, which may have increased your awareness of energy efficiency upgrades.*
>
> *Other factors, including all other influences on your decision.*
>
> *What was more important to your decision to install these efficiency upgrades?*
>
> 1. *Your experiences with Efficiency Maine*
> 2. *Other influences*
>
> 96. *Don't know*

[Assume Option 1 was selected.]

Comparing your experiences with Efficiency Maine to other influences, how would you rate the importance of your experiences with Efficiency Maine? Were your experiences with Efficiency Maine …

1. *1 - about the same as other influences*
2. *2*
3. *3*
4. *4*
5. *5*
6. *6 - your experiences with Efficiency Maine was the only important factor*

96. *Don't know*

The program influence scores were calculated as shown in Table L-3 above. This part of the analysis completes Step 3 as listed in Section L-2.

L-2.3 Additional Heat Pump SO

During the analysis period, rebates were offered for only one heat pump installed at the same location in the same year. However, the heat pump survey indicated that some participants installed multiple units at the same time or within a year. In these cases, the additional installations were also considered to be spillover.

No specific self-report questions were asked about the extra heat pumps installed at the same time as the rebated units as this eventuality was not anticipated. The proportion of the savings attributed to the program were estimated from the program influence questions given in Section L-2.2, as these questions are the most general for all SO measures.

L-2.4 SO Calculation

For each survey respondent, the SO upgrades installed after HESP program participation was identified and the self-report NTG and program influence (PI) score were calculated. The two measures of program influence (NTG and PI score) were averaged as described in Section L-1.3. The SO savings were estimated as follows:

$$SO\ Savings = Units_{installed} \times PI_{combined}$$

Where

SO Savings are the savings per survey respondents

$Units_{installed}$ are the number of units installed by the respondent, which was 1 for all measures except heat pumps

$PI_{combined}$ is the average value of the self-report NTGR and the program influence score

The SO savings were aggregated over all respondents to obtain the total SO savings, which was divided by the total program reported savings during the evaluation period to determine the SO as a percent of program savings.

This process was conducted separately for kWh and MMBtu. The final estimate for the program was determined by converting the both the SO and total program reported kWh to MMBtu and calculating the SO as percent of the total program reported MMBtu. The standard conversion factor of 3,412 Btu/kWh was used.

Appendix M

Benefit-Cost Analysis Details

Appendix M: Benefit-Cost Analysis Details

M-1 BCR Equations

This section provides the equations used to calculate the benefit cost ratios for the Primary Benefit Cost Test (PBCT) and Program Administrator Cost Test (PACT). For both the PBCT and the PACT the avoided cost categories are:

- Avoided utility energy costs
- Avoided utility capacity costs
- Avoided utility Transmission & Distribution costs
- Avoided social costs of Greenhouse Gas Emissions (monetized)
- Avoided Renewable Portfolio Standard (RPS) compliance costs
- Avoided customer unregulated fuels costs

EQUATION M- 1: PBCT

$$Costs_{trc} = \sum_{t=1}^{N} \frac{Admin_t + NTGR * Max(Meas\$_t +, Incent_t) + (1 - NTGR) * ({}_tIncent_t)}{(1+d)^t} + \sum_{t=1}^{N} \frac{EC_t}{(1+d)^t}$$

Where

$Admin_t$= Program administrative costs
NTGR= Net-to-gross ratio
$Meas\$_t$= Incremental costs (*before* Rebate is received)

$Incent_t$= Incentive to participant
EC_t= Supply costs for the *net* additional fuel use in year t

d= Discount rate

$$Benefits_{trc} = \sum_{t=1}^{N} \frac{AC_t}{(1+d)^t}$$

Where

AC_t= Avoided costs in year *t* based on *net* program savings (i.e., adjusted gross kWh, kW, therms, and MMBtu savings multiplied by the NTGR)

d= Discount rate

t= The number of periods over which future values are discounted, specific to measure life.

EQUATION M- 2: PACT

$$B_{pa} = \sum_{t=1}^{N} \frac{AC_t}{(1+d)^t}$$
$$C_{pa} = \sum_{t=1}^{N} \frac{Admin_t + Incent_t}{(1+d)^t} + \sum_{t=1}^{N} \frac{EC_t}{(1+d)^t}$$

Where

AC_t=	Avoided costs in year *t* based on *net* program savings (i.e., adjusted gross kWh, kW, therms, and MMBtu savings multiplied by the NTGR)
$Admin_t$=	Program administration and marketing costs in year *t*
$Incent_t$=	Incentive to participant
EC_t=	Supply costs for the *net* additional fuel use in year t
d=	Discount rate
t=	The number of periods over which future values are discounted, specific to measure life

The basic Cost Benefit Analysis Tool (CBAT) calculations are presented below.

EQUATION M-2: PBCT (CBAT)

TotalBenefit = (ElectricNPV+ NonElectricNPV) * (1 - FreeRidershipRate + SpilloverRate)

Where

ElectricNPV =	WinterPeakkWhNPV + WinterOffPeakkWhNPV + SummerPeakkWhNPV + SummerOffPeakkWhNPV + WinterkWNPV + SummerkWNPV + WinterkWTandDNPV + SummerkWTandDNPV
NonElectricNPV =	ThermsNPV + PropaneNPV + WoodNPV + KeroseneNPV + HeatingOilNPV + WaterNPV
NPV=	Net present value
TandD=	Transmission and distribution

TotalCost = TotalCost = ((ParticipantCost) + (-1 * NegativeSavingsNPV[a]))*

(1 - FreeRidershipRate + SpilloverRate) + ProgramCostNPV + Incentive

Where

ParticipantCost =	CASE WHEN MeasureCostAmount - IncentiveAmount <= 0 THEN 0 ELSE (MeasureCostAmount – IncentiveAmount)
NegativeSavingsNPV =	ElectricNPVNeg + NonElectricNPVNeg
ProgramCostNPV[b] =	ProgramDeliverCost + MarketingCost + EvaluationCost[c] + ProgramPlanningCost
NPV=	Net present value

[a] Negative savings indicate a fuel switch or interactive effect that results in additional energy use for a given fuel type. The costs of the additional energy use are calculated against the same avoided costs used for savings and added to the cost side of the C/E calculation.

[b] Note that program costs are not included in measure level and are included in program level cost-effectiveness screening.

[c] Note that evaluation costs are not included in program level and are included in portfolio level cost-effectiveness screening.

EQUATION M-3: PACT (CBAT)

TotalBenefit = (ElectricNPV+NonElectricNPV) * (1–FreeRidershipRate+SpilloverRate)

Where

ElectricNPV =	WinterPeakkWhNPV + WinterOffPeakkWhNPV + SummerPeakkWhNPV + SummerOffPeakkWhNPV + WinterkWNPV + SummerkWNPV + WinterkWTandDNPV + SummerkWTandDNPV
NonElectricNPV=	ThermsNPV + PropaneNPV + WoodNPV + KeroseneNPV + HeatingOilNPV + WaterNPV
NPV=	Net present value
TandD=	Transmission and distribution

TotalCost = (ProgramCostNPV + IncentiveCost) + (-1 * NegativeSavingsNPV)

Where

NegativeSavingsNPV=	(ElectricNPVNeg + NonElectricNPVNeg) * ((1 – FreeRidershipRate) + SpilloverRate)
ProgramCostNPV=	ProgramDeliverCost + MarketingCost + EvaluationCost + ProgramPlanningCost
NPV=	Net present value

Note: Negative savings indicate a fuel switch or interactive effect that results in additional energy use for a given fuel type. The costs of the additional energy use are calculated against the same avoided costs used for savings and added to the cost side of the C/E calculation

Table M- 1: Base Case Inputs For Each Measure

	Per Unit Savings[1]												
Measures	**kWh**	**Winter kW**	**Summer kW**	**Therms**	**Propane**	**Oil**	**Kerosene**	**Wood**	**Measure Cost**	**FR**	**Energy RR**	**Demand RR**	**SO**
Air Sealing	55	0.000	0.023	10.54	0.72	6.44	0.19	1.07	$708	0.300	0.447	0.447	0.029
Attic Insulation	130	0.000	0.044	24.38	1.58	12.71	1.04	2.03	$2,656	0.300	0.573	0.573	0.029
Attic Insulation (NG Only)	39	0.000	0.069	300.62	0.00	0.00	0.00	0.00	$2,617	0.300	0.622	0.622	0.029
Basement Insulation	168	0.000	0.011	37.71	3.07	24.17	2.00	4.01	$2,744	0.300	0.253	0.253	0.029
Wall Insulation	645	0.000	0.156	81.03	4.92	43.80	3.49	7.55	$2,797	0.300	0.157	0.157	0.029
Ductless HP	1,902	0.000	0.000	0.00	0.00	0.00	0.00	0.00	$682	0.420	0.587	0.587	0.110
Ductless HP second head/unit	1,902	0.000	0.000	0.00	0.00	0.00	0.00	0.00	$682	0.420	0.587	0.587	0.110
Boiler	-	0.400	0.050	81.81	6.92	0.83	0.02	0.00	$1,736	0.345	0.642	0.642	0.060
Furnace	-	0.400	0.050	72.10	7.95	1.86	0.60	0.00	$1,511	0.345	1.000	1.000	0.060
Pellet Boiler	-	0.000	0.000	0.00	37.02	36.14	0.00	-45.68	$12,942	0.345	1.000	1.000	0.060
Pellet Stove	-	0.000	0.000	0.00	0.00	0.00	0.00	21.10	$3,000	0.345	1.000	1.000	0.060
Wood Stove (72%->75%)	-	0.000	0.000	0.00	0.00	0.00	0.00	21.08	$3,000	0.345	1.000	1.000	0.060
Central Heat Pump	2,806	0.402	0.038	0.00	0.00	0.00	0.00	0.00	$2,000	0.345	1.000	1.000	0.060
Geothermal HP Closed Loop	-6,592	-2.048	-0.014	0.00	0.00	109.63	0.00	0.00	$23,258	0.345	1.000	1.000	0.060
Geothermal HP Open Loop	-6,604	-2.048	-0.012	0.00	0.00	109.90	0.00	0.00	$23,941	0.345	1.000	1.000	0.060

[1] All values are gross. Unregulated fuel units are MMBtu.

M-2 Sensitivity Analysis Results

The results for each of the tests completed as part of the sensitivity analysis are presented below. Each test was run one-at-a-time, as described in Section 9.1.3 of the report.

Removing Cost of Incentives Paid to Free Riders

After calculating the verified ex ante BCRs in Section 9.1.2 of the report, the results were compared to the BCRs produced by removing the cost associated with paying incentives to free riders. Table M- 2 presents the results of this comparison[1].

As expected, the improvement in the PBCT results at both the measure-level and program-level are substantial—around 11% overall—ranging as high as 25% for certain measures.

TABLE M- 2: PBCTS AFTER EXCLUDING INCENTIVES TO FREE RIDERS AS A COST BY MEASURE

Measures	Included as Cost	Excluded as Cost	% Increase
Air Sealing	0.94	1.14	17%
Attic Insulation	1.20	1.32	9%
Attic Insulation (NG Only)	0.62	0.72	14%
Basement Insulation	0.91	1.00	9%
Wall Insulation	1.04	1.15	9%
Ductless HP	1.18	1.57	25%
Ductless HP second head/unit	1.34	1.57	14%
Boiler	1.29	1.45	11%
Furnace	2.78	3.16	12%
Pellet Boiler	0.72	0.76	5%
Pellet Stove	2.76	2.93	6%
Wood Stove (72%->75%)	2.75	2.93	6%
Central Heat Pump	1.24	1.37	9%
Geothermal HP Closed Loop	0.82	0.86	5%
Geothermal HP Open Loop	0.80	0.85	5%
Program-Level	0.99	1.11	11%

[1] This is consistent with the recommendation made in Woolf, Tim, Chris Neme, Marty Kushler, Steven R. Schiller, and Tom Eckman. (2017). *National Benefit-Cost Framework for Assessing Cost-Effectiveness of Energy Efficiency Resources.* Prepared for the National Efficiency Screening Project (p. 99). With respect to the issue of how to treat incentives paid to free riders, the NSPM states: 1) Financial incentives paid to free riders are a cost ***only if*** the cost-effectiveness test ***excludes*** participant impacts; otherwise the value of the financial incentive to the participant offsets the cost of the financial incentive to the utility system. In other words, the net cost of free riders is zero under any test that includes participant impacts. 2) No benefits from free riders should be included in any cost-effectiveness test.

Varying Realization Rates

Realization rates near 100% mean the program's *ex ante* estimates of gross savings matched the *ex post* estimates of gross savings reasonably well. This increases the probability that the expectations regarding the cost-effectiveness of each measure *and* the overall program will be realized. Of course, a high realization rate for a given program year does not guarantee a PBCT or PACT result greater than 1.0 since the *ex post* gross savings (adjusted for free ridership) still have to exceed costs. The purpose of this sensitivity test is to demonstrate the influence of changes in the realization rate on BCR results and to emphasize the importance of accurate *ex ante* estimates in program planning and *ex post* estimates in the evaluation.

The results of increasing and decreasing the realization rates by 30%, 20% and 10% are presented in Table M-3 below.

Table M-3: Higher and Lower Realization Rate Scenarios

		Higher Realization Rates			Lower Realization Rates				Higher Realization Rates			Lower Realization Rates		
	Base Case	+30%	+20%	+10%	-30%	-20%	-10%	Base Case	+30%	+20%	+10%	-30%	-10%	-20%
Measure	**SCT**	**SCT**	**SCT**	**SCT**	**SCT**	**SCT**	**SCT**	**PAC**	**PAC**	**PAC**	**PAC**	**PAC**	**PAC**	**PAC**
Air Sealing	0.94	1.22	1.13	1.03	0.66	0.75	0.84	1.46	1.89	1.75	1.6	1.02	1.16	1.31
Attic Insulation	1.20	1.56	1.44	1.32	0.84	0.96	1.08	6.35	8.25	7.61	6.98	4.44	5.08	5.71
Attic Insulation (NG Only)	0.62	0.81	0.74	0.68	0.43	0.50	0.56	1.21	1.58	1.46	1.34	0.85	0.97	1.09
Basement Insulation	0.91	1.18	1.09	1.00	0.63	0.73	0.82	2.59	3.37	3.11	2.85	1.81	2.07	2.33
Wall Insulation	1.04	1.36	1.25	1.15	0.73	0.83	0.94	3.03	3.94	3.64	3.34	2.12	2.43	2.73
Ductless HP	1.18	1.53	1.41	1.30	0.82	0.94	1.06	1.48	1.92	1.77	1.62	1.03	1.18	1.33
Ductless HP second head/unit	1.34	1.75	1.61	1.48	0.94	1.08	1.21	2.95	3.83	3.54	3.24	2.06	2.36	2.65
Boiler	1.29	1.67	1.54	1.41	0.9	1.03	1.16	3.28	4.26	3.93	3.61	2.3	2.62	2.95
Furnace	2.78	3.62	3.34	3.06	1.95	2.23	2.51	6.68	8.68	8.01	7.35	4.67	5.34	6.01
Pellet Boiler	0.72	0.80	0.78	0.75	0.61	0.65	0.69	3.95	5.14	4.74	4.35	2.77	3.16	3.56
Pellet Stove	2.76	3.59	3.31	3.04	1.93	2.21	2.48	13.18	17.13	15.81	14.49	9.22	10.54	11.86
Wood Stove (72%->75%)	2.75	3.58	3.30	3.03	1.93	2.20	2.48	12.90	16.77	15.48	14.19	9.03	10.32	11.61
Central Heat Pump	1.24	1.61	1.49	1.37	0.87	0.99	1.12	3.91	5.08	4.69	4.30	2.74	3.13	3.52
Geothermal HP Closed Loop	0.82	0.96	0.92	0.87	0.64	0.70	0.76	4.63	6.02	5.56	5.09	3.24	3.70	4.17
Geothermal HP Open Loop	0.80	0.95	0.90	0.86	0.63	0.69	0.75	4.58	5.95	5.49	5.04	3.20	3.66	4.12
Program	0.99	1.24	1.16	1.08	0.72	0.81	0.90	2.17	2.83	2.61	2.39	1.52	1.74	1.96

The program-level PBCT impacts over the Base Case range from 9% to 27%. Program-level PACT increases are of a similar magnitude. This sensitivity of the PBCT and PACT to the realization rate is not surprising since realization rates directly impact the gross benefits but not the costs.

Varying Rates of Free ridership

The results of increasing and decreasing the free ridership rates by 30%, 20% and 10% are presented in Table M-4.

TABLE M-2: HIGHER AND LOWER FREE RIDERSHIP RATE SCENARIOS

		Higher Free Ridership			Lower Free Ridership				Higher Free Ridership			Lower Free Ridership		
	Base Case	+30%	+20%	+10%	-30%	-20%	-10%	Base Case	+30%	+20%	+10%	-30%	-10%	-20%
Measure	SCT	SCT	SCT	SCT	SCT	SCT	SCT	PAC	PAC	PAC	PAC	PAC	PAC	PAC
Air Sealing	0.94	0.86	0.89	0.91	1.01	0.99	0.96	1.46	1.28	1.34	1.40	1.64	1.58	1.52
Attic Insulation	1.20	1.15	1.17	1.18	1.25	1.23	1.22	6.35	5.56	5.82	6.08	7.13	6.87	6.61
Attic Insulation (NG Only)	0.62	0.58	0.59	0.61	0.66	0.64	0.63	1.21	1.06	1.11	1.16	1.36	1.31	1.26
Basement Insulation	0.91	0.86	0.88	0.89	0.94	0.93	0.92	2.59	2.27	2.38	2.48	2.91	2.80	2.70
Wall Insulation	1.04	0.99	1.01	1.03	1.08	1.07	1.06	3.03	2.66	2.78	2.91	3.41	3.28	3.16
Ductless HP	1.18	1.00	1.06	1.12	1.34	1.29	1.23	1.48	1.21	1.30	1.39	1.74	1.65	1.57
Ductless HP second head/unit	1.34	1.22	1.26	1.31	1.45	1.41	1.38	2.95	2.41	2.59	2.77	3.48	3.30	3.13
Boiler	1.29	1.21	1.23	1.26	1.35	1.33	1.31	3.28	2.81	2.96	3.12	3.75	3.59	3.44
Furnace	2.78	2.6	2.67	2.73	2.94	2.89	2.84	6.68	5.71	6.03	6.36	7.64	7.32	7.00
Pellet Boiler	0.72	0.70	0.71	0.72	0.74	0.73	0.73	3.95	3.38	3.57	3.76	4.52	4.33	4.14
Pellet Stove	2.76	2.67	2.7	2.73	2.84	2.81	2.79	13.18	11.27	11.91	12.54	15.08	14.45	13.81
Wood Stove (72%->75%)	2.75	2.66	2.69	2.72	2.83	2.81	2.78	12.90	11.03	11.66	12.28	14.76	14.14	13.52
Central Heat Pump	1.24	1.18	1.20	1.22	1.29	1.28	1.26	3.91	3.34	3.53	3.72	4.47	4.29	4.10
Geothermal HP Closed Loop	0.82	0.79	0.80	0.81	0.84	0.83	0.82	4.63	3.96	4.18	4.41	5.30	5.08	4.85
Geothermal HP Open Loop	0.80	0.78	0.79	0.80	0.82	0.82	0.81	4.58	3.92	4.14	4.36	5.24	5.02	4.8
Program	0.99	0.91	0.94	0.97	1.06	1.04	1.02	2.17	1.85	1.96	2.07	2.5	2.39	2.28

As shown in Table M-4 above, changes in free ridership rates have relatively small effects on the program-level PBCTs because the NTGR (1 – Free ridership) affects both the benefits and the costs. The increases in the program-level PBCT range from approximately 2% to 5%, and as a result, even a 30% reduction in free ridership only pushes one of the six measures that had Base Case PBCTs less than 1.0 to greater than 1.0. The increases in the PACTs are somewhat larger since the NTGR only applies to the benefits and range from approximately 5% to 14%.

While the effects of free ridership on PBCTs and PACTs are relatively small, they have a critical and direct impact on net savings.

Varying Spillover Rates

The results of increasing and decreasing participant spillover rates by 30%, 20% and 10% are presented in Table M-5.

TABLE M-5: HIGHER AND LOWER PARTICIPANT SPILLOVER RATE SCENARIOS

		Higher Spillover			Lower Spillover				Higher Spillover			Lower Spillover		
	Base Case	+30%	+20%	+10%	-30%	-20%	-10%	Base Case	+30%	+20%	+10%	-30%	-10%	-20%
Measure	SCT	SCT	SCT	SCT	SCT	SCT	SCT	PAC	PAC	PAC	PAC	PAC	PAC	PAC
Air Sealing	0.94	0.95	0.94	0.94	0.93	0.93	0.94	1.46	1.47	1.47	1.46	1.44	1.44	1.45
Attic Insulation	1.20	1.21	1.20	1.20	1.20	1.20	1.20	6.35	6.42	6.4	6.37	6.27	6.29	6.32
Attic Insulation (NG Only)	0.62	0.62	0.62	0.62	0.62	0.62	0.62	1.21	1.23	1.22	1.22	1.20	1.20	1.21
Basement Insulation	0.91	0.91	0.91	0.91	0.90	0.90	0.91	2.59	2.62	2.61	2.60	2.56	2.57	2.58
Wall Insulation	1.04	1.05	1.05	1.04	1.04	1.04	1.04	3.03	3.07	3.06	3.05	3.00	3.01	3.02
Ductless HP	1.18	1.22	1.21	1.19	1.13	1.15	1.16	1.48	1.55	1.52	1.50	1.40	1.43	1.45
Ductless HP second head/unit	1.34	1.37	1.36	1.35	1.31	1.32	1.33	2.95	3.09	3.04	2.99	2.81	2.85	2.90
Boiler	1.29	1.3	1.29	1.29	1.27	1.28	1.28	3.28	3.36	3.33	3.31	3.20	3.22	3.25
Furnace	2.78	2.81	2.8	2.79	2.75	2.76	2.77	6.68	6.85	6.79	6.73	6.51	6.57	6.62
Pellet Boiler	0.72	0.73	0.72	0.72	0.72	0.72	0.72	3.95	4.05	4.02	3.98	3.85	3.88	3.92
Pellet Stove	2.76	2.77	2.77	2.76	2.75	2.75	2.76	13.18	13.51	13.4	13.29	12.84	12.95	13.07
Wood Stove (72%->75%)	2.75	2.77	2.76	2.76	2.74	2.74	2.75	12.90	13.22	13.12	13.01	12.57	12.68	12.79
Central Heat Pump	1.24	1.25	1.25	1.25	1.23	1.24	1.24	3.91	4.01	3.97	3.94	3.81	3.84	3.88
Geothermal HP Closed Loop	0.82	0.82	0.82	0.82	0.81	0.82	0.82	4.63	4.75	4.71	4.67	4.51	4.55	4.59
Geothermal HP Open Loop	0.80	0.81	0.81	0.81	0.80	0.80	0.80	4.58	4.69	4.65	4.62	4.46	4.50	4.54
Program	0.99	1.01	1.00	1.00	0.98	0.98	0.99	2.17	2.24	2.21	2.19	2.11	2.13	2.15

Table M-5 demonstrates that the impact of spillover rates on the program-level PBCTs is quite small and ranges from 0.5% to 1.5%. As a result, even a 30% reduction in free ridership does not push any of the six measures that have Base Case PBCTs less than 1.0 to greater than 1.0. The increases in the PACT are also relatively small and range from approximately 0.9% to 2.8%.

Non-Participant spillover and market effects were not estimated in this evaluation, but can potentially have significant impacts on the PBCT and PAC.

Varying Carbon Benefits

The purpose of this sensitivity was to assess the impact of including varying amounts of carbon benefits on the PBCT and PAC. The benefits of including carbon were calculated for all fuels except wood.

Table M- 6 presents the results of including carbon at the starting price (SP) of $4.02/ton[2] and increasing this price in increments of 10% 20% and 30%. It also includes, as a point of comparison, the current price set by the California Cap and Trade Program (CA C&TP) of $15/ton. Table M- 6 presents only the PBCT results since the percent increases for both the PBCT and the PACT are the same.

[2] Potomac Economics. *Market Monitor Report for Auction 40*. Prepared for: RGGI, Inc., on behalf of the RGGI Participating States, June 2018.

TABLE M- 6: CARBON SCENARIOS (PBCT ONLY)

Measures	Baseline	Starting Price	10%>SP	20%>SP	30%>SP	CA C&TP
Air Sealing	0.938	0.983	0.987	0.992	0.996	1.104
Attic Insulation	1.201	1.247	1.252	1.256	1.261	1.373
Attic Insulation (NG Only)	0.620	0.675	0.680	0.686	0.691	0.825
Basement Insulation	0.906	0.988	0.996	1.004	1.013	1.211
Wall Insulation	1.043	1.194	1.209	1.225	1.240	1.609
Ductless HP	1.178	1.256	1.264	1.272	1.279	1.469
Ductless HP second head/unit	1.344	1.433	1.442	1.451	1.460	1.676
Boiler	1.285	1.335	1.340	1.345	1.350	1.470
Furnace	2.784	2.849	2.855	2.861	2.868	3.024
Pellet Boiler	0.722	0.738	0.739	0.741	0.742	0.779
Pellet Stove	2.760	2.760	2.760	2.760	2.760	2.760
Wood Stove (72%->75%)	2.754	2.754	2.754	2.754	2.754	2.754
Central Heat Pump	1.242	1.308	1.315	1.321	1.328	1.488

With a low starting price assumption of $4.02/ton, the program-level PBCT increases were small, ranging from 4.7% to 6.2% for a 30% increase in the starting price. However, the effect on the PBCT of using the CA C&TP starting price of $15/ton was considerable at almost 18% over the Base Case.

Sensitivity Analysis using ACDR Assumptions[3]

We also estimated the prospective program-level and measure-level PBCTs and PACTs using the ACDR assumptions instead of the TPIII assumptions in the Base Case. Table M-7 below presents the results.

[3] At the time the BCR analysis was performed for this evaluation, the 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). The M&As proposed by Efficiency Maine in the initial filing of the Triennial Plan were used in the sensitivity analysis and dubbed the ACDR data set. Since the analysis was performed, the Trust has submitted and the Maine PUC has accepted a new set of M&As for TPIV that vary slightly from the ACDR in avoided costs values 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 results presented in this report do not reflect the final TPIV M&As.

Table M-7: ACDR Scenario

	TPIII Assumptions		ACDR Assumptions	
Measure	**SCT**	**PAC**	**SCT**	**PAC**
Air Sealing	0.94	1.46	1.32	2.05
Attic Insulation	1.20	6.35	1.61	8.52
Attic Insulation (NG Only)	0.62	1.21	0.89	1.74
Basement Insulation	0.91	2.59	1.28	3.66
Wall Insulation	1.04	3.03	1.45	4.21
Ductless HP	1.18	1.48	1.66	2.07
Ductless HP second head/unit	1.34	2.95	1.89	4.14
Boiler	1.29	3.28	1.87	4.76
Furnace	2.78	6.68	4.04	9.69
Pellet Boiler	0.72	3.95	1.11	6.12
Pellet Stove	2.76	13.18	2.78	13.28
Wood Stove (72%->75%)	2.75	12.90	2.78	13.00
Central Heat Pump	1.24	3.91	1.91	6.01
Geothermal HP Closed Loop	0.82	4.63	1.24	6.93
Geothermal HP Open Loop	0.80	4.58	1.22	6.85
Program	0.99	2.17	1.39	3.05

The use of the ACDR assumptions rather than the TPIII assumptions resulted in a substantial increase in the program-level PBCT and PACT of slightly more than 40%. In addition, all but one of the six measures with a Base Case PBCT of less than 1.0 now have a PBCT greater than 1.0 resulting in all measures except attic insulation in homes heated with natural gas being cost effective against the ACDR assumptions.

Appendix N
TRM Detailed Analysis

Appendix N: TRM Detailed Analysis

This appendix includes additional details on Technical Reference Manual (TRM) methods and adjustments. The first section describes how the TRM savings were calculated and the second discusses the sensitivity analysis conducted to determine the sensitivity of the savings to changes in some of the key inputs into the engineering calculations.

N-1 Air Sealing and Insulation

This section provides a discussion of TRM adjustments based on the evaluation results. Table N-1 shows the deemed savings values in the 2015 and 2017 TRMs for air sealing and insulation measures. The program reported savings for the homes in the model are close to the 2015 TRM values and the billing analysis indicates the realization rate is 50%. The insulation savings in the 2017 TRM are substantially higher than the 2015 TRM, which is a cause for concern.

The last row in the table compares the TRM savings if all three types of insulation (attic, wall and basement) and air sealing were installed. As homes with no insulation would be expected to use more than average, the annual consumption of 200 MMBtu/year for the least efficient homes from the NMR 2015 residential baseline study was used as the comparison.[1] Using the 2017 TRM, comprehensive insulation and air sealing would save 75% of the pre-install use.

TABLE N-1: TRM DEEMED AND PROGRAM REPORTED SAVINGS

	TRM Deemed Savings (MMBtu/year)		Program Reported (2014-2016)
	2015	2017	
Attic Insulation (Natural Gas)	25.5	30.6	25.1
Wall Insulation	22.5	71.6	23.2
Basement Insulation	20.3	38.1	20.5
Air Sealing	8.2	10.1	9.3
Total if all Measures Installed	76.5	150.3	78.0
% of Least Efficient Pre-Install Use if all Measures Installed[1]	38%	75%	39%

[1]"Maine Single-Family Residential Baseline Study," submitted by NMR Group to Efficiency Maine, September 2015, Figure 8, page 26; the estimated annual heating use for the least efficient homes was 200 MMBtu/year.

The TRM savings for insulation and air sealing are estimated from modeling. Efficiency Maine provided the "Air Sealing and Insulation Savings Model NG Attic.xlsx" spreadsheet, which shows how the insulation and air sealing savings were calculated for the 2017 TRM. The main approach for estimating savings from insulation measures was to calculate the reduction in conduction losses using standard heat loss calculations and then add savings from reduced air leakage due to the insulation.

[1] "Maine Single-Family Residential Baseline Study," submitted by NMR Group to Efficiency Maine, September 2015.

The impact evaluation team reviewed the new energy savings spreadsheet utilized in the 2017 TRM and it did not appear to model the following energy effects: thermal mass effects, internal heat gains, solar heat gains, multiple conductive heat transfer pathways, convective and radiative effects, thermostatic set-point effects, hourly variations in operation, and part load efficiencies in equipment. If an energy modeling path is used for savings, the impact evaluation team recommends that an energy simulation program tested and validated in accordance with ASHRAE 140 be utilized which accounts for these effects to more accurately estimate savings.

There are several possible reasons that the TRM approach may overestimate savings:

1. The TRM method uses simplified calculations to model the complexity of heat loss in residential homes
2. The TRM savings are estimated for each measure in isolation and do not take into account interactive effects among measures[2]
3. The TRM savings are not adjusted to take into account actual heating patterns and annual consumption

Some reasons why the results from the model might be different from the billing analysis results are summarized in Table N-2.

[2] About 30% of HESP participants with insulation and air sealing install more than one type of insulation.

TABLE N-2: REVIEW OF TRM ASSUMPTIONS

Source of Uncertainty	Description	Comments	Impacts
Simplified heat loss calculations	Does not account for all heat transfer modes, e.g., stack effect or radiant heat	Heat loss is complicated and cannot be easily modeled	Unknown
Internal and solar gains	Does not account for internal or solar gains	Missing internal and solar gains will overestimate savings	Overestimate savings
Normalized using TMY3 data	TMY3 data is based on 30 years averages of weather data, some of which dates back to 1961	Current weather patterns are warmer	Overestimate savings
Heating Degree Days (HDD) base temperature	Uses base 65°F	Previous modeling experience suggests base 60°F is more accurate	Overestimate savings
Cavity R-value	Does not account for framing, which increases R-value	Lower pre-install R-value will increase savings	Overestimate savings
Framing	Reduces insulated areas by 23% to account for framing	Conservative estimate, but does not fully counter using the cavity R-value	Underestimate savings
Nominal R-values	Uses nominal R-values for installed condition	Actual installations may not achieve the nominal R-value	Overestimate savings
Average heating system efficiency	Uses average heating system efficiency of 80.5%	NMR 2015 baseline study gives 83% as average boiler efficiency (Table 22); could be higher for natural gas	Overestimate savings

N-1.1 Sensitivity Analysis of Heat Loss Calculations

The evaluation team conducted a sensitivity analysis to identify inputs that are likely causing a significant impact on TRM savings. The modeling file provided by EMT and used to calculate the 2017 TRM savings was the source for the sensitivity analysis. Individual inputs were changed in isolation to determine the impacts on the savings. This analysis is provided for illustrative purposes only; it was not the basis for making adjustments to the TRM. The results are presented in Table N-3.

TABLE N-3: SENSITIVITY ANALYSIS OF INSULATION MODELING

Source of Uncertainty	Comment	Change	Impacts
Cavity R-value	Does not account for framing	Add R-2.5 to pre-install R-value	22% (attic) to 60% (basement) reduction in savings
Nominal R-values	Uses nominal R-values for installed condition; nominal values may not be achieved	Do not adjust post-install R-value for framing[1]	
Internal and solar gains	NMR 2015 baseline study indicates gains reduce heat load by 20% (Table 11)	Reduce savings by 20%	20% reduction in savings
Heating Degree Days (HDD) base temperature	Base 65°F was used; our experience with billing models suggests that base 60°F is more accurate	Change to 60°F	14% reduction
Normalized using TMY3 data	5-6 year averages more appropriate for changing climate	Use 5-year average	5 to 15% reduction in savings depending on the base period and climate zone
Average heating system efficiency	Underestimating heating efficiency inflates savings; better to overestimate as conservative assumption	Use efficiency of 85%	6% reduction

[1] As the pre-install R-value was increased by R-2.5 to account for framing, leaving the post-installation R-value at the cavity insulation effectively decreases the level of added insulation by R-2.5.

Overall, this analysis indicates that the engineering-based approach without calibration to bills could be overestimating savings by 50%. Understanding how changes in the assumptions can affect the savings may allow for a more nuanced approach to modeling. For example, savings are very sensitive to small changes in the pre-installation R-value but are not sensitive to the small changes in the post-installation R-value.