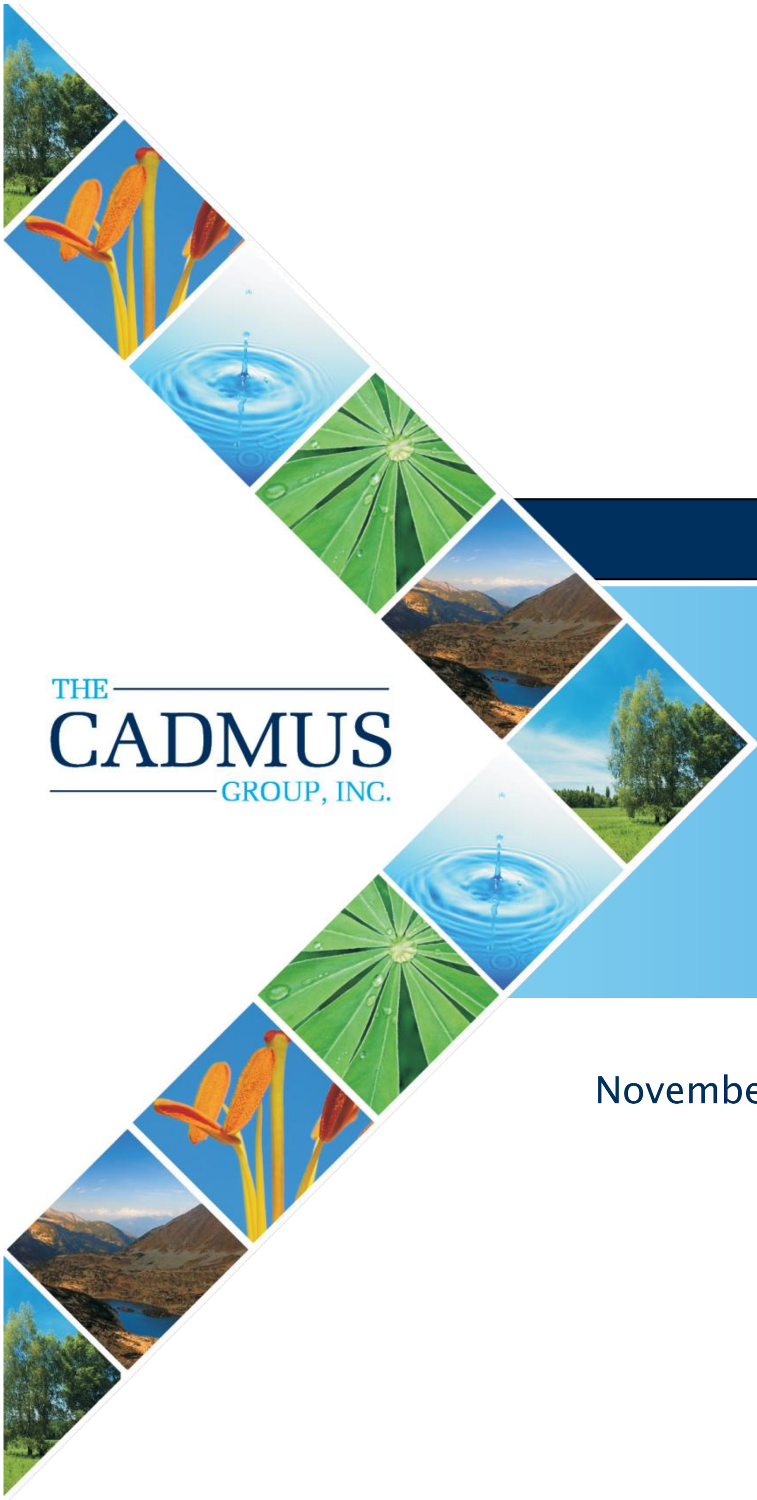

THE CADMUS GROUP, INC.

Efficiency Maine Trust
Home Energy Savings Program
Final Evaluation Report

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Contents

Figures

Tables

Executive Summary

This report presents the results of an impact evaluation of the Efficiency Maine Trust (Efficiency Maine or Trust) Home Energy Savings Program (HESP or Program), conducted by The Cadmus Group, Inc. (Cadmus). The HESP is a residential, whole-house, energy-efficiency program that targets existing homes in Maine, and is available to any residence in Maine that is heated during the winter (regardless of occupants' income levels).

The evaluation addressed the following research objectives:

- Determine energy savings;
- Evaluate the cost-effectiveness and job creation potential (due to funding from the American Recovery and Reinvestment Act (ARRA));
- Compute carbon emissions reductions and environmental impacts; and
- Assess customer satisfaction.

Cadmus understands Efficiency Maine could offer a rebate to Maine residents for whole-home retrofits because of the availability of ARRA funds. The funds have since been exhausted. The HESP program structure remains to help residents initiate and complete whole home retrofits and participants can borrow through the Maine PACE program to help finance the upgrades, but the monetary rebate/partial reimbursement is no longer offered. However, some of the recommendations in this report are contingent on the availability of future funding.

Energy Savings

Cadmus visited 41 HESP project sites and, using engineering review and simulation modeling, estimated gross program savings (verified savings) and realization rates. Cadmus compared verified savings with the limited number of utility bills available. Given the number of bills and variability of fuel deliveries, this was a qualitative assessment, rather than a formal billing analysis. Cadmus determined net savings via a customer survey.

As a result of the analysis, Cadmus determined the following:

- **The average gross realization rate for the verified measures was 90%.** Realization rates varied among the installed measures and can be found in Table E-1.

Table E-1. Realization Rate by Measure Type

Measure Type	Reported Savings	Verified Savings	Realization Rate
Air Sealing	566	585	103%
Attic Hatch	29	18	62%
Basement Insulation	381	305	80%
Ceiling Insulation	568	328	58%
Wall Insulation	462	584	127%
Furnace/Boiler	82	51	62%
Total (41 Sites)	**2,087**	**1,871**	**90%**

- **Cadmus found that program documented and claimed (reported) HESP measure installations matched field observations, except at a few sites.**
  - Cadmus staff conducted blower door testing at 31 of the 41 sites. At these sites, air sealing results were nearly identical (99%) of values reported by Efficiency Maine.
  - The verified area in square feet of insulation was 98% of the reported area.
- **The Efficiency Maine HESP had a gross program realization rate of 88% and a net program realization rate of 76%.**
  - Table E-2 and E-3 compare annual reported energy savings by fuel type with annual verified gross energy savings by measure type, and by fuel type, respectively. These data were expressed in MMBTUs, where all fuel types, including electricity, were converted to MMBTUs.

Table E-2. Annual Energy Savings by Fuel Type

Annual Energy Savings by Fuel Type (MMBTUs)	Reported Gross Savings	Verified Gross Savings	Gross Realization Rate	Net-to-Gross (NTG)	Verified Net Savings (Verified Gross * NTG)	Net Realization Rate	Measures (n)
Fuel Oil	132,063	110,638	84%	0.86	95,148	72%	8,373
Natural Gas	1,244	4,965	399%	0.86	4,270	343%	2,070
Propane	763	2,052	269%	0.86	1,765	231%	1,376
Wood	3,635	3,315	91%	0.86	2,851	78%	374
Kerosene	732	615	84%	0.86	529	72%	102
Electric	3,024	2,908	96%	0.86	2,501	83%	749
Corn Pellet	22	17	76%	0.86	15	65%	17
Total (1780 Sites)	**141,485**	**124,509**	**88%**	**0.86**	**107,077**	**76%**	**13,061**

Table E-3 shows *lifetime* net energy savings attributable to the HESP.

Table E-3. Lifetime Energy Savings by Fuel Type

Lifetime Energy Savings by Fuel Type (MMBTUs)	Reported Gross Savings	Verified Gross Savings	Gross Realization Rate	Net-to-Gross (NTG)	Verified Net Savings (Verified Gross * NTG)	Net Realization Rate	Measures (n)
Fuel Oil	3,044,152	2,569,517	84%	0.86	2,209,785	73%	8,373
Natural Gas	87,296	156,880	180%	0.86	134,917	155%	2,070
Propane	55,068	76,932	140%	0.86	66,162	120%	1,376
Wood	91,216	83,203	91%	0.86	71,555	78%	374
Kerosene	17,617	14,786	84%	0.86	12,716	72%	102
Electric	40,278	37,597	93%	0.86	32,333	80%	749
Corn Pellet	563	426	76%	0.86	367	65%	17
Total (1780 Sites)	**3,336,191**	**2,939,342**	**88%**	**0.86**	**2,527,834**	**76%**	**13,061**

Carbon Emissions Reductions and Environmental Impacts

Cadmus calculated displaced greenhouse gas emissions, associated with Efficiency Maine's HESP. To conduct this analysis, Cadmus used verified net energy impacts, in terms of net tons of carbon emissions, avoided over the effective useful life of the projects.

Table E-4. Annual and Lifetime Carbon Emissions Displaced from HESP

Fuel Type	Total GHG Emissions Displaced Tons CO2e	
	Annual	**Lifetime**
All Fuels (without Biomass)	8,443	196,735
Biomass	347	8,707

Cost-Effectiveness of ARRA-Funded Programs

Table E-5 presents results of cost-effectiveness analysis, based on the Total Resource Cost (TRC) Test, calculated using gross reported savings, adjusted realized savings, and adjusted net savings. The HESP is comfortably cost-effective in all three scenarios.

Table E-5. Program TRC

Value	Reported Gross Savings Scenario	Verified Gross Savings Scenario	Verified Net Savings Scenario
MMBTU Savings	141,485	124,509	107,077
Avoided Energy Benefits	$70,097,059	$59,597,884	$51,254,180
Added Energy Costs	$6,879,199	$4,710,016	$4,050,614
Participant Incremental Costs	$16,387,212	$16,387,212	$14,093,002
Program Delivery	$1,078,868	$1,078,868	$1,078,868
Marketing	$642,111	$642,111	$642,111
Administration	$187,155	$187,155	$187,155
TRC Benefits	$70,097,059	$59,597,884	$51,254,180
TRC Costs	$25,174,546	$23,005,363	$20,051,751
TRC Ratio	**2.78**	**2.59**	**2.56**

The DOE SEP-RAC test is an alternate, cost-effectiveness metric, evaluating whether projects save at least 10 million source BTUs (10 MMBTUs) annually, the threshold for ARRA-funded programs. The HESP saves 13.41 net adjusted MMBTU per $1,000 in ARRA expenditures, passing the SEP-RAC test. Table E-6 provides details of the SEP-RAC test analysis.

Table E-6. Components and Results of the SEP-RAC Test

Category	Value
RHA MMBTU Savings – Adjusted Gross	124,509
TR MMBTU Savings – Gross	8,762
Total Gross MMBTU Savings	133,271
Net-to-Gross Ratio	86%
Total Net MMBTU Savings	114,613
HESP Incentives (Including Bonus Payments)	$6,641,237
Program Delivery	$1,078,868
Marketing	$642,111
Administration	$187,155
Total ARRA Expenditures	$8,549,371
MMBTU/$1000	**13.41**

Customer Satisfaction

This evaluation included talking with HESP participants about their program experiences. Cadmus conducted surveys, overseeing implementation of 100 participant surveys by a subcontractor, the Gilmore Group; this included full participants—defined as those completing home energy upgrades and receiving an HESP rebate—and partial participants, defined as those with an energy audit but not following through to completion. Cadmus also talked with participants during site visits. At the highest level, survey results indicate the following:

- **Program participants were very satisfied.** Field staff described participants as very satisfied with services and incentives they received. Participants reported being more comfortable in their homes, and seeing a noticeable decreases in their fuel bills.
    - Most full survey participants (87%) reported being “very satisfied” with program participation.

- The HESP rebate motivated participants to initiate the audit and invest in improvements, as did the possibility of saving money on their energy bills.
- The rebate provided a more effective incentive to complete energy upgrades, compared to tax credits.
- Upfront costs presented the most significant participation barrier to making recommended energy upgrades.

Key Recommendations

Cadmus recommends that Efficiency Maine:

1. Continue to emphasize the importance of thorough air sealing practices.
2. Work with its energy advisors to:
    a. Ensure they target areas within the home that will lead to the greatest energy savings achievements (e.g., empty wall cavities).
    b. Emphasize the importance of installation quality.
    c. Continue building partnerships and supplying contractors with information that can be used to help promote program offerings.
3. Consider expanding its current marketing techniques by:
    a. Using "homeowner stories" in program promotional channels beyond the Website.
    b. Developing marketing messages that inspire residents' trust, and highlight participants' very positive experiences with program paperwork.
    c. Enhancing the "return on investment" (ROI) appeal for low-cost measures to increase uptake on these recommended improvements.

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1. Introduction

1.1 Evaluation Objectives

The Efficiency Maine Trust (Efficiency Maine or Trust) hired The Cadmus Group, Inc (Cadmus) to verify energy savings and program effects of the Home Energy Savings Program (HESP). The HESP was funded by the State Energy Program (SEP) American Recovery and Reinvestment Act (ARRA) funds. Cadmus' evaluation estimated the:

- Gross and net energy savings impacts over the effective useful life (EUL) of the program's actions;
- The net tons of carbon not released into the atmosphere over the EUL of projects implemented;
- The number of short-term and long-term, and full-time and part-time jobs generated due to the program; and
- Results of the SEP Recovery Act cost-effectiveness test, applied to the energy impacts achieved.

1.2 Program Description

From December 2009 through 2011, Efficiency Maine delivered a residential whole-house efficiency program, targeted toward existing homes in Maine. Any Maine home heated during the winter was eligible to apply for and receive a program rebate, regardless of income level of the owner or occupant.

Predominantly a weatherization program, HESP focused on air sealing and on wall, attic and ceiling insulation measures. Other eligible measures included heating system replacement, domestic hot water (DHW) system replacement, controls, windows, doors, and renewable energy systems, such as wind or solar.

The program sought to weatherize and improve the overall energy efficiency of residences throughout Maine and to, on average, achieve 25% total annual energy savings per residence. The program addressed all fuels (heating oil, kerosene, natural gas, propane, wood, and electricity), primarily focusing on fuels used for space heating and hot water.

The program offered financial incentives (rebates) to homeowners for the installation of eligible efficiency measures. The program offered two incentive levels:

- Tier 1 (a maximum of $1,500 per home) for projects projected to save at least 25% of the annual thermal (heating and hot water) energy used in the home; and
- Tier 2 (a maximum of $3,000 per home) for more comprehensive projects, such as multi-measure installations projected to result in energy reductions of 50% or more.

1.3 Evaluation Design

The evaluation sample frame was designed to use as much program data as possible, while still ensuring evaluation participants would have had a chance to observe changes within their home post-measure installation, and decreasing the risk that Cadmus technicians would inspect sites where the installation was incomplete. Considering these factors, the sample frame was defined as HESP participants who received an energy audit between December 1, 2009, and December 31, 2010. This resulted in a total of 1,780 sites as a part of the evaluation population.

Table 1 shows how the evaluation period compares to the total program period.

Table 1. Program and Evaluation Period Metrics

Metric	HESP Program	Evaluation Period
Audits Completed	5,026	1,780
Rebate Reservations (Actual)	3,667	1,780
Completed Upgrades (Actual)	3,211	1,540
Average Upgrade Cost	$8,349	$12,286
Total Cost, All Upgrades	$26,810,236	$19,019,182
Average HESP Incentive Paid	$2,610	$2,585
Total HESP Incentives Paid	$8,380,265	$4,559,951

Cadmus used a variety of techniques to evaluate impacts of the HESP, as shown in Table 2.

Table 2. Summary of Evaluation Tasks

Action	Impact	Process	Details
Verify Measure Installation	✓		Conducted 41 site visits (includes on-site, detailed customer interviews) and measurement and verification.
Engineering and Simulation (Modeling) Analysis	✓		Developed revised deemed unit savings estimates for installed measures and conducted an engineering analysis (including engineering review and simulation modeling) to estimate program savings and gross realization rates.
Analyze Energy Bills (limited)	✓		Examined gas, electric, oil, and propane bills as a point of comparison to modeling. After extensive efforts Cadmus obtained 5 gas bills, 15 fuel oil bills, and 2 propane bills. Cadmus was able to report findings for a total of 19 bills (15 fuel oil bills and 4 gas bills).
Survey Participants		✓	Conducted telephone survey to measure customer satisfaction and areas for improvements and attribution. (n=70)
Survey Partial-Participants		✓	Conducted telephone survey to measure program awareness and reasons for not participating. (n=30)

The impact analysis compared program savings estimated from Cadmus' engineering and simulation modeling (verified savings) to the program's reported savings. The verified energy savings were based on data Cadmus collected from the 41 site visits.

Responses from the full and partial participant survey were used to calculate net-to-gross (NTG) and obtain a qualitative understanding of program spillover.

Verified energy savings were qualitatively compared with energy consumption observed through the billing data, which was collected separately from Maine fuel providers.

Cadmus estimated additional HESP impacts including the number of jobs created, the program's Total Resource Cost (TRC) and MMBTUs saved per $1,000 spent, and the displaced greenhouse gas emissions in terms of net tons of carbon emissions avoided over the EUL of the measures.

2. Methodology

2.1 Impact Evaluation Methodology

Sampling

Cadmus designed a site visit sample to reach the goal, stated in the proposal, of a one-tailed 90% confidence and ±10% precision (90/10) across the HESP's participants. In designing the sample, Cadmus estimated 41 site visits would be required to reach 90/10.

Site Visits

Cadmus visited 41 HESP sites during the first two weeks in August 2011. During these site visits, Cadmus technicians:

- Offered $25 gift cards as an incentive to participants who agreed to partake in a site visit.
- Verified the installation of claimed measures:
  - Type of measure;
  - Application area of the measure;
  - Thickness (where applicable) of the installation; and
  - R-Value (where applicable) of the installation.
- Documented the quality of the installation and operation.
- Gathered efficiency measure characteristics (e.g., furnace model and efficiency setting).
- Used infrared cameras or thermal scans (where possible) to check for proper installation of wall insulation.
- Completed blower door tests (where possible) to determine air exchanges per minute to assess the success of building weatherization. Figure 1 illustrates an installed blower door during a site visit.

Figure 1. Illustration of Blower Door Testing

- Recorded temperature and schedule settings of programmable thermostats.

- Checked aerator and showerhead flow rates through flow bags.
- Interviewed participants to better understand their use of their home's heating system(s).
- Gathered the necessary home characteristics (e.g., square footage of home, number of windows).

Engineering and Simulation Analysis

Cadmus examined HESP program databases, visited 41 sites, and gathered detailed information about each site, as described in the previous section. Using collected house and user behavior data, Cadmus used REM/Rate[1] software to create a model that simulated the energy performance of each house and estimated its energy consumption during (1) pre-installation conditions and (2) post-installation conditions.

To establish the home's state prior to the weatherization, Cadmus staff interviewed the homeowner and inspected the structure to determine baseline insulation levels, and assess the operational mechanical equipment installed. Each home was then modeled based on the level of energy efficiency observed during the site visit (post-installation conditions: installed measure and home characteristics) and the level of energy efficiency before participation in the HESP program as indicated by the homeowner and, where possible, verified by Cadmus (pre-installation conditions).

Cadmus used REM/Rate to evaluate weather-dependent measures[2]. Weather-dependent measures include air sealing, insulation (wall, ceiling, and basement or crawlspace), attic hatch, and heating equipment. Two REM/Rate models were run for each house, taking into account heating system type, and observed wall, ceiling, and basement dimensions, and insulation values.

The resulting total home energy savings from the models divided into per-measure energy savings values. The difference in the pre- and post-consumption was used to estimate energy savings at the measure level. Cadmus compared the verified savings for each house and measure to reported values, producing realization rates at the measure level.

Utility Billing Analysis

At the start of the evaluation, Cadmus planned to collect billing data from the 41 site visit participants to assess their fuel consumption during the 12-month period prior to the installation of HESP measures, and compare this with their consumption during the 12-month period after the installation. The intent was to give Cadmus a qualitative view of consumption to compare with results of the modeling efforts.

[1] REM/Rate software produces a home energy rating report based on the RESNET (Residential Energy Services Network) National HERS Technical Standards. It is endorsed by RESNET and is HERS BESTEST certified. REM/Rate is designed in accordance with the Mortgage Industry National Home Energy Rating Systems Standard, a widely accepted standard to gauge home energy performance and apply a HERS rating. Our experience with REM/Rate has shown it to accurately model insulation and predict energy usage, and provide accurate and cost-effective energy savings results for typical residential homes.

[2] Cadmus verified the installation of hot water, lighting, and appliance measures during site visits.

Cadmus believed this comparison would be a valuable addition to the evaluation, but anticipated that the billing analysis could be constrained by the small sample, or difficulty when interpreting fuel deliveries. Unfortunately, it was more challenging to obtain and interpret fuel data than expected so the analysis was limited to simple comparison of the billing data with our engineering analysis of savings for a subsample of sites.

Verified Savings and Realization Rate

Cadmus used data collected from the site visits to complete the engineering and simulation analysis. This analysis estimated verified energy savings attributable to the HESP. These verified gross energy savings were then compared with reported gross energy savings to determine realization rates. For this report, gross realization rate has been defined as follows:

[Verified Gross Energy Savings / Reported Gross Energy Savings = Gross Realization Rate]

Cadmus determined gross realization rates for the following specific measure types:

- Air sealing
- Attic hatch
- Basement insulation
- Ceiling insulation
- Wall insulation
- Furnace/Boiler

The realization rate for furnace or boiler replacement measures resulted from Cadmus' modification of assumed efficiency levels. Out of the 41 sites sampled, four sites completed furnace or boiler replacements. The sample of four sites was too small to predict a realization rate, so Cadmus completed a file review of 247 of the 480 heating system replacements. The measure's baseline efficiency was fixed at 80% based on Cadmus' experience that all but the oldest units have moderate efficiencies. The nominal furnace efficiency was retained (e.g. 93%), however the upper level of the replacement boiler efficiency was set to 90% based on our concern that return water temperatures limit upper level efficiencies in practice. (See Appendix C for a detailed discussion of condensing efficiencies.) Savings were calculated from these adjusted efficiency levels and consumption predicted by the implementation contractor. Savings were further adjusted by a ratio of Cadmus' modeled consumption and the predicted consumption which decreased the savings by about 5%.

Cadmus applied measure-level savings estimates to all relevant measures in the population. This led to verified annual energy savings for the program (in MMBTUs). This was then broken out by fuel type to obtain annual energy savings (in fuel-specific units).

Then, Cadmus estimated the lifetime verified energy savings by fuel type by applying the EUL values of the specific measures (as provided in the HESP database) to all measures installed as a part of the projects within the sample frame.

Subsequent analysis led to an overall program gross realization rate, which was the ratio of the total verified gross energy savings to the total reported gross energy savings for the specific measures.

Net Savings and Attribution Analysis

In the participant survey, Cadmus asked targeted questions to pinpoint attribution of impacts to SEP ARRA funding. The questions had varied approaches to ensure effects attributable to the SEP ARRA funds would be differentiated from effects attributable to other funding sources included in the program (e.g., federal tax credits), and from effects of other events and sources not related to SEP ARRA funds.

The results of these questions were tabulated and analyzed using methods similar to those of the overall participant and partial participant surveys.

Cadmus used the survey results to develop estimates of freeridership. These estimates were then used to compute an NTG ratio. The NTG ratio was applied to the verified gross savings to determine verified net savings. For this report, net realization rate has been defined as follows:

[Verified Net Energy Savings / Reported Gross Energy Savings = Net Realization Rate]

Additionally, the estimated net savings served as the inputs for the TRC and SEP Recovery Act Cost (SEP-RAC) tests.

Greenhouse gas emissions reduction equivalents associated with verified energy impacts, in terms of net tons of carbon emissions avoided over the effective useful life of the projects, were also calculated using the net verified savings.

Cost-Effectiveness Analysis

Cadmus calculated HESP cost-effectiveness using the SEP-RAC test and the TRC test. The SEP-RAC test, developed by the Department of Energy (DOE), specifies that, on average, each state's portfolio of programs' energy impacts should be no less than 10 million source BTUs per year, per $1,000 of SEP ARRA funds spent. The TRC test is an industry-standard metric for evaluating program cost-effectiveness outlined in the California Standard Practice Manual,[3] which compares energy savings benefits (avoided costs) to program administrator and customer costs.

For the cost-effectiveness tests, Cadmus used net savings determined by verified gross energy savings and the NTG ratio. This approach will aid the Trust in successfully determining the program's cost-effectiveness, with respect to achieving its declared energy-efficiency goals.

[3] California Public Utilities Commission (CPUC). 2001. *California Standard Practice Manual Economic Analysis of Demand-Side Programs and Projects*. Sacramento, CA: Governor's Office of Planning and Research, State of California.

2.2 Survey Research Methodology

Survey Sampling

Efficiency Maine provided Cadmus with a participant list for all participants in the sample frame, which included contact information and identified program steps participants completed. Cadmus conducted a survey using a random sample of full and partial participants, completing: 70 interviews with full participants; and 30 interviews with HESP partial participants.

Table 3. Participant Sampling

Measure	Total Participants	Completed Surveys
Full Participants	1,548	70
Partial Participants	216	30

This evaluation defines a full participant as someone who received an HESP rebate from Efficiency Maine for installing energy improvements in their home, and a partial participant as someone who completed the energy audit portion of HESP, but had not completed improvements and received a rebate at the time of the survey.

The survey instrument had items in common and unique to each participant type. Through the telephone survey, Cadmus sought to explore participants' experiences with the HESP.

Survey Analysis

Cadmus used the survey results to examine topics within the objectives outlined below as well as to provide inputs for an NTG calculation, including freeridership and spillover issues. This report's Impact Analysis Findings section presents details on the NTG analysis, including the relevant survey findings.

Surveys sought to collect participant responses regarding the following topics:

- Sources of program awareness, energy advisor selection, and qualification elements.
- Participant motivations (reasons for completing an audit and for completing installation of efficient measures).
- Participant barriers (reasons for not participating or not completing installation of efficient measures).
- Participant experience and satisfaction with:
    - Program administration;
    - Incentives and program requirements; and
    - Post-installation results.
- Perceptions of program benefits.
- Household and participant characteristics (demographics).

There were instances where Cadmus received non-responses and "don't know" responses. As a result, the base size (n=number of responses) for responses to certain questions fell below 70 for full participants, 30 for partial participants, or 100 for all participants.

3. Participant Profile and Characteristics

3.1 Demographics

Table 4 shows household and individual characteristics for full and partial HESP participants, based on the survey data. On average, 2.6 persons were living in HESP participant households. Full participants tended to have smaller households than partial participants. Specifically, 63% of full participant households included one or two people living in the home full-time, while 61% of partial participant households included three or more people living in the home full-time. All full and partial survey respondents owned their homes.

Full participants were, on average, older than partial participants, with 53% of full participants ages 55 or older, compared to 27% of partial participants.

The most common income bracket for both full and partial participants was $50,000 to $100,000, with 54% of participants reporting that level. A total of 35% of partial participants reported annual household incomes of $100,000 or higher, compared to 16% of full participants. More full participants (30%) lived in households making $50,000 or less annually than did partial participants (12%).

Table 4. Demographic Information

Number of people living in home on a full-time basis	Full (n=69)		Partial (n=28)		Total (n=97)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
1	12	17%	3	11%	15	15%
2	32	46%	8	29%	40	41%
3	10	14%	6	21%	16	16%
4	12	17%	7	25%	19	20%
5	1	1%	3	11%	4	4%
6	2	3%	1	4%	3	3%
Homeownership status	Full (n=70)		Partial (n=30)		Total (n=100)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Own	70	100%	30	100%	100	100%
Rent	0	0%	0	0%	0	0%
Age category of survey respondent	Full (n=69)		Partial (n=30)		Total (n=99)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
18 to 24	0	0%	0	0%	0	0%
25 to 34	4	6%	3	10%	7	7%
35 to 44	10	14%	5	17%	15	15%
45 to 54	18	26%	14	47%	32	32%
55 to 64	23	33%	2	7%	25	25%
65 to 74	11	16%	5	17%	16	16%
75 or more	3	4%	1	3%	4	4%
Annual household income	Full (n=61)		Partial (n=26)		Total (n=87)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Less than $25,000	1	2%	1	4%	2	2%
$25,000 up to $50,000	17	28%	2	8%	19	22%
More than $50,000 up to $100,000	33	54%	14	54%	47	54%
More than $100,000 up to $200,000	8	13%	8	31%	16	18%
More than $200,000	2	3%	1	4%	3	3%

Highest educational attainment	Full (n=68)		Partial (n=30)		Total (n=98)	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Less than a high school diploma	1	1%	2	7%	3	3%
Completed high school diploma or equivalent (GED)	4	6%	0	0%	4	4%
Some college	1	1%	2	7%	3	3%
Completed a 2 year or technical degree/certification	5	7%	3	10%	8	8%
Completed a four year degree	25	37%	7	23%	32	33%
Graduate or professional degree-MA, MSc, PhD, LLB	32	47%	16	53%	48	49%
Gender of survey-taker	**Full (n=70)**		**Partial (n=30)**		**Total (n=100)**	
	Frequency	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Male	42	60%	18	60%	60	60%
Female	28	40%	12	40%	40	40%

3.2 Descriptive Statistics

As a part of this evaluation, Cadmus completed basic data analysis to compile descriptive statistics regarding the homes participating in the HESP. The tables below show reported data as well as the data collected by Cadmus during the site visits.

Table 5. HESP Participant Home Descriptive Statistics

Statistic	Program Reported Averages (1780 Sites)	Program Reported Averages (41 Sites)	Verified Averages (41 Sites)
Occupants	3.09	2.51	Not collected
Living Space Square Footage	2,296	1,948	2,314

Fuel and Distribution Type

The subsequent charts and tables show the reported and verified primary heating system and fuel types for all of the sites within the evaluation period. This analysis was performed for the four different participant subsets:

1. The data from all projects within the evaluation period as reported in the HESP database. The population size is 1,780, unless otherwise specified.
2. The data from the projects within the evaluation period that were a part of Cadmus' site visit sample as reported in the HESP database. The sample size is 41, unless otherwise specified.
3. The observed (verified) data from the Cadmus site visits. The sample size is 41, unless otherwise specified.
4. The responses received from the full and partial participant survey. The sample size is 30, 70, or 100, or specified otherwise.

Primary Fuel Type

This section outlines primary fuel types used by the HESP participants, based on program data and Cadmus site inspections. The majority of residents in Maine heat their homes with oil. This was also the case with HESP participants as the primary fuel source for three-quarters of all participants was oil. Nine percent heated their home primarily with natural gas, and 6% primarily heated with propane.

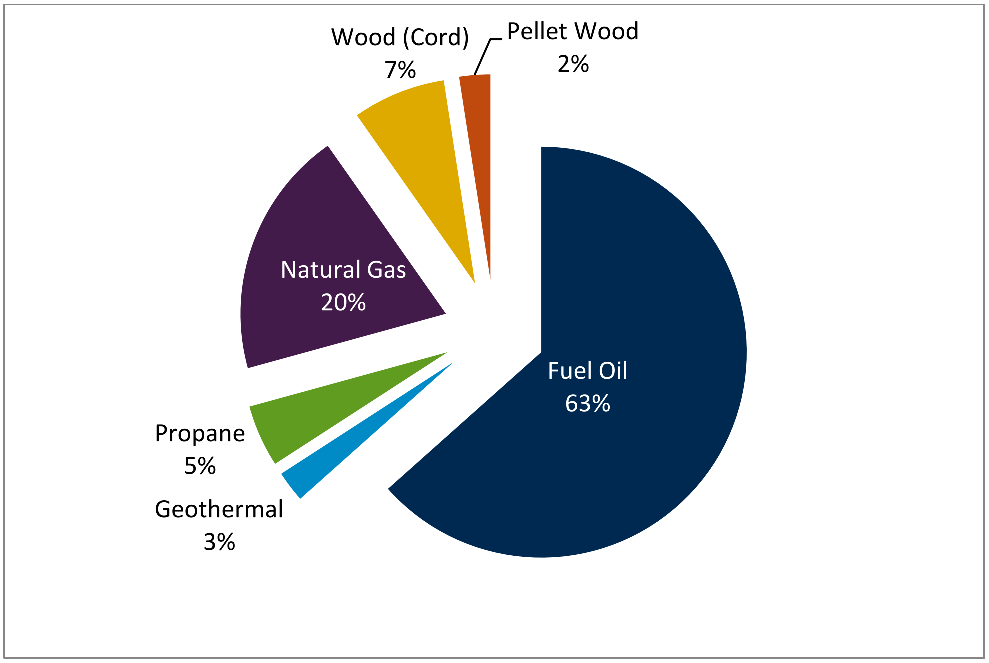
The distribution of reported primary fuel type of sampled sites was similar to that for the entire sample frame, showing the random sample generally represented the larger population.

Table 6. Primary Fuel Type

Primary Fuel Type	Reported Primary Fuel Type (Total Sites)	Reported Primary Fuel Type (Sampled Sites)	Verified Primary Fuel Type (Sampled Sites)
Fuel Oil	74.94%	68.29%	63.41%
Natural Gas	8.71%	9.76%	19.51%
Propane	6.12%	4.88%	4.88%
Wood	1.97%	2.44%	7.32%
Electric	1.07%	0%	0%
Kerosene	0.96%	0%	0%
Geothermal	0%	0%	2.44%
Pellet Wood	0%	0%	2.44%
Not Listed	6.24%	14.63%	0%
Total (Sites)	**1,780**	**41**	**41**

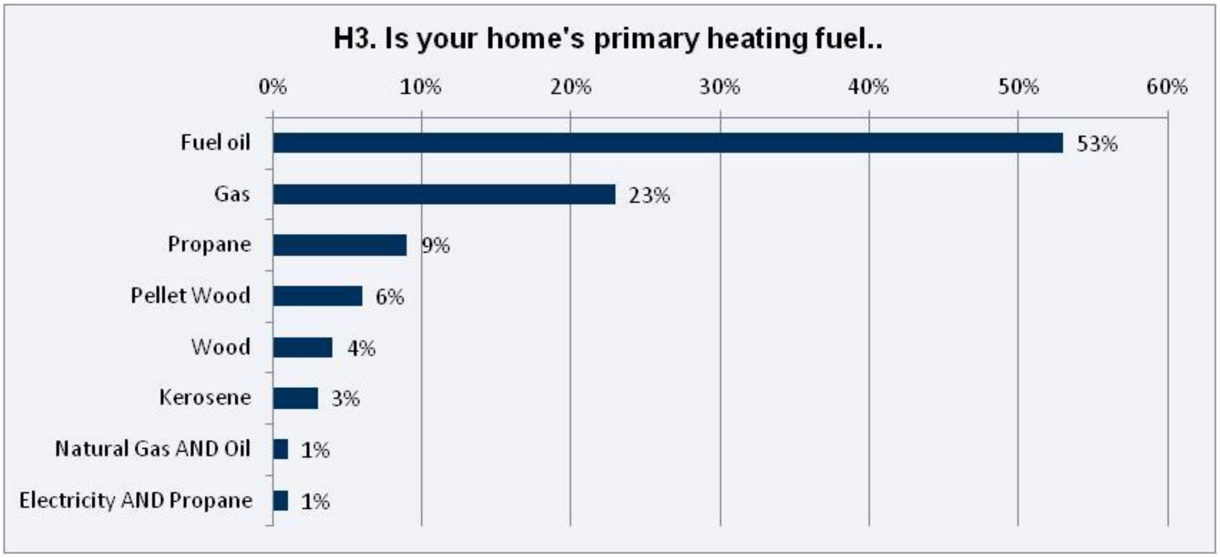
The fuel types observed during Cadmus' site visits generally matched that reported in program data. Oil and natural gas were the two most dominant fuel types. However, Cadmus technicians documented geothermal and pellet wood as a primary source of fuel for 5% of participants. There was a higher usage of natural gas and wood observed by Cadmus.

Figure 2. Primary Fuel Type (41 Sites: Cadmus Observations)



According to the participant surveys, fuel oil was the most common primary heating source fuel, matching the population at the site visit sample. Gas and propane did not match as closely, however, participants may not fully understand their fuel use.

Figure 3. Home's Primary Heating System Fuel Type



Secondary Fuel Type

The HESP program database and Cadmus site visits also captured secondary fuel types. Only a small portion of the participants (n=175) in the evaluation period reported any secondary fuel source in program data. Of those 175, 31% used oil as their secondary source and 21% used wood. Thirteen percent used natural gas and 12% used propane.

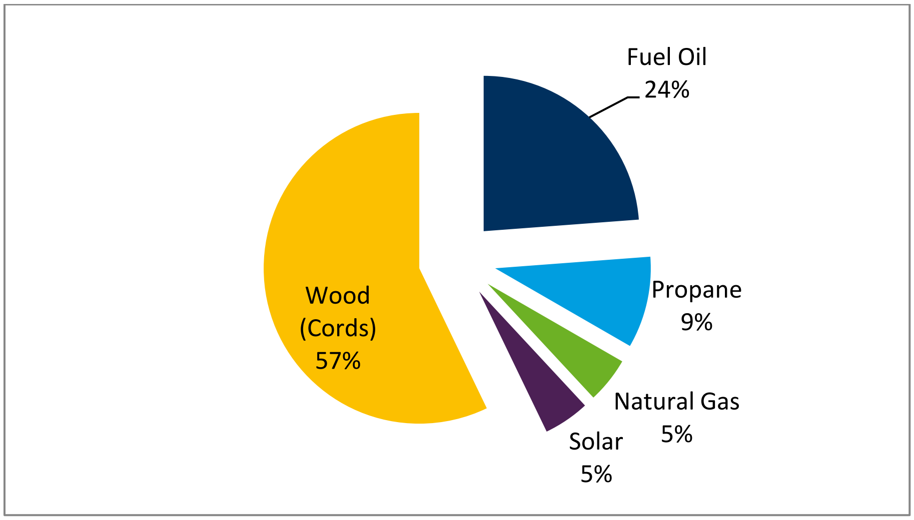
Table 7. Secondary Fuel Type

Secondary Fuel Type	Reported Secondary Fuel Type (Total Sites)	Reported Secondary Fuel Type (Sampled Sites)	Verified Secondary Fuel Type (Sampled Sites)
Corn Pellet	1.14%	0%	0%
Electric	12.00%	0%	0%
Natural Gas	13.14%	20%	4.76%
Kerosene	6.86%	0%	0%
Oil	30.86%	20%	23.81%
Pellet Wood	2.86%	0%	0%
Propane	12.57%	40%	9.52%
Wood	20.57%	20%	57.14%
Solar	0%	0%	4.76%
Total (Sites)	**175**	**5**	**21**

Secondary fuel type was only reported in the HESP database at five of the 41 sampled sites (12%). During the site visits, Cadmus identified a total of 21sites (16 additional sites) that used a secondary heating source, with 57% using wood, 24% using oil, 9% propane, 5% natural gas, and 5% solar.

Program implementation staff has reported energy auditors likely did not record this information when submitting to Efficiency Maine, which would explain why Cadmus observed additional secondary heating systems beyond those reported in the database.

Figure 4. Secondary Fuel Type (21 Sites: Cadmus Observations)



HVAC Distribution System

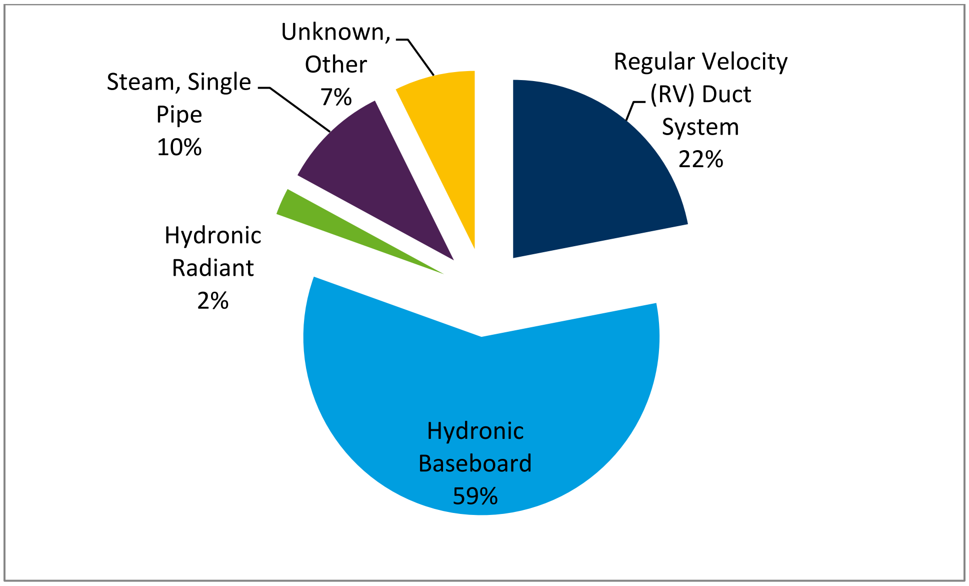
Primary HVAC Distribution System

The majority of the participating sites in the HESP used hydronic baseboards (hot water baseboard) to distribute heat. The second largest portion used a regular velocity duct system (Table 8). The reported primary heating distribution systems for the sites Cadmus sampled were similar to overall participant population. Cadmus technicians found similar results on-site.

Table 8. Primary HVAC Distribution System

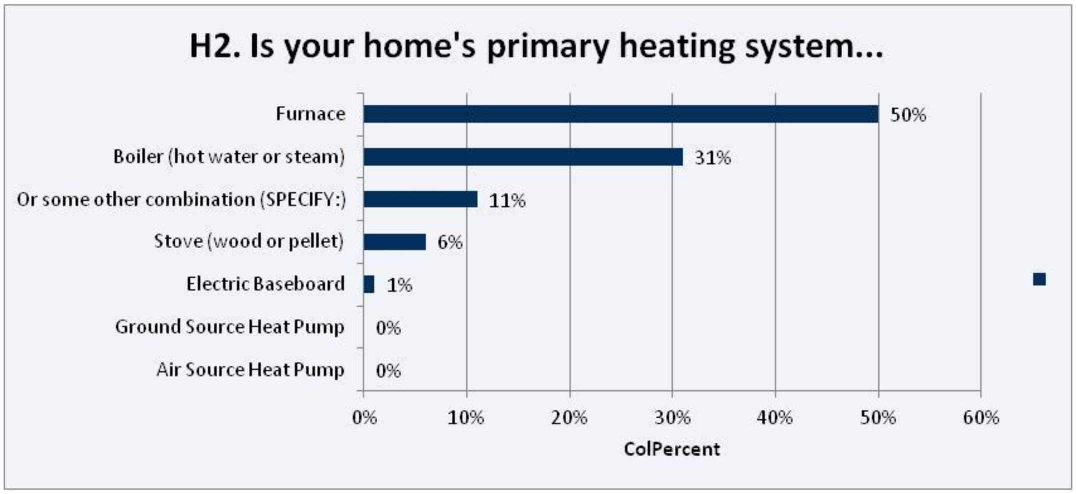
Primary Distribution System	Reported Primary Distribution System (Total Sites)	Reported Primary Distribution System (Sampled Sites)	Verified Primary Distribution System (Sampled Sites)
High Velocity (HV) Duct System	0.11%	0%	0%
HV Duct System with Electronically Commutated Magnet (ECM) Motor	0.11%	0%	0%
Regular Velocity (RV) Duct System	18.20%	19.51%	21.95%
RV Duct System with ECM	0.28%	0%	0%
Electronic Baseboard	0.84%	0%	0%
Electronic Radiant	1.01%	0%	0%
Gravity (75 and 91)	0.28%	0%	0%
Hydronic Baseboard	59.61%	56.10%	58.54%
Hydronic Radiant	2.58%	2.44%	2.44%
Space Heater	4.94%	2.44%	0.00%
Steam, Single Pipe	5.11%	4.88%	9.76%
Steam, Two Pipe	0.67%	0%	0%
Unknown, Other	6.24%	14.63%	7.32%
Total (Sites)	**1,780**	**41**	**41**

Figure 5. Primary HVAC Distribution System (41 Sites: Cadmus Observations)



HVAC distribution systems were also captured during the participant survey, but with different results. According to participants in the survey sample, furnaces were the most common type of primary home heating (50%), with boilers accounting for about one-third (31%), while the program database and on-site observations showed almost 79% used a boiler, and less than 20% used a furnace (ducts). Responses to this question could be to the result of customer confusion about heating systems.

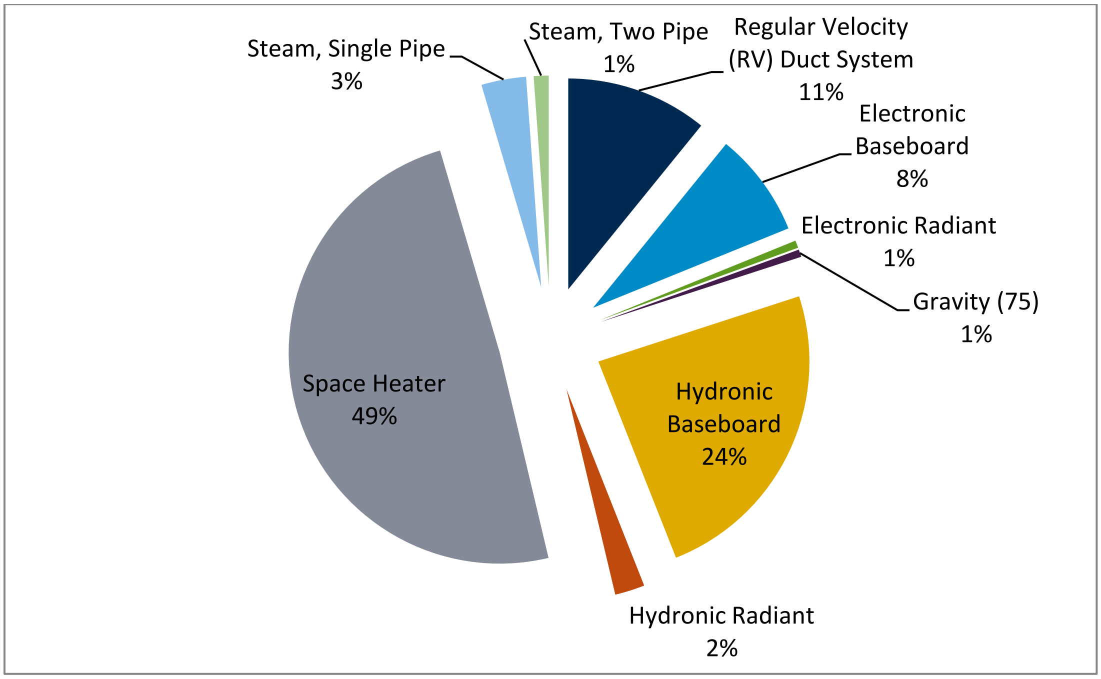
Figure 6. Home's Primary Heating System



Secondary HVAC Distribution System

Figure 7 displays reported secondary heating system types and fuels for all of the sites where a secondary fuel source was reported (n=175). Heating with a space heater was the most frequently observed secondary heating distribution system type at 49%, followed by hydronic baseboard at 24%.

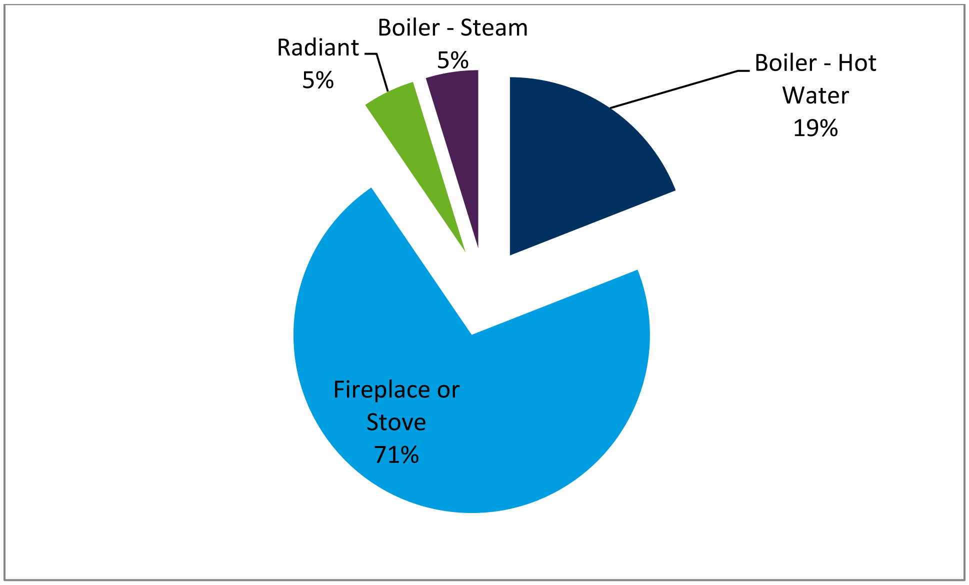
Figure 7. Secondary HVAC Distribution System (175 Sites: Reported Data)



Space heaters were the dominant reported secondary heating system type at the five sampled sites where a secondary fuel source was reported. Hydronic baseboard and electric radiant was seen as a secondary source by 20%.

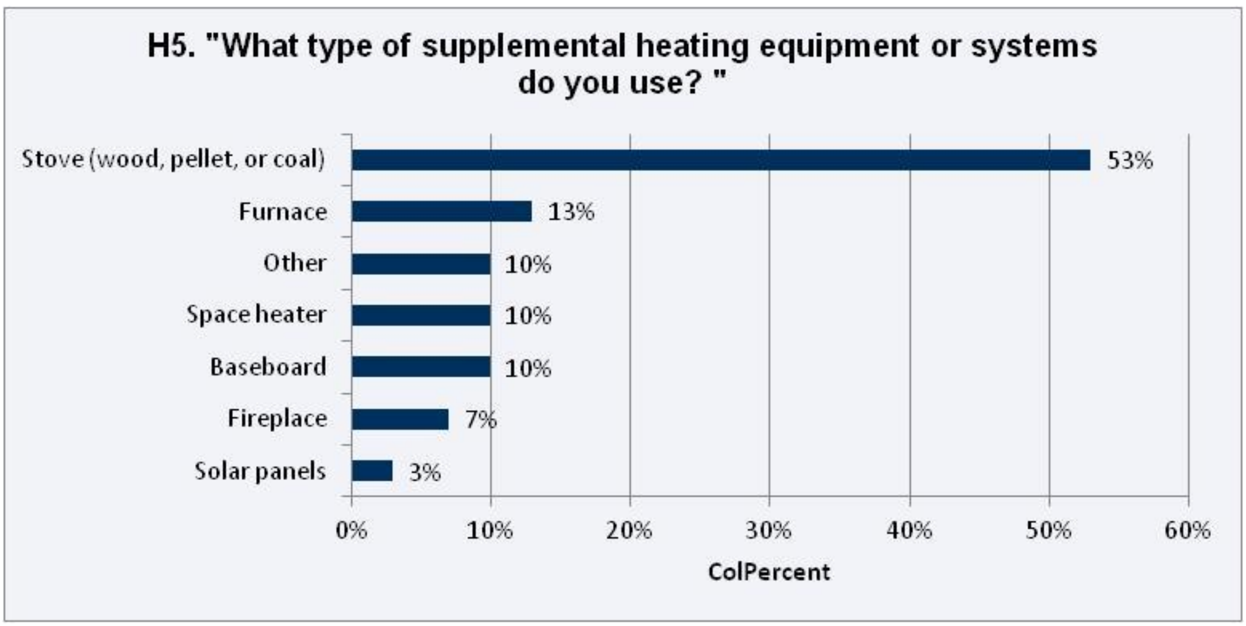
Cadmus observed additional secondary heating systems beyond those reported in the database. Figure 8 summarizes the secondary heating systems found during the site visits: 71% of inspected sites with a secondary distribution system used wood (fireplace or stove) as a secondary heating distribution type. It has been reported that contractors likely did not record this information when submitting to Efficiency Maine.

Figure 8. Secondary HVAC Distribution System (21 Sites: Cadmus Observations)



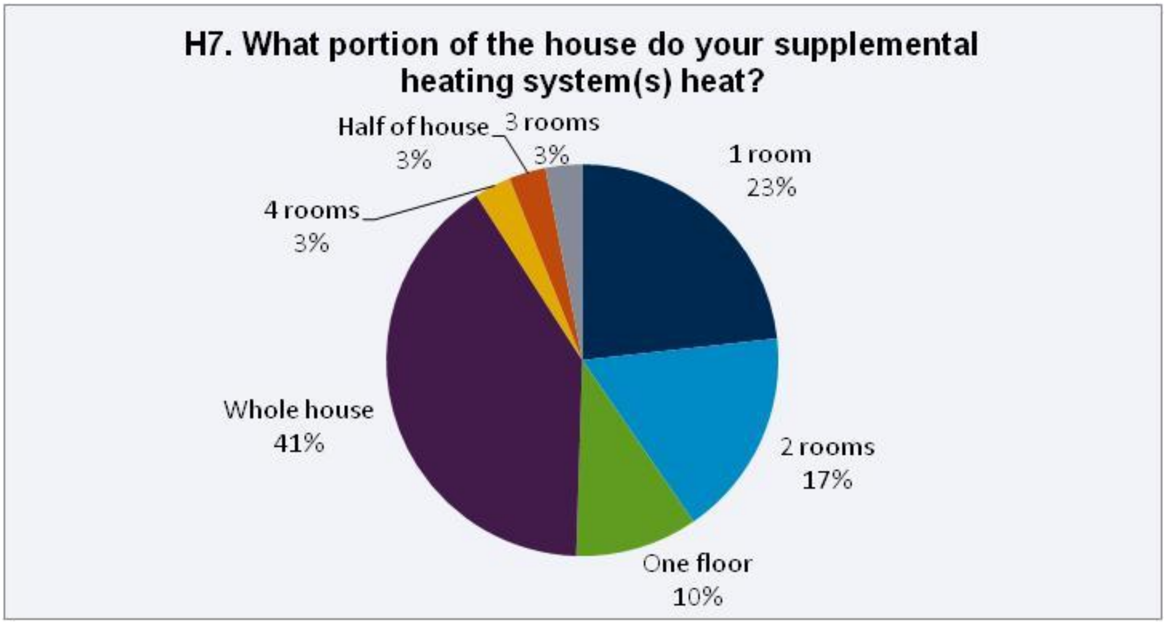
A majority of the survey participants (53%) with secondary heating systems indicated they used a stove for secondary heating.

Figure 9. Type of Supplemental Heating System (n=30)



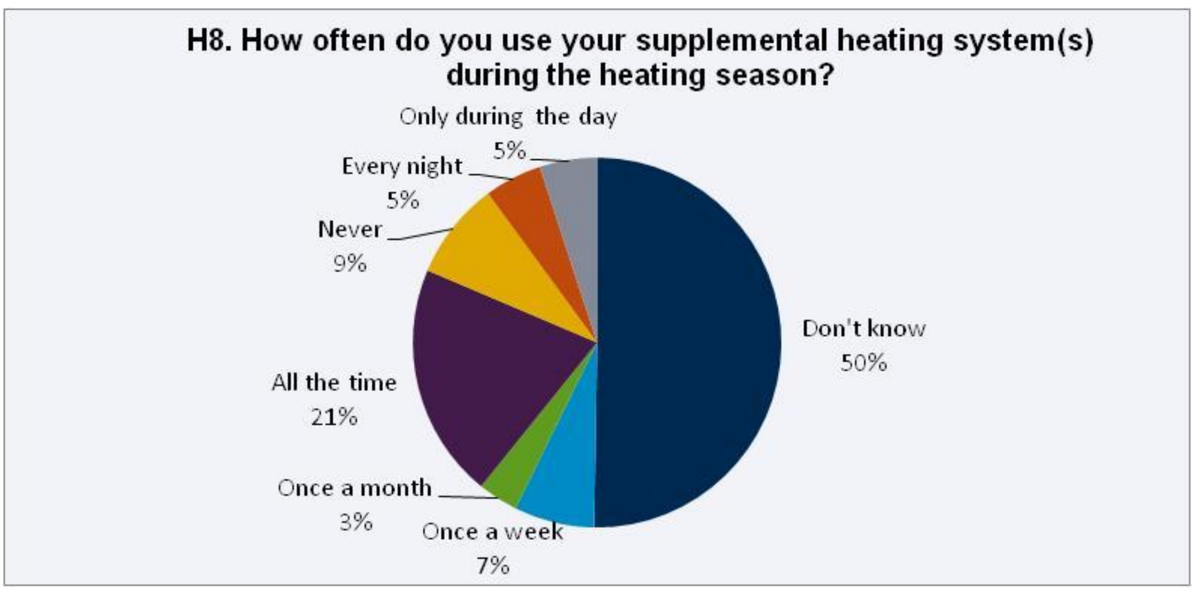
In addition to observing types of equipment and fuel sources in place within the homes of HESP participants, Cadmus also documented certain behaviors affecting the operating energy efficiency of the homes. Survey respondents with supplemental heating systems tended to use it to heat the whole house (41%). About one-quarter (23%) used it to heat a single room.

Figure 10. Portion of House Heated by Supplemental System (n=30)



The survey also addressed the frequency with which supplemental heating is used. Half of survey respondents (50%) did not know how frequently they used the supplemental heating system. One in five (21%) said they used it all the time.

Figure 11. Frequency of Supplemental Heating Use (n=29)



Water Heating Type and Fuel

Water Heating Fuel

The program database and Cadmus site visit data also documented the water heating fuel used by HESP participants. For the sample frame, program data show the majority of customers used oil, with the second most common fuel electricity; 9% and 8% used natural gas and propane, respectively.

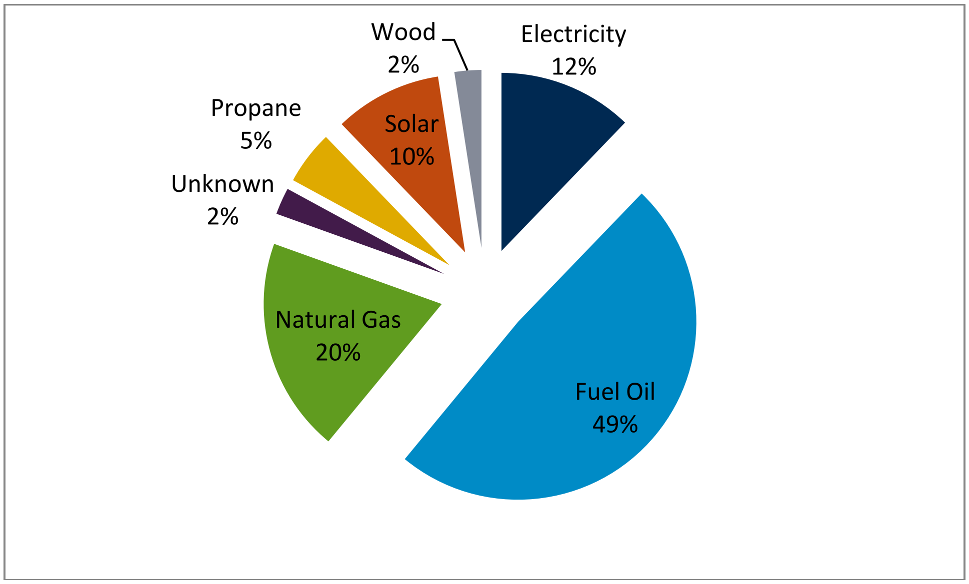
Table 9. Water Heating Fuel Type

Water Heating Fuel Type	Reported Water Heating Fuel Type (Total Sites)	Reported Water Heating Fuel Type (Sampled Sites)	Verified Water Heating Fuel Type (Sampled Sites)
Electric	23.43%	8.57%	12.20%
Natural Gas	9.44%	11.43%	19.51%
Kerosene	0.22%	0%	0%
Oil	52.08%	68.57%	48.78%
Other	0.67%	0%	0%
Propane	7.58%	8.57%	4.88%
Wood	0.11%	0%	2.44%
Solar	0%	0%	9.76%
Unknown, Other	6.46%	2.86%	2.44%
Total (Sites)	**1,780**	**35**	**41**

Some similarities were seen within the sample frame from the HESP database. The majority of customers used oil (69%). However, the second largest group used natural gas (11%), closely followed by propane and electricity (both with 9% of customers using this fuel type).

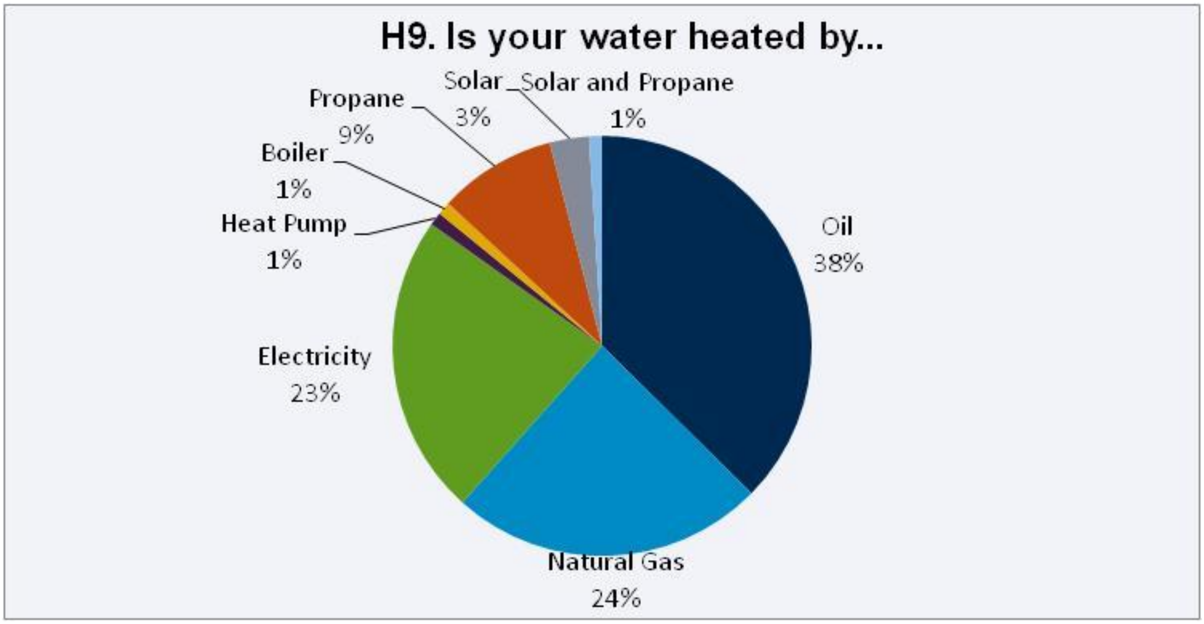
While the percentages were similar, a few additional fuel types were documented by Cadmus. Forty-nine percent of the sites sampled used oil to heat their water, 20% used natural gas, and 12% used electricity. However, solar was also a source of heat, with 10% using solar. There is a higher use of electricity reported in the HESP database.

Figure 12. Water Heating Fuel Type (41 Sites: Cadmus Observations)



This information was also captured during the survey, and some similarities were seen. Fuel oil was also the most common (yet, at a lower observance rate of 38% compared with the other three data sets) fuel type used for water heaters. There is higher electricity usage; similar to the HESP database, but different from the verified site data. Figure 13 shows the proportion of different water heating fuel types.

Figure 13. Water Heating Fuel Type (n=70)



Water Heating System

The charts that follow show the water heating system type documented for all sites in the HESP database, within the evaluation period and within the sample frame. The third chart shows data obtained during Cadmus' site visits. Table 10 shows that 37% of the participants used a storage tank, 28% had a tankless water heater, and 19% used an indirect water heater.

Table 10. Water Heating Type

Water Heating System Type	Reported Water Heating System Type (Total Sites)	Reported Water Heating System Type (Sampled Sites)	Verified Water Heating System Type (Sampled Sites)
Heat Pump	0.06%	0%	0%
Indirect	19.21%	19.51%	51.22%
On Demand	4.21%	4.88%	0%
Tank	36.52%	24.39%	41.46%
Tank High	4.89%	4.88%	0%
Tankless	28.37%	31.71%	7.32%
Tankless Backup	0.11%	0%	0%
Unknown, Other	6.63%	14.63%	0%
Total	**1,780**	**41**	**41**

Of sampled sites, the predominant water heating system was tankless water heaters, with 32% of the 41 participants using this system. Twenty-four percent used a storage tank, and 19% used an indirect water heater.

Cadmus' review of the hot water system type produces results different from those in the HESP database. Forty-six percent of participants used an indirect water heater, 39% used a storage tank, and only 7% had a tankless water heating system installed, as shown in Figure 14.

Figure 14. Water Heating System Type (41 Sites: Cadmus Observations)

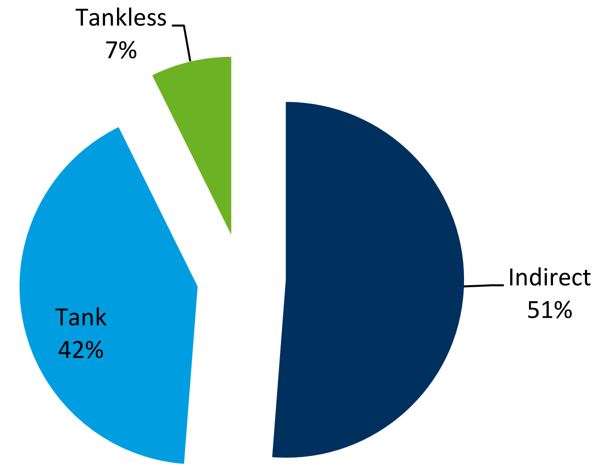


Table 11 shows average water temperature and thermostat settings. The average water temperature of sites visited was 124 °F. This is an efficient setting and typical of what Cadmus sees in other locations. We do not recommend lower settings because of concerns over bacterial growth. The average thermostat setpoint on a weekday, when the participant was home, was just below 67 °F. This is lower by several degrees than we see in other locations. The average setpoint during the week, when the participant was sleeping, was just above 63 °F.

Table 11. Behavioral Statistics

Statistic	Verified Average (41 Sites)
Water Temperature (°F)	123.9
Thermostat Setpoint Weekday (at home)	66.6
Thermostat Setpoint Weekday (at home while sleeping)	63.4

3.3 Site Visit Observations

In this section, Cadmus presents selected observations made during the 41 sites visits.

Cadmus field staff received positive feedback from many program participants, and noted the following:

- Overall, participants reported high satisfaction with the program, and were very happy about services and incentives they received.
- Participants displayed a high interest level in home performance during site visits.
- Participants were familiar with energy efficiency, and with steps that could be taken to improve the efficiency of their homes.
- Many participants reported being more comfortable in their homes after participation. Some heating oil users reported a noticeable decrease in fuel use since project implementation.

Overall, contractor performance was successful and effective. In general, Cadmus found that the measures reported in the program database were installed. Specific findings include:

- Air sealing appears to have been completed excellently, and the quality of contractor air sealing work was high.
    - Results of our blower door tests appear to indicate homes have been tightly sealed, in some instances exceeding IECC 2009 Code.
    - Cadmus completed 31 blower door tests (BD) during the 41 site visits for the HESP evaluation. Table 12 details the number of sites (n=10) where a BD test was not performed, and the reasons why Cadmus could not complete them.

Table 12. Reasons for Blower Door Test Incompletes

Reason for Not Completing BD	Quantity
Participant Declined Test	4
Site Required Two or more BD Kits	3
No Insulation Installed	1
Could Not Pressurize Home	1
Tenant Not Home to Permit Access to Seal Unit	1
Total	**10**

- Bulkhead doors were insulated and sealed with weather-stripping and were generally very well built (illustrating contractors' high-quality work). Bulkhead doors were, in many cases, custom-built doors in the foundation wall, made of plywood and rigid foam that were weather-stripped.

- Figure 15 shows insulated and sealed bulkhead doors, which were generally constructed with 2 inches of rigid foam and plywood. Weather stripping was applied to seal air leakage.

Figure 15. Basement Bulkhead Doors

- Attic hatches and pull-down stairs were similarly weather-stripped and insulated well. They were pulled tight with clasps, and fit frames well.
  - Figure 16 shows a new attic access built by a contractor to replace an existing attic access. The door was solidly built, and insulated with several sheets of 2 inches of rigid foam. The door's perimeter was sealed with rubber weather stripping and secured with clasps. This is a good example of particularly effective work completed by the HESP contractor.

Figure 16. Attic Hatch

- Rim joist insulation was also completed well. Figure 17 shows 2 inches of rigid spray foam applied to rim joists. This type of insulation doubles as an air barrier sealing up the home.

Figure 17. Rim and Band Joist Insulation

- According to Cadmus' observations, accurate insulation square footage measurements were made. When verifying the installed square footage of the insulation measures, the verified and observed values were within 97%[4] of the values reported in the HESP database. As can be expected in any large-scale program, there were some minor discrepancies noted:
    - In a few cases, contractors documented the total area of insulation, rather than simply documenting what was added. Documenting additional insulation was the appropriate method of data entry.
    - At one site, the program data reported 600 square feet of spray insulation installed in the basement walls. Cadmus measured only 483 square feet of insulation. Cadmus explains the estimation difference below:
        - The wall heights of this basement were between 2 and 6 feet (the result of completing multiple additions to the home). The original estimate appeared to have been based on 4 feet of insulation around the entire perimeter (not excluding areas with shorter foundation walls). Figure 18 and Figure 19 show the layout of this particular basement.

[4] When Cadmus excludes the measures that were not verified as installed, the verified square footages are within 99% of the HESP database reported square footages.

Figure 18. Six-Foot Wall

Figure 19. Two-Foot Wall

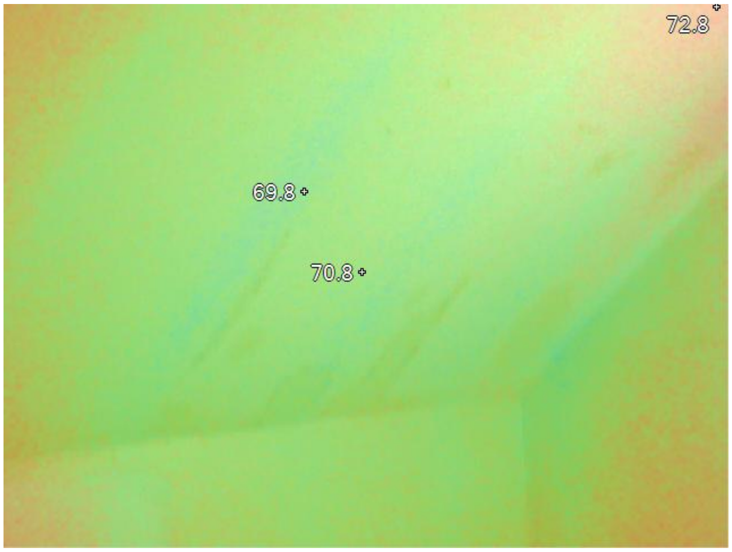
- Infrequently, insulation was installed in areas where it would be marginally effective (i.e., areas where no, or minimal energy savings would result: adiabatic walls, floor of a partially conditioned basement, etc…).

- Additionally, contractors were diligent when sealing and insulating hard-to-reach areas and building additions.
  - Many participating homes were over 100 years old with many remodels and additions. Contractors were meticulous, and made great efforts to insulate and seal areas generally difficult to address.
  - Cadmus used infrared cameras (thermal scans) to check for proper installation of wall insulation[5]. Figure 20 shows what was seen from infrared inspections performed in

[5] These devices work best when the outdoor temperature is 20 degrees less than the indoor temperature. Daytime temperatures during the site visits in August were in the high 60s to low 70s, but were not overly different from ambient indoor temperatures. On sunny days, attics with no or limited access could be viable for analysis because the sun could heat the roof to high-enough temperatures. Ideal conditions for infrared inspection would require temperatures below 50 degrees Fahrenheit (F) or above 90 degrees F. Consequently, infrared camera images and results were inconclusive.

Maine due to a low temperature difference. Framing is barely visible, and possible insulation voids are not visible at all. This photo illustrates infrared inspection is not effective during times of low temperature difference between the conditioned space and the outdoors. Cadmus could achieve useful thermal images at only two of the 41 homes.

Figure 20. Sloped Ceiling of a One-and-a-Half Story Maine Cape-Style Home



- We observed that contractors did an excellent job of dealing with closed constructions (e.g., walls, ceilings). However, based on our experience observing home construction, there are house elements that are a challenge to insulate.
  - The common home type observed in Maine was a cape-style home, with an upper floor built into the roofline. This type of construction contains cavities that are “closed-off,” but must be individually insulated. This means the wall and ceiling interiors are only accessible if holes are drilled, or if framing is modified. Also, when insulating closed constructions, conditions are not optimal due to plumbing, wiring, and other obstructions in the cavity. Due to this complexity, contractors and residents sometimes also deem it cost-prohibitive to pursue complete insulation.
  - While infrared inspection of sloped ceilings and walls was inconclusive, site visit evidence sometimes suggested installed insulation did not always fill the entire cavity, and the necessary insulation density was not achieved. At one HESP site (shown in Figure 21 and Figure 22), where IR inspection of the attic was possible, the ceiling showed insulation voids in hard-to-reach areas: where the roofline changed and at transitions between sloped and flat ceilings.

Figure 21. Temperature Differential in a Closed Structure (A)

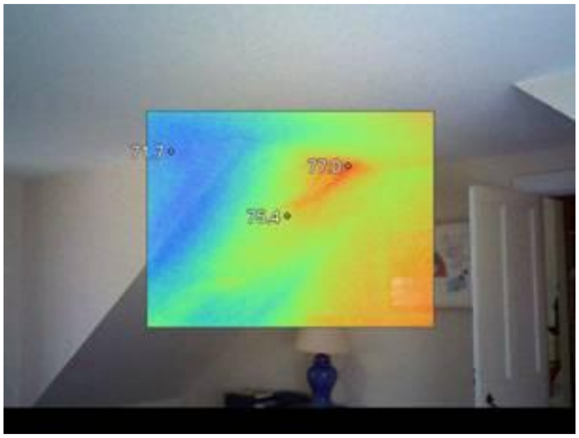
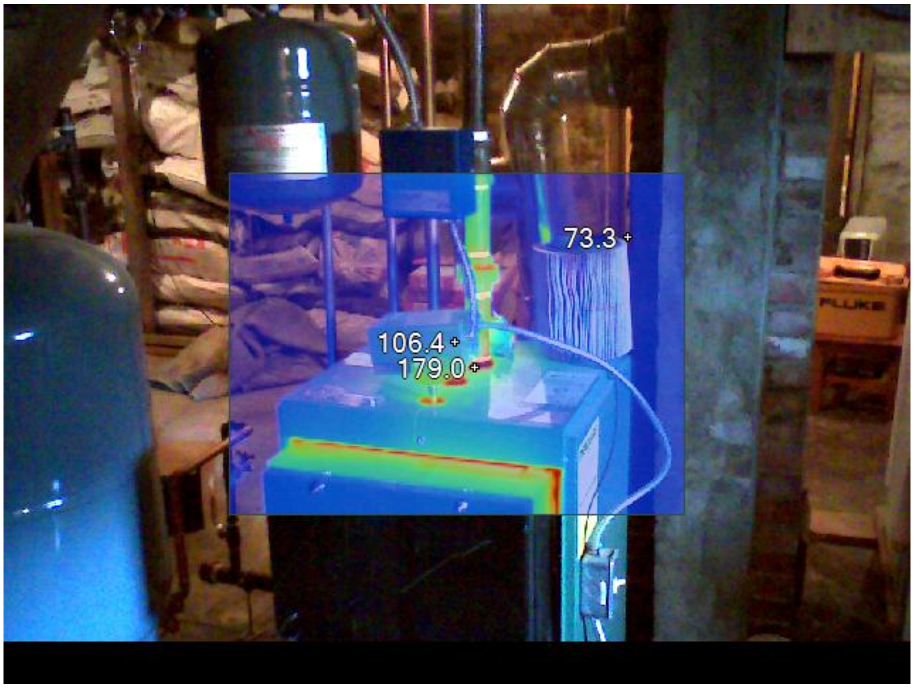


Figure 22. Temperature Differential in a Closed Structure (B)

- Cadmus also identified several situations where the insulation installed around piping was less than adequate.
    - Figure 23 shows a boiler system with an indirect water heater. A boiler generally must run all year as it provides domestic hot water to the home. These large, cast iron boilers and their plumbing produce substantial heat, dissipated to basements. During non-heating months, this heat is generally wasted in the basement. This particular home had, as part of the HESP program, insulated the ceiling of the basement. This insulation made the basement uncomfortably warm in the summer and, according to the homeowner, quite warm all winter. While some heat in the basement is necessary to provide freeze protection for plumbing, insulating the direct hot water loop would be useful to prevent wasted heat.

Figure 23. Indirect Water Heater



Overall, Cadmus found a low incidence of installation issues at the sites visited. Based on observations during site inspections, contractors were thorough and performed high-quality work. This is especially impressive, considering the age of some homes and complexity of some of the insulation and air sealing projects. While most homes that had installed wall insulation as part of their HESP participation could not be verified for proper density with thermal inspection, the otherwise high-quality work supported the impression that a thorough job was likely done.

4. Impact Analysis Findings

4.1 Gross Savings

Using Rem/RATE, Cadmus created a model that simulated how energy is used and wasted in a sampled home in Maine. The models' inputs included all data collected by Cadmus during site visits.

The model enabled Cadmus to create energy savings figures for each home and for measures installed within each home. Cadmus computed measure-level savings for air sealing, attic hatch, basement insulation, ceiling insulation, wall insulation, and furnace or boiler. The realization rate of each of these measures is present below in Table 13.

Table 13. HESP Realization Rate: Measure-Level

Measure Type	Reported Savings	Verified Gross Savings	Realization Rate
Air Sealing	565	585	103%
Attic Hatch	29	18	62%
Basement Insulation	381	305	80%
Ceiling Insulation	568	328	58%
Wall Insulation	462	584	127%
Furnace/Boiler	82	51	62%[6]
Total (41 Sites)	**2,087**	**1,871**	**90%**

These measure-level verified gross savings were compared with the HESP database reported savings to obtain gross realization rates. The resulting realization rates ranged from 58% to 127%. Relative to savings reported in the program database, the Cadmus savings estimates, based on site visit data and REM/Rate modeling, were higher for wall insulation and air sealing, but lower for attic hatch, basement and ceiling insulation, and furnace and boiler installations.

The three measures with the lowest realization rates were the ceiling insulation, furnace or boiler replacement, and attic hatch measures. Ceiling insulation installation, when measured in the field and modeled using REM/Rate, saved participants 58% of the energy, compared to the program-reported figures.

The 62% realization rate for furnace or boiler replacement measures resulted from Cadmus' modification of assumed efficiency levels, as described in the Methods section.

While modeled attic hatch savings were lower than those reported for attic hatch upgrades, Cadmus engineers believe that this is an important upgrade and that, in some cases, savings might be higher due to leaky, or poorly insulated existing hatches.

Air sealing showed savings at a level that is 103% of the reported values. Cadmus also compared reported savings from air sealing with values calculated by Cadmus for the 41 sites in

[6] Realization rate is based on file review of furnace or boiler replacement measures.

the evaluation sample. This method involved computing the average CFM 50[7] reduction for the 30 sites that received a blower door test and had pre-existing measurements.[8]

Cadmus found the average CFM 50 reduction for sites tested was 1,396, whereas the CFM 50 reduction from the 30 sites in the HESP database was 1,416. The reported data (n=1,391) had an overall average CFM 50 reduction of 1,662. This data is shown in Table 14.

Table 14 also shows the reported CFM 50 values for sampled sites and for the entire database. A minimal difference occurred between the reported (inspected) data and the data Cadmus collected during the site inspections.

Table 14. Comparison between Reported Database and Verified Infiltration Values

	Sample Size (n)	Pre-Sealing CFM 50 (Reported)	Post-Sealing CFM 50	CFM 50 Reduction	Percent Infiltration Reduction	Ratio
Proposed (HESP Database)	2,103	4,658	2,916	1,742	37.4%	95%
Measured (HESP Database)	1,391	4,487	2,837	1,662	36.8%	
Sampled (HESP Database)	30	3,698	2,399	1,416	35.1%	99%
Sampled (Cadmus)	30	3,698	2,343	1,396	36.7%	

"Proposed (HESP Database)" compares the measured, pre-installation infiltration rate with the proposed (energy advisors' best guesses) post-installation infiltration rate reported in the database. "Measured (HESP Database)" compares the measured, pre-installation infiltration rate with the data documented by the energy advisor after completing a post-installation inspection (CFM 50 value after efficiency measures were installed and the project was completed). Finally, Cadmus computed the CFM 50 reductions as reported for the sample frame (n=30) and as measured and verified by Cadmus during the site visits.

The average percent infiltration reduction for the evaluated sample (36.7%) was essentially the same as the average measured percent reduction (35.1%) reported in the database for these sites. It is likely that the lower CFM 50 reduction of 1,396 (when compared with the reduction measured in the population 1,662) can be explained by the smaller sample size rather than an evidence of lower savings.

4.2 Net-To-Gross Analysis

Cadmus implemented an NTG methodology to examine the energy savings attributable to the program and not to other factors. Freeridership and spillover are the two components that comprise NTG. Freeriders reduce savings attributable to an energy-efficiency program because they are participants who would have purchased a measure without a program's influence. Spillover—the amount of additional savings obtained by participants investing in additional energy-efficient measures or activities due to their program participation, but not incented by the program—increases savings attributable to the program.

[7] CFM 50 is the air leakage measured with a blower door in cubic feet per minute (CFM) with a house pressurized to 50 Pascals.

[8] One site within the HESP database did not have a pre-existing CFM value; so a comparison could not be completed.

Freeridership Analysis

The freeridership estimation[9] determined freeridership using patterns of responses to a series of five simple questions. The questions, which allowed "yes," "no," or "don't know" responses, dealt with whether participants would have installed the same equipment in the program's absence, at the same time, at the same amount, and at the same efficiency. Response patterns to these questions were assigned freerider scores, and confidence and precision estimates were calculated on score distributions.

A detailed explanation of Cadmus' freeridership methodology is included in Appendix A. The appendix explains the survey design, and describes Cadmus' freeridership methodology. It also provides:

- Full-text versions of the NTG survey questions administered to participants;
- The freeridership scoring matrix, showing all possible combinations of responses to the freeridership survey questions; and
- The scores Cadmus assigned each combination.

After conducting participant surveys, which contained the relevant questions, Cadmus converted resulting responses into a freeridership score for each participant, using an Excel-based matrix. Each participant's freerider score was derived by translating responses into a matrix value, and then using a rules-based calculation to obtain the final score[10]. Table 15 shows results of freeridership calculations for HESP measures. Overall, the program had an average freeridership of 14% across all 70 respondents.

Table 15. HESP Freeridership Results

Program	N	FR
HESP	70	14%*

* ± 4.5% Absolute Precision

Thirty-nine percent (27 out of the 70) answered they would not have installed the measure within one year, in absence of the HESP. These respondents were scored as 0% freeriders because they were not seriously considering installing the measure within one year.

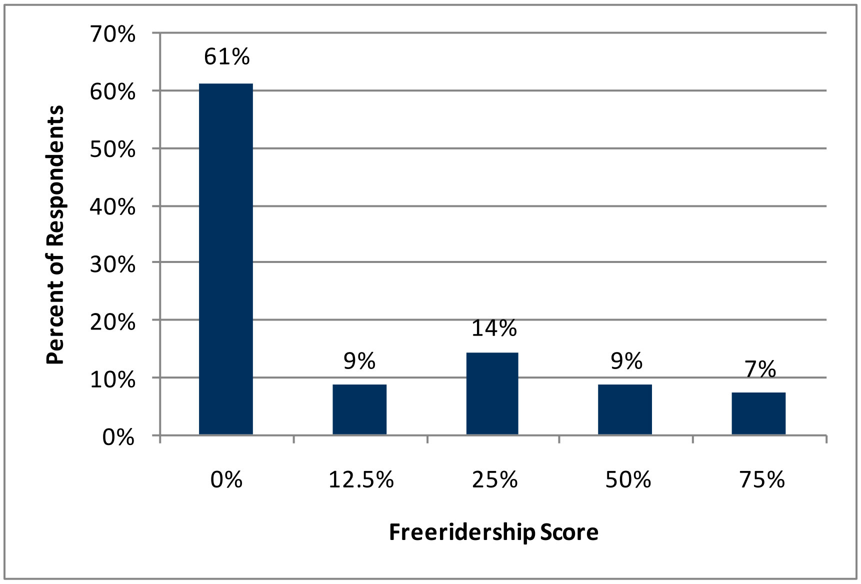
Figure 24 shows a distribution of respondents by the freeridership score assigned to each. Approximately 61% of survey respondents were scored as non-freeriders (0%), while 23% of respondents are exhibiting low levels of freeridership (12.5% and 25%). Nine percent of

[9] This approach is described in the freeridership methodology section in Appendix A. This specific approach was based on a previously developed approach by the Senior Vice President of the Cadmus Group, M. Sami Khawaja, Ph.D. It is cited in the National Action Plan for Energy Efficiency (NAPEE) Handbook on DSM Evaluation (2007, page 5-1), which can be found here: http://www.epa.gov/cleanenergy/documents/suca/evaluation_guide.pdf.

[10] Appendix A presents all combinations of responses received for HESP, and the scores assigned to each combination. Participant responses tended to group around a subset of common patterns. Freeridership scores were calculated for each measure category, based on the distribution of scores within the matrix.

respondents are showing a moderate level of freeridership (50%), while 27% of respondents were scored at a higher level of freeridership (75%). The analysis indicated none of the respondents were true (100%) freeriders.

Figure 24. Overall Distribution of HESP Freeridership Scores



Spillover Analysis

Participant spillover measures additional energy savings obtained by program participants who invest in additional energy-efficient measures or activities due to their program participation, but who are not incented by a program. A "spillover response" survey indicates the participant reported purchasing or installing other energy-efficiency improvements following their participation in HESP.

Spillover responses are considered attributed to the program if the respondent answers participation in HESP was very influential in deciding to make other energy-efficient improvements or purchases outside the program. As part of this evaluation, participant spillover savings were not quantified because participants did not provide many responses that could indicate spillover. Spillover actions mentioned by full participant respondents highly influenced by the HESP program are listed in Table 16.

Table 16. Qualitative Spillover Responses Attributable to Program

Spillover Response
We did an efficient air cooling system and refrigerator, washer, and dryer
Sealed the basement
Insulation garage door
Weatherizing
Upgraded to more modern air conditioning to save on electricity
Inexpensive minor things like sealing gaps
There's a place from the garage to the attic that is not accessible, and so we poked a whole in the wall, added more insulation
We had the entire house rewired, and put in 30 more outlets so we can plug in energy efficient appliances, and put fans to distribute the air more properly, they are all energy star, the roof, is a metal reflective roof
We figured out that when we don't need hot water we shut off our furnace during the summer, we save oil, because we have a hot water reserve tank
Washer and dryer
Mini split system
Put in all new windows and thermal window

Additionally, six full-participant respondents reported that, after participating in the program, they purchased CFLs not marked down, discounted, or eligible for a coupon. These respondents said their participation in HESP was very influential in their decision to purchase additional CFLs outside the program.

NTG

Table 17 shows NTG calculation results for HESP measures. Because spillover was not quantified, the net to gross value only takes into account the freeridership rate. Overall, the program had an average NTG of 86%, across all 70 respondents. The calculation used for the final NTG estimate for the HESP was: [1 – Freeridership % = NTG].

Table 17. HESP NTG Results

Program	N	FR	NTG
HESP	70	14%	86%

4.3 Program-Level Savings

Cadmus used the calculated measure realization rates to determine annual verified gross savings estimates for the HESP. The evaluation sample (n=41) did not include certain measures, and, in those instances, Cadmus used a realization rate of 1. To compute annual verified net energy savings, Cadmus applied the NTG ratio to verified gross savings.

Table 18 lists the program-level savings by verified measure type.

Table 18. Annual Energy Savings by Measure Type in MMBTUs

Measure Type	Reported Gross MMBTU Savings	Verified Gross MMBTU Savings	Gross Realization Rate	NTG	Verified Net Savings (Verified Gross * NTG)	Verified Net Savings	Measures (n)
Air Sealing	42,993	44,467	103%	0.86	38,242	89%	1,846
Attic Access: Existing (Hatch)	2,107	1,310	62%	0.86	1,127	53%	1,248
HVAC: System (Furnace/Boiler)	14,649	9,139	62%	0.86	7,859	54%	730
Insulation: Attic	30,732	17,756	58%	0.86	15,270	50%	2,849
Insulation: Basement/Floors	20,353	16,309	80%	0.86	14,026	69%	2,656
Insulation: Walls	18,394	23,271	127%	0.86	20,013	109%	967
Remaining Measures	12,257	12,257	100%	0.86	10,540	86%	2,765
Total[11] (1780 Sites)	**141,485**	**124,509**	**88%**	**0.86**	**107,077**	**76%**	**13,061**

Savings were broken out by fuel type. Annual Energy Savings by fuel type (in MMBTUs) can be seen in Table 19.

Table 19. Annual Energy Savings in MMBTUs

Annual Energy Savings by Fuel Type (MMBTUs)	Reported Gross Savings	Verified Gross Savings	Gross Realization Rate	NTG	Verified Net Savings (Verified Gross * NTG)	Net Realization Rate	Measures (n)
Fuel Oil	132,063	110,638	84%	0.86	95,148	72%	8,373
Natural Gas	1,244	4,965	399%	0.86	4,270	343%	2,070
Propane	763	2,052	269%	0.86	1,765	231%	1,376
Wood	3,635	3,315	91%	0.86	2,851	78%	374
Kerosene	732	615	84%	0.86	529	72%	102
Electric	3,024	2,908	96%	0.86	2,501	83%	749
Corn Pellet	22	17	76%	0.86	15	65%	17
Total (1780 Sites)	**141,485**	**124,509**	**88%**	**0.86**	**107,077**	**76%**	**13,061**

[11] Includes all measures installed within evaluation period.

Cadmus converted the savings figures into fuel consumption units, as shown in Table 20.

Table 20. Annual Energy Savings by Fuel Type (in Consumption Units)

Annual Energy Savings by Fuel Type	Reported Gross Savings	Verified Gross Savings	Gross Realization Rate	NTG	Verified Net Savings (Verified Gross * NTG)	Net Realization Rate	Measures (n=13,061)
Fuel Oil (gallons)	953,526	798,827	84%	0.86	686,991	72%	8,373
Natural Gas (therms)	12,440	49,646	399%	0.86	42,696	343%	2,070
Propane (gallons)	8,342	22,423	269%	0.86	19,284	231%	1,376
Wood (cord= 24 MMBTU)	151	138	91%	0.86	119	78%	374
Kerosene (gallons)	5,424	4,558	84%	0.86	3,920	72%	102
Electric (kwh)	886,127	852,013	96%	0.86	732,731	83%	749
Corn Pellet (7400 BTU/lb)	3,030	2,289	76%	0.86	1,969	65%	17

For this report, Cadmus calculated lifetime verified gross and net energy savings generated by the HESP. Cadmus used the reported EUL of the measure included in the program data to calculate lifetime verified net energy savings. These data (in MMBTUs) are shown in Table 21.

Table 21. Lifetime Energy Savings in MMBTUs

Lifetime Energy Savings by Fuel Type (MMBTUs)	Reported Gross Savings	Verified Gross Savings	Gross Realization Rate	NTG	Verified Net Savings (Verified Gross * NTG)	Net Realization Rate	Measures (n)
Fuel Oil	3,044,152	2,569,517	84%	0.86	2,209,785	73%	8,373
Natural Gas	87,296	156,880	180%	0.86	134,917	155%	2,070
Propane	55,068	76,932	140%	0.86	66,162	120%	1,376
Wood	91,216	83,203	91%	0.86	71,555	78%	374
Kerosene	17,617	14,786	84%	0.86	12,716	72%	102
Electric	40,278	37,597	93%	0.86	32,333	80%	749
Corn Pellet	563	426	76%	0.86	367	65%	17
Total (1780 Sites)	**3,336,191**	**2,939,342**	**88%**	**0.86**	**2,527,834**	**76%**	**13,061**

Cadmus also converted lifetime savings figures into fuel consumption units. The results of this are shown in Table 22.

Table 22. Lifetime Energy Saving by Fuel Type

Lifetime Energy Savings by Fuel Type	Reported Gross Savings	Verified Gross Savings	Gross Realization Rate	NTG	Verified Net Savings (Verified Gross * NTG)	Net Realization Rate	Measures (n=13,061)
Fuel Oil (gallons)	21,979,438	18,552,471	84%	0.86	15,955,125	73%	8,373
Natural Gas (therms)	872,964	1,568,801	180%	0.86	1,349,169	155%	2,070
Propane (gallons)	601,841	840,789	140%	0.86	723,079	120%	1,376
Wood (cord= 24 MMBTU)	3,801	3,467	91%	0.86	2,981	78%	374
Kerosene (gallons)	130,496	109,524	84%	0.86	94,190	72%	102
Electric (kwh)	11,801,276	11,015,827	93%	0.86	9,473,611	80%	749
Corn Pellet (7400 BTU/lb)	76,108	57,596	76%	0.86	49,533	65%	17

The verified annual net energy savings of the HESP are 107,077 MMBTUs. The verified net lifetime energy savings of the HESP are 2,527,834 MMBTUs. These two calculations yield a gross realization rate of 88%. The final, net realization rate of the Efficiency Maine HESP is 76%.

The Program reported reducing residents' energy consumption by 40%, on average. Cadmus observations verify that the Program saved customers 31% in energy savings, on average

4.4 Utility Bill Review

As part of this evaluation, Cadmus attempted to obtain direct fuel usage data from billing or delivery information for selected sites to augment the engineering analysis. The difficulty of obtaining billing data for the sample sites became apparent as the evaluation progressed.[12] It was challenging to collect viable liquid fuel usage data for Maine residents due to the following:

- Unlike other areas of the country, where residents are served primarily by one utility company, Maine has many different fuel suppliers from which to choose.
    - To obtain the fuel oil and propane delivery information, Cadmus had to contact a large number of individual fuel companies (n=28) directly.
- Individuals often chose to use multiple suppliers during the course of a heating season.
- Individuals used multiple fuel types.
- Utility companies were non-responsive to Cadmus' requests.

[12] In total, Cadmus spent nearly half as much time attempting to collect bills as its staff spent in the field at the 41 houses, yet, satisfactory bills for less than half of the houses were obtained. The process Cadmus used to attempt to obtain fuel usage information is explained in Appendix D.

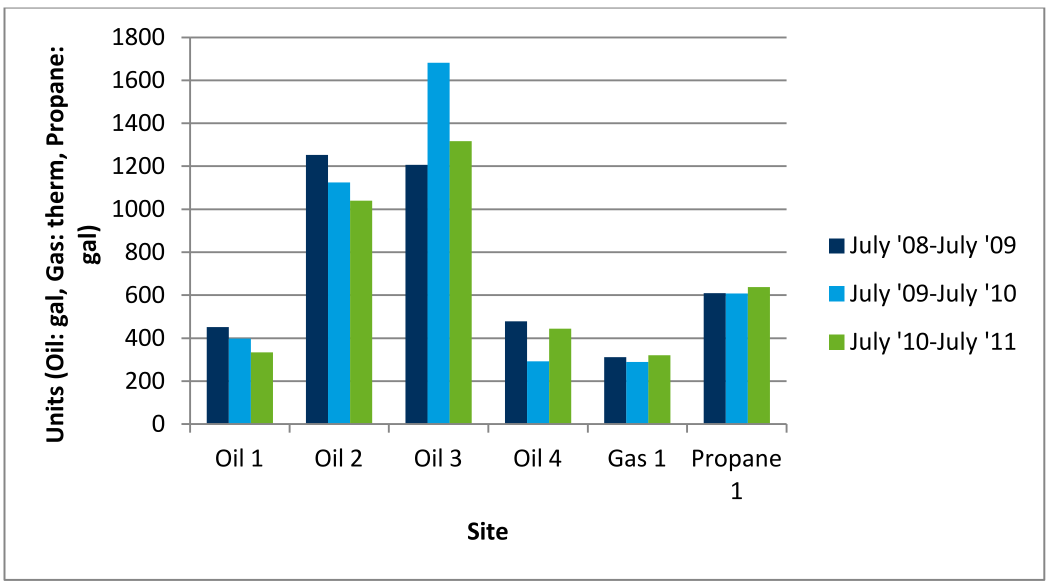
- To obtain Unitil gas billing data, Cadmus had to contact participants directly to receive their billing data (per the request and recommendation of Unitil). Many customers were not willing to provide the data, or, simply, did not provide the data.
- As billing data is proprietary, residents were asked to sign an authorization form to allow Cadmus to receive their information. If customers were not willing to complete the form (n=9), Cadmus could not receive the information from the fuel provider.

Ultimately, Cadmus could obtain usable fuel usage information from only 19 of the 41 sampled participants. Unfortunately, subsequent to that, many bills received also were difficult to interpret in the billing analysis due to the following:

- Oil was delivered inconsistently. Customers often did not receive "fill-ups," meaning their oil tank was not empty when they ordered additional fuel, making it difficult to track consumption consistently.
- Residents received deliveries infrequently. As a result, assumptions were made to determine when fuel was consumed and how frequently.
- More than half of the sites used supplemental fuel. The most significant supplemental heat source was wood, used by 57% (12 residents) of sampled residents with supplemental fuel. In the survey, a large portion of sites with supplemental fuel used it continuously or often, and 60% heated 3 rooms or more with that heat.
  - Seven percent of participants used wood and 2% of participants used pellet wood as the primary fuel source for their home.

Cadmus collected 9 sets of bills for 2008-2009, 19 for 2009-2010, and 22 for 2010-2011 (though these bill sets are subject to missing deliveries). Of these sets, only 5 sets of oil bills and one set of gas bills included all three heating seasons, which is shown in Figure 25.

Figure 25. Fuel Deliveries as Indicated by Bills



Given that inventory carry over can significantly impact annual bills, there is no reliable way to calculate changes in pre- and post-program consumption. The absolute magnitude of the oil bill yearly deliveries has variability between 2.8 and 6.5 to 1, and many yearly usage amounts are far lower than expected.

Cadmus determined that the data obtained would not support the statistical billing analysis proposed as a part of the evaluation.

The fuel savings observed in the limited billing data Cadmus was able to obtain fell below what was modeled and expected. This likely could be attributed to the following:

- The widespread use of supplemental heat. There is clear evidence from field observations, file records, and surveys that many customers have wood as a secondary heat source and use it often. The homeowner for Oil 1 indicated that wood is the primary heat source. Oil 2 uses wood for cold days to supplement oil heat. Oil 3 heats only with oil. No notes regarding supplemental heat use for Oil 4 and Gas 1 were recorded, but their use is consistent with use patterns of residents with a substantial use of supplemental fuel. Propane 1 had converted from kerosene, and it is not known whether any residual use of kerosene remains.
- Missing deliveries, due to price-shopping suppliers and differing delivery dates, especially relating to summer usage, make it difficult to interpret data as does fuel storage potential. For example, one homeowner with a small house had 600 gallons of storage capability and held a large inventory of fuel oil.

4.5 Job Impacts

Cadmus estimated the number and type of short-term and long-term jobs generated due to the HESP. As agreed upon with the Trust, Cadmus took a simple approach to this analysis, using the U.S. DOE's analytical protocol, which assumes one job-year is created for every $92,000 in program spending.

Efficiency Maine's total ARRA expenditures were calculated at $8,549,371. Per the DOE analysis, the HESP program should have created approximately 93 job-years through its implementation.

4.6 Cost-Effectiveness

Total Resource Cost Test

Assessment of cost-effectiveness for the HESP began with a valuation of each energy efficiency measure's net "total resource" benefits, as measured by electric avoided costs and the measure's total incremental installed costs. The program was deemed cost-effective if its net "total resource" benefits were positive, as calculated:

$$\frac{\textit{Total Resource Benefits}}{\textit{Total Resource Costs}} \geq 1$$

where,

$$Total\ Resource\ Benefits = \text{NPV}\left(\sum_{year=1}^{measurelife}\left(\sum_{i}^{i=8760}(\text{impact}_i \times \text{avoidedcost}_i)\right)\right)$$

and,

The Trust provided cost and savings information as well as the inputs shown in Table 23. Cadmus calculated TRC results for each HESP project in the evaluation period that had been modeled with RHA[13] in the program database. Measure-level TRC results for RHA homes could not be calculated as costs were only available and provided at the project level.[14]

Realization rates calculated by Cadmus were applied to savings values provided by Efficiency Maine.

Table 23. TRC Inputs and Assumptions

Category	Value
Discount Rate	4.51%
Line Loss	6.50%
2010 Avoided Costs by Fuel	
Electric Energy, Winter Off Peak ($/kWh)	$0.06
Electric Energy, Winter On Peak ($/kWh)	$0.07
Electric Energy, Summer Off Peak ($/kWh)	$0.05
Electric Energy, Summer On Peak ($/kWh)	$0.07
Electric Demand, Winter ($/KW)	$0.00
Electric Demand, Summer ($/KW)	$67.15
Transmission and Distribution ($/KW)	$80.00
Natural Gas Heating ($/MMBTU)	$9.58
Natural Gas Water Heat ($/MMBTU)	$12.32
Kerosene ($/MMBTU)	$15.49
Oil ($/MMBTU)	$15.95
Propane ($/MMBTU)	$24.52
Wood ($/MMBTU)	$10.12
Corn Pellet ($/MMBTU)	$10.12

[13] TRC results could not be calculated for projects where savings were reported using TREAT or REM/Rate. Measure-level information was not provided for these projects.

[14] It would have introduced error into the calculations to attempt to allocate the project level costs to measure level costs.

Table 24 shows annual MMBTU savings, avoided fuel costs, and increased fuel costs for each fuel type for the HESP. Reported savings reflected total savings associated with projects, adjusted for any increased fuel consumption as a result of fuel switching. Lighting savings reflected baseline changes due to Energy Independence and Security Act (EISA) legislation.

Table 24. Annual Savings, Avoided Fuel Costs, and Added Fuel Costs, by Fuel Type

Fuel Type	MMBTU Savings	Avoided Fuel Costs	Added Fuel Costs
Electric	2,908	$1,571,123	$157,571
Natural Gas	4,965	$2,500,148	$1,425,241
Propane	2,052	$4,825,491	$2,939,778
Oil	110,638	$49,874,294	$187,398
Kerosene	615	$283,394	$0
Wood	3,315	$540,640	$28
Corn Pellet	17	$2,794	$0
Total Adjusted Gross Values	**124,509**	**$59,597,884**	**$4,710,016**
Total Net Values	**107,077**	**$51,254,180**	**$4,050,614**

Incremental participant measure costs were based on reported project costs and standard industry baseline cost sources the Database of Energy Efficient Resources (DEER) and ENERGY STAR. Costs were adjusted to reflect federal tax credits, consistent with the California Standard Practices Manual.

A TRC analysis was conducted on three savings scenarios. The first scenarios calculated cost-effectiveness using gross reported savings. The second adjusted these gross savings values using the realization rates described above. The third scenario adjusted both savings and project costs using a NTG ratio of 86%. In all three scenarios, the HESP passed the TRC test comfortably. Table 25 presents the results of the TRC analysis.

Table 25. TRC Results for the HESP

Value	Reported Gross Savings Scenario	Verified Gross Savings Scenario	Verified Net Savings Scenario
MMBTU Savings	141,485	124,509	107,077
Avoided Energy Benefits	$70,097,059	$59,597,884	$51,254,180
Added Energy Costs[15]	$6,879,199	$4,710,016	$4,050,614
Participant Incremental Costs	$16,387,212	$16,387,212	$14,093,002
Program Delivery	$1,078,868	$1,078,868	$1,078,868
Marketing	$642,111	$642,111	$642,111
Administration	$187,155	$187,155	$187,155
TRC Benefits	$70,097,059	$59,597,884	$51,254,180
TRC Costs	$25,174,546	$23,005,363	$20,051,751
TRC Ratio	**2.78**	**2.59**	**2.56**

[15] The California Standard Practice Manual, the industry standard for cost-effectiveness evaluation, notes any added fuel costs resulting from DSM programs should be considered as components of TRC Costs, rather than as reductions to TRC Benefits. Here, "added energy costs" refers to these increased fuel costs from fuel-switching programs. For fuel-switching measures (like replacing a propane furnace with a higher-efficiency natural gas furnace), there is a reduction in supply costs for one fuel, and an increase for another fuel. The overall effect should be a decrease in fuel costs. Added fuel costs and avoided fuel costs are separated out so that the avoided costs can be factored into TRC Benefits, and the added costs can be factored into TRC Costs.

SEP-RAC Test

The U.S. DOE SEP-RAC test compares net MMBTU savings per $1,000 of ARRA expenditures (costs).

Costs used in the SEP-RAC test were the sum of all the Trust's expenditures, related to the HESP, through the end of the evaluation period. This included measure incentives (excluding any partner rebates paid by Unitil), program delivery expenditures, marketing costs, and administrative costs. MMBTU savings were provided for each home.

Similar to the TRC test process, measure-level savings information was provided for homes with savings evaluated using the RHA method. The realization rates established through engineering analysis were applied to RHA homes.[16] MMBTU savings for both RHA and TREAT or REM/Rate homes were adjusted using a NTG ratio of 86% (as noted previously).

The DOE SEP-RAC test is an alternate cost-effectiveness metric, evaluating whether projects save at least 10 million source BTUs (10 MMBTUs) annually, the threshold for ARRA-funded programs.

The Trust's Program saved 13.41 net MMBTU per $1,000 in ARRA expenditures, passing the SEP-RAC test. Table 26 provides details of SEP-RAC test analysis.

Table 26. Components and Results of the SEP-RAC Test

Category	Value
RHA MMBTU Savings – Adjusted Gross	124,509
TR MMBTU Savings – Gross	8,762
Total Gross MMBTU Savings	133,271
NTG Ratio	86%
Total Net MMBTU Savings	114,613
HESP Incentives (Including Bonus Payments)	$6,641,237
Program Delivery	$1,078,868
Marketing	$642,111
Administration	$187,155
Total ARRA Expenditures	$8,549,371
MMBtu/$1000	**13.41**

4.7 Carbon Emission Displacement

Cadmus calculated displaced greenhouse gas emissions associated with Efficiency Maine's HESP. To conduct this analysis, Cadmus used the verified net energy impacts, in terms of net tons of carbon emissions avoided over the EUL of the projects. Cadmus used the following tools

[16] As savings for TREAT and REM/Rate homes could not be separated by end use or measure type, these savings were not adjusted.

in this analysis: the World Resource Institute's GHG Protocol;[17] and the Maine Department of Environmental Protection (DEP) Greenhouse Gas Worksheet (Worksheet).[18]

Data used to calculate the displaced greenhouse gas emissions over the EUL, as well as annually, can be seen in Table 19 (*Annual Energy Savings in MMBTUs*) and Table 21 (*Lifetime Energy Savings in MMBTUs*). Cadmus did not factor in emissions from corn pellets in this analysis as the amount claimed was insignificant when compared with other fuels.

Cadmus referenced Maine's DEP requirements for emission factor selection. According to the DEP, "Greenhouse gas inventories are still evolving and the Department will accept any emission factor with proper documentation."[19] The three primary sources of emissions factor information indicated by DEP were:

- The World Resource Institute (WRI)/World Business Council for Sustainable Development;
- The U.S. Environmental Protection Agency, AP-42; and
- DOE, Energy Information Administration.[3]

The DEP Worksheet uses emissions factors from the Intergovernmental Panel on Climate Change (IPCC) National Greenhouse Gas Inventory Program.[20] Cadmus utilized this Worksheet to calculate displaced annual and lifetime greenhouse gas emissions for the HESP. When possible, emissions factors from the Worksheet were used; however, if a fuel type was not included in the Worksheet, Cadmus obtained emissions factors from two other primary sources: the GHG Protocol Initiative;[21] and DOE, Energy Information Administration.[22]

Using the fuel type, the amount of fuel, and the emissions factor, Cadmus calculated carbon dioxide (CO2) emissions, methane (CH4) emissions, and nitrous oxide (N2O) emissions, displaced in tons per year. Using the global warming potentials from the 2007 IPCC Fourth Assessment Report, Cadmus converted the annual and lifetime greenhouse gas emissions displaced into net tons of CO2 equivalent.

The WRI requires reporting CO2e emissions from biomass separately from GHG emissions from fossil fuels because biomass emissions are considered accounted for by land-use analysis.[23] Therefore, values of total GHG emissions from fossil fuels have been reported separately from the total CO2e emissions from biomass in this analysis. Table 27 shows the results.

[17] http://www.ghgprotocol.org/calculation-tools/all-tools
[18] http://maine.gov/dep/air/emissions/ghg-tools.htm
[19] http://maine.gov/dep/air/emissions/ghg-rptng.htm
[20] http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm (as of 2 July 2003), http://maine.gov/dep/air/emissions/ghg-tools.htm
[21] http://www.ghgprotocol.org/templates/GHG5/layout.asp?type=p&MenuId=OTAx
[22] http://www.eia.gov/pub/oiaf/1605/cdrom/pdf/e-supdoc.pdf
[23] http://www.ghgprotocol.org/calculation-tools/faq

Table 27. Annual and Lifetime Carbon Emissions Displaced from HESP

Fuel Type	Total GHG Emissions Displaced Tons CO2e	
	Annual	Lifetime
All Fuels (without Biomass)	8,443	196,735
Biomass	347	8,707

In completing these calculations, Cadmus relied on several assumptions.

The amount of carbon displaced was an estimation, based on best practice tools available. As referenced above, per Maine's DEP requirements for emission factor selection, Maine does not have one singular methodology for calculating displaced carbon emissions at this time. If another tool was used, calculations could come out slightly differently.

In calculating carbon emissions displaced over the effective useful life of each measure type, Cadmus applied currently available emissions factors to these savings, by measure and fuel type, over the effective useful life of the measure.

In the future, depending on legislation and the progression of study in this area, emissions factors will likely be updated. Thus, the level of rigor for this study is not sufficient to monetize these carbon data.

5. Survey Analysis Findings

Through the participant and partial participant surveys, Cadmus found the following:

Program Awareness: Efficiency Maine's print and media marketing materials reached Maine residents, and drove program participation. Contractors provided another effective channel to inform residents about the program and to encourage their continued participation after residents began to understand benefits gained through implementation of energy-saving improvements.

Program Information Sources: All participant classes used the Efficiency Maine Website as their primary source for identifying an energy advisor to conduct the home energy assessment or audit. To select energy advisors, full participants also used contractors they already knew, while partial participants relied on word-of-mouth and referrals from Efficiency Maine.

Participant Profile: When compared to full participants, partial participants tended to be younger and have larger households. Household and respondent characteristics identified through these surveys may prove useful for messaging and segmentation efforts.

5.1 Motivations and Decisions

The HESP rebate and the potential to save money on energy bills motivated residents to begin participating in the program by having an energy audit. Among those who completed energy upgrades (full participants), respondents indicated the rebate provided a greater incentive than the federal tax credit. The two incentives' combined effects may have motivated, at most, an additional 31% to make improvements.

Participants (full and partial) reported that energy advisors most commonly recommended all types of insulation and air sealing. These measures were also the ones most commonly installed, as recorded in the program database.[24] Very few survey respondents installed low-cost measures, such as CFLs and low-flow showerheads, as part of their HESP project. This survey finding is consistent with data regarding installed measures in the program database.

Initial Program Participation

To better understand outreach channels proving most influential with participants, Cadmus asked about participants' initial contacts with the program. HESP participants (both full and partial combined) most commonly (36%) cited print advertising and media as their first source of information about HESP. Print advertising included brochures, newspaper ads, and direct mailings; and media sources included radio and TV spots. After print advertising and media, full participants most frequently (29%) first learned about the program through a contractor, while partial participants most often (24%) learned about the program through word-of-mouth/recommendations from others.

Figure 26 depicts multiple sources first informing full and partial participants about the program.

[24] The program database extract, provided by Efficiency Maine for the evaluation, was used to generate the survey sample.

Figure 26. Initial Program Exposure, All Participants (n=88, Multiple Responses Allowed)

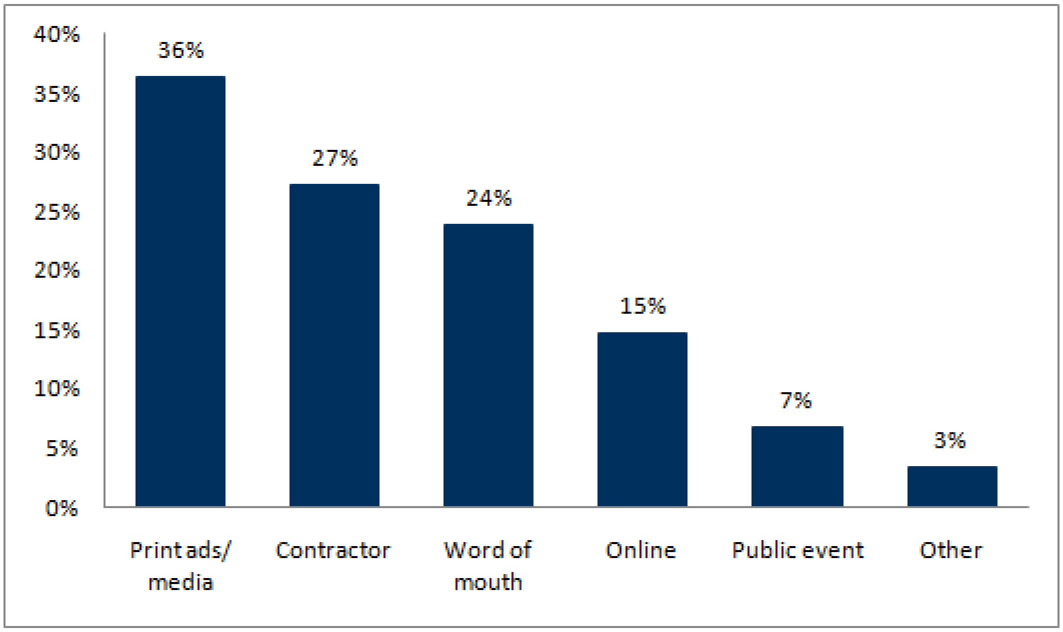
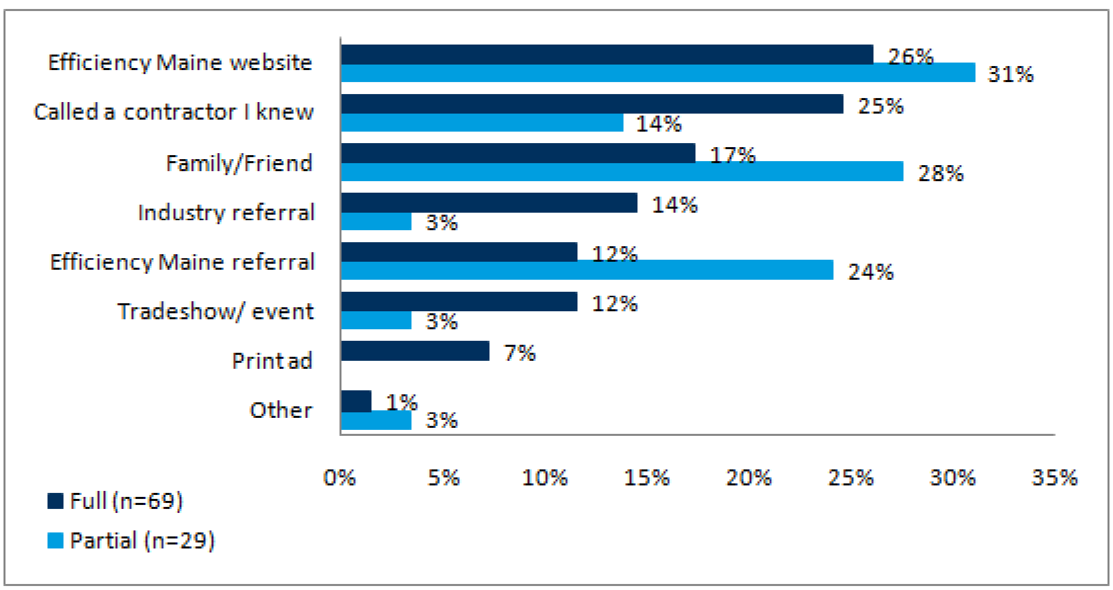


Figure 27 illustrates reported sources participants utilized to find energy advisors to conduct home energy audits. Both full (26%) and partial (31%) participants most frequently relied on Efficiency Maine's Website to find energy advisors. Full participants (25%) also commonly called contractors they already knew, while partial participants also relied on family and friends (28%) and referrals from Efficiency Maine (24%).

Figure 27. Energy Advisor Selection Sources (Multiple Responses Allowed)

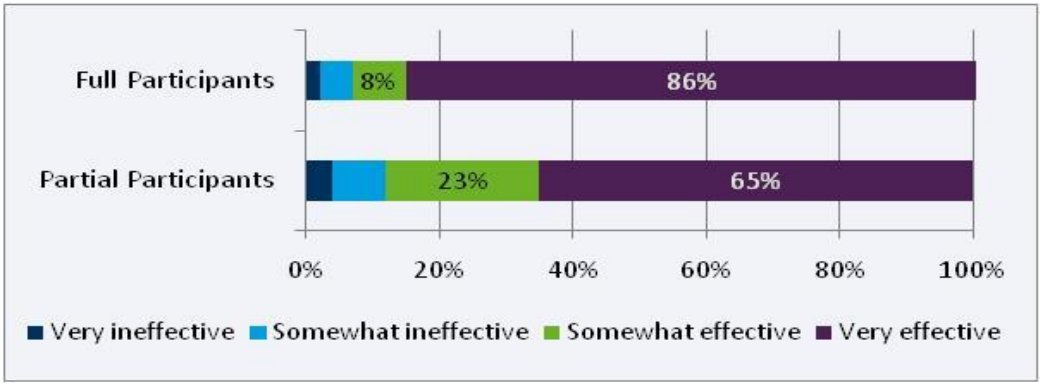


Once participants selected an energy advisor, the advisor conducted an energy audit to assess efficiency measures and improvements to decrease energy use in their homes.

Both full (94%) and partial (88%) participants found audit reports somewhat to very effective. More full participants than partial participants found them very effective. Qualitative responses indicated they found the reports clear and detailed. Participants liked being presented with options for improvements and their associated savings estimates. A typical positive comment was: "*I was amazed at what energy was saved by doing such little things.*"

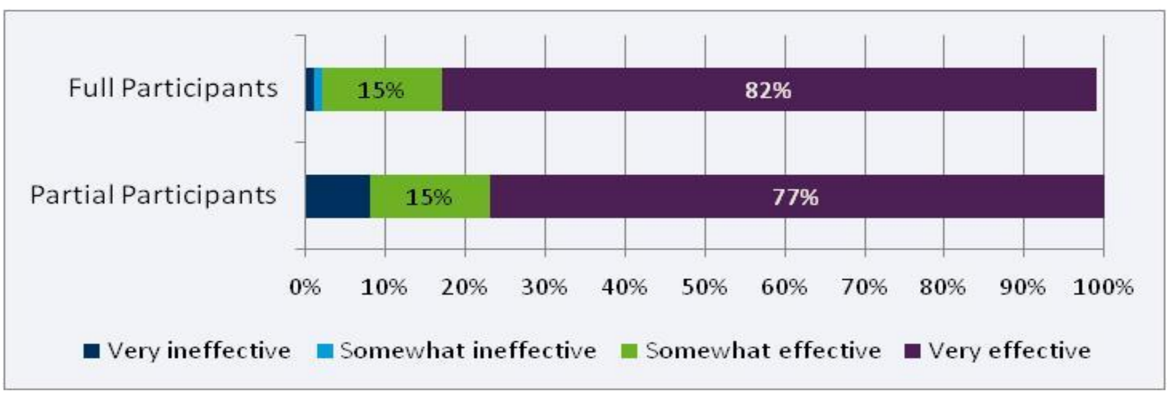
Conversely, some participants had negative comments, including that they waited "a long time" to receive the audit report, or, in a couple of cases, never received it. Figure 28 shows respondents' ratings for the audit report's effectiveness.

Figure 28. Effectiveness of Audit Report



Full (97%) and partial (92%) participants also attributed similar effectiveness levels to the energy advisor. Several respondents indicated the advisor "explained things thoroughly" and "identified improvements that I wasn't aware of." Figure 29 shows respondents' ratings for the energy advisor's effectiveness.

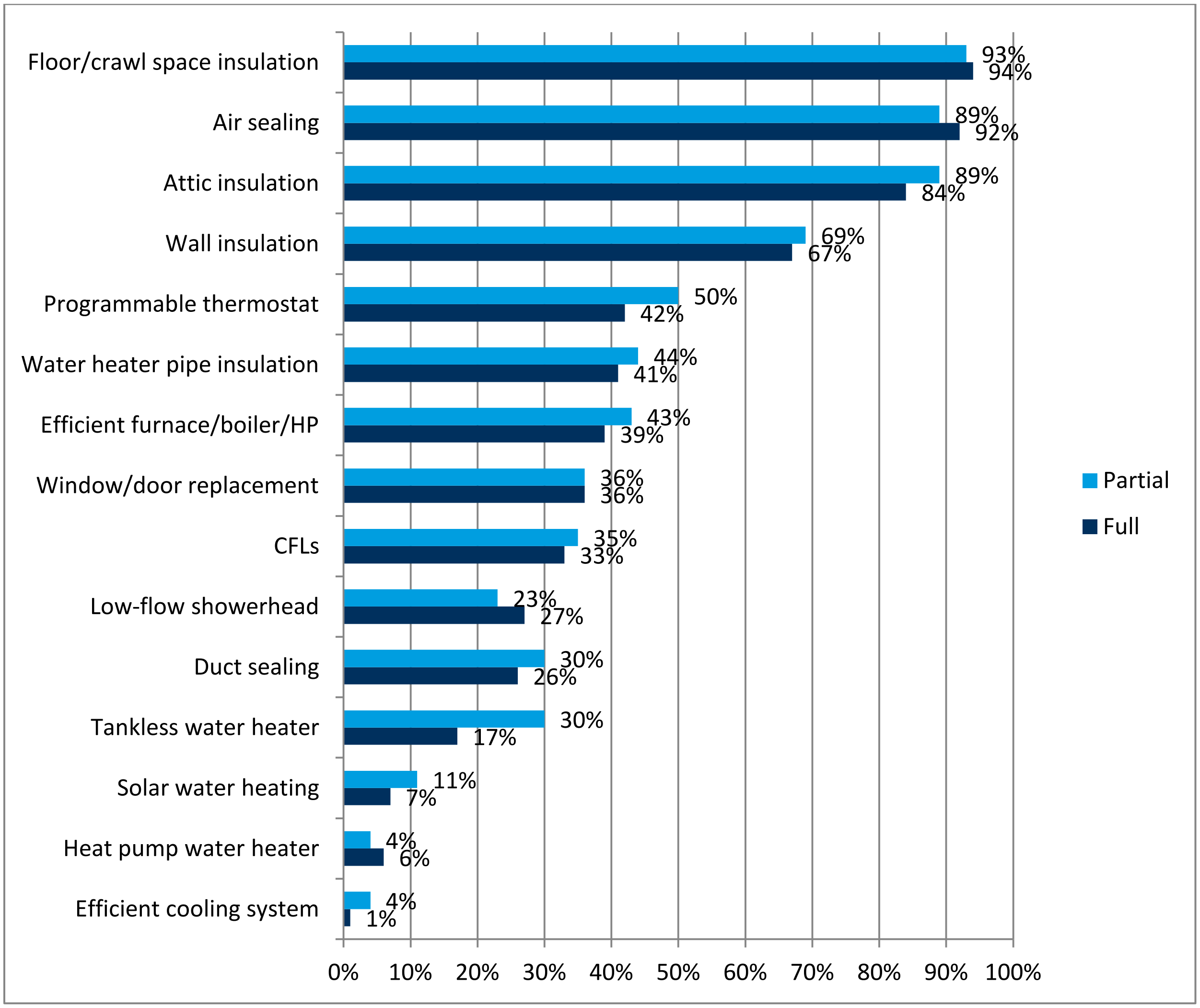
Figure 29. Effectiveness of Energy Advisor



Audits led to recommendations for energy-efficiency improvements to each home. Improvements recommended through the energy audit process were consistent between full and partial participants, with floor and crawl space insulation (93%–94%) and air sealing (89%–92%) most commonly recommended measures. Lower-cost measures, such as CFLs and low-flow showerheads, were recommended for one-quarter (23%–27%) to one-third of (33%–35%) participants.

When partial participants were asked if any of the recommended improvements had been completed in their homes, two-thirds (67%) said “yes” (33% said “no”). Of the 20 partial participants that had completed some improvements, attic insulation (65%) was the most common measure, followed by air sealing (50%) and floor/crawlspace insulation (45%). Only one participant reported purchasing a CFL, and none reported installing low-flow showerheads or aerators.

Figure 30. Recommended Improvements

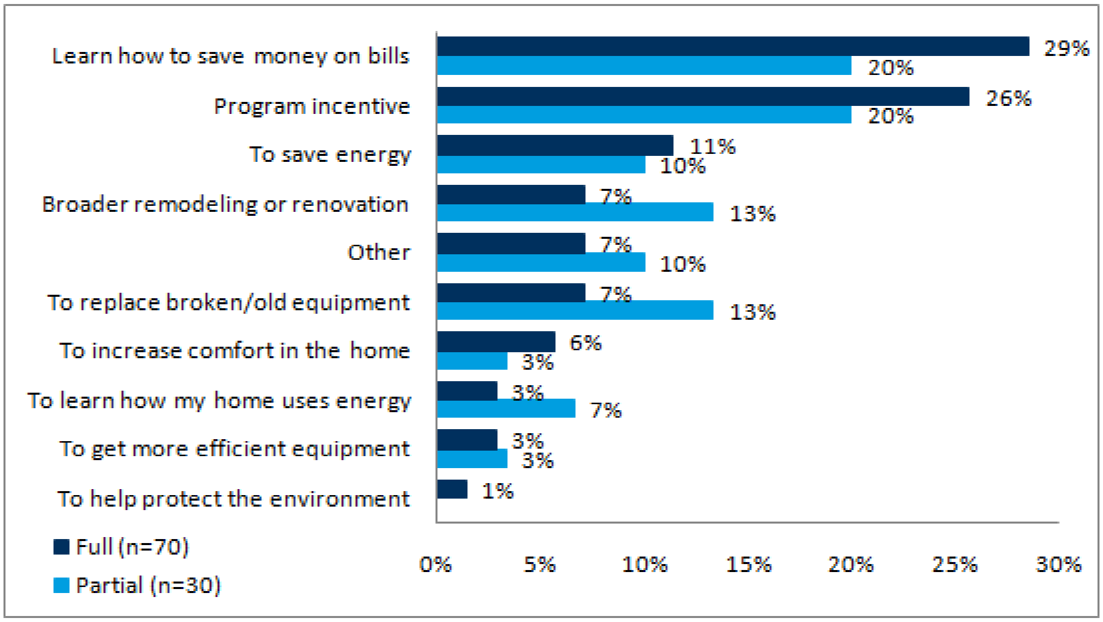


Participation Motivations

To assess program motivations, Cadmus asked survey questions designed to help Efficiency Maine better understand elements influencing residents to participate in the program.

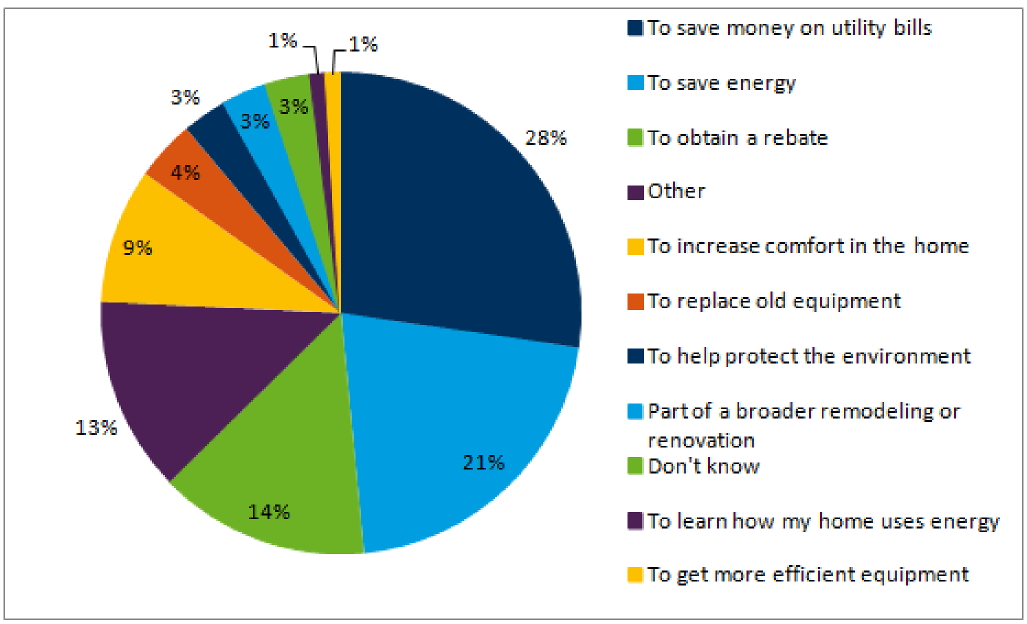
Figure 31 illustrates reported reasons why full and partial participants chose to receive energy audits. Desire to identify ways to save money on utility bills (26% of full and partial participants) and receipt of the program’s rebate (24% of full and partial participants) provided the two most common motivating factors leading participants to complete a home energy audit.

Figure 31. Home Energy Audit Motivations



When asked to identify the most important reason in deciding to complete energy-efficiency improvements to their homes after receiving audits, full participants most often cited saving money on utility bills (28%) or saving energy (21%). Full participants also referenced the HESP rebate and increasing their homes' comfort as motivations.

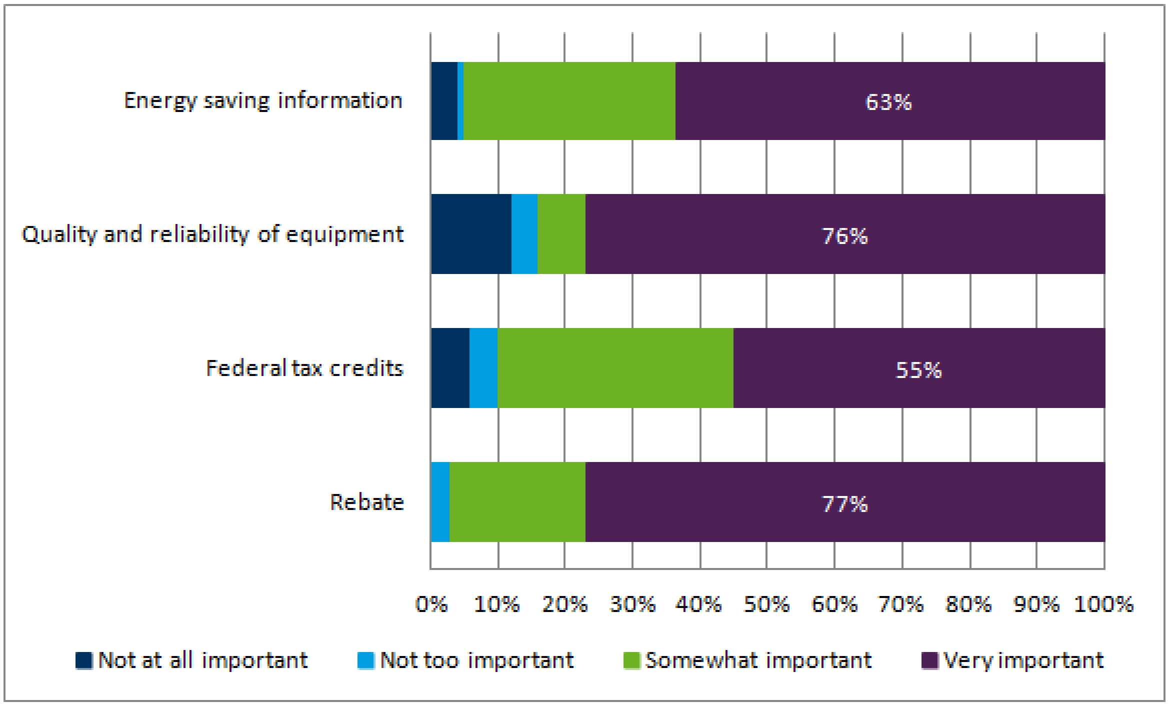
Figure 32. Energy Improvement Installation Motivations



Participation Decision Factors

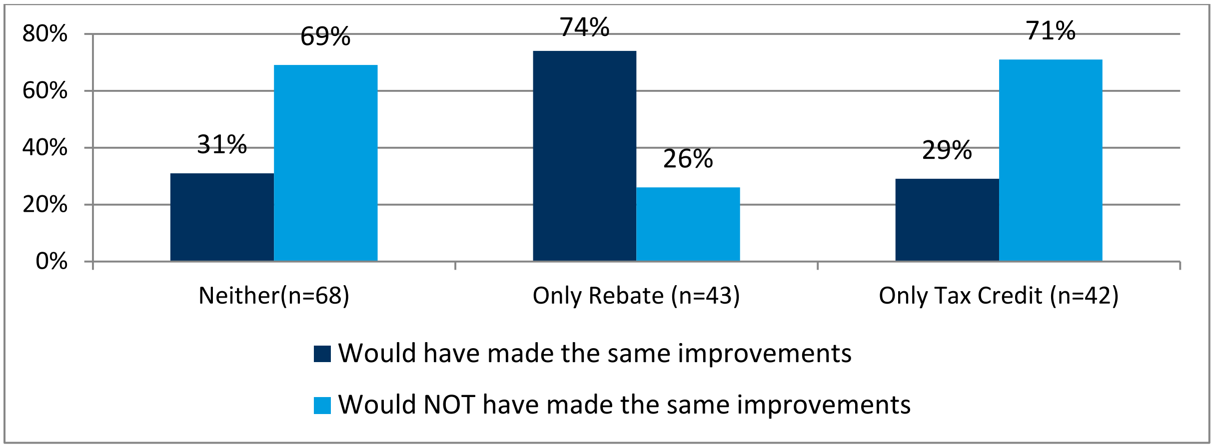
As federal tax credits were available for home energy improvements during the same period, surveys asked full participants about the importance of these incentives as well as program rebates. Figure 33 shows how full participants rated the importance of federal tax credits and HESP rebates to participants' decisions to invest in energy-saving improvements. More than three-quarters (77%) of full participants saw the HESP rebate as a very important factor in their decision to invest in energy improvements, and more than half (55%) saw the federal tax credit as a very important factor. Energy saving information, and quality and reliability of equipment were noted to be more important than the federal tax rebate.

Figure 33. Influences on the Decision to Invest in Energy Improvements



Surveys asked participants about the interactive influence of tax credits and the HESP rebate by having them estimate whether they would have completed the home-energy improvements, had either or both of these two incentives not been available to them. Figure 34 shows the relative influence of the tax credit and the HESP rebate, as reported by full participants' decisions to make improvements.

Figure 34. Interactive Influence of Federal Tax Credit and Rebate



Without either the rebate or the tax credit, more than two-thirds of participants (69%) would likely not have made the same improvements. Without the rebate, less than one-third (29%) would have made the improvements, had only tax credits been available. Without the tax credit, the rebate sufficiently incented about three-quarters of participants (74%) to make improvements.

5.2 Barriers

The upfront costs of making energy improvements presented the primary reason partial participants did not follow through with making improvements at this time. Some partial participants indicated they made improvements, and had submitted a rebate claim form, or were waiting on contractors' availability to complete the work.

Although participation barriers can be best understood from a nonparticipant perspective, surveying nonparticipants fell beyond the evaluation's scope. To examine barriers to participation, the survey included a question asking participants to determine whether they had concerns about participating before pursuing the energy assessment. The survey also included questions to identify when and why partial participants discontinued their participation.

In terms of general concerns before having the energy assessment, relatively few full (26%) or partial (24%) participants reported concerns about participating in the program. Most concerns cited were financial. Among full participants who reported concerns, one-third (33%) cited the high upfront costs associated with the program, and another third (33%) expressed concerns that the rebate amount would be too low, and/or they might not ultimately qualify for and receive the rebate. Others (22%) expressed concerns that the program application and participation process would "be a hassle" and take too long or too much effort.

Table 28. Full Participant Concerns, Prior to Participation (n=18)

Response	Full (n=18)	
	Frequency	Percent
Upfront costs (audit and improvements)	6	33
Incentive/ rebate would be too low	6	33
Process would take too long	4	22
Trusting contractor to do the paperwork	1	6
Finding a contractor that met program qualifications	1	6

Among partial participants who reported concerns, just under half (45%) expressed concerns about upfront costs. Partial participants cited the timing of the installation as another barrier: either they actually proceeded and made efficiency improvements, and had a rebate claim in progress; or they were waiting for their contractors to have the time to perform the installations; or they had not yet had time to pursue completing the improvements. Table 29 presents partial participant responses.

Table 29. Participation Barriers (Multiple Responses Allowed)

Response	Partial (n=30)	
	Frequency	Percent
Installation was too expensive/don't have the money	14	45
I made the improvements—rebate application in progress	5	15
Construction delay/contractor's schedule	2	6
Waiting to do insulation—on cool day/when we can replace siding	2	6
Planning to make the improvements/haven't had time yet	2	6
Don't have audit report yet	1	3
Did not know how to proceed (i.e., don't know what the next steps are)	1	3
No improvements were recommended	1	3
Other	3	10

5.3 Satisfaction

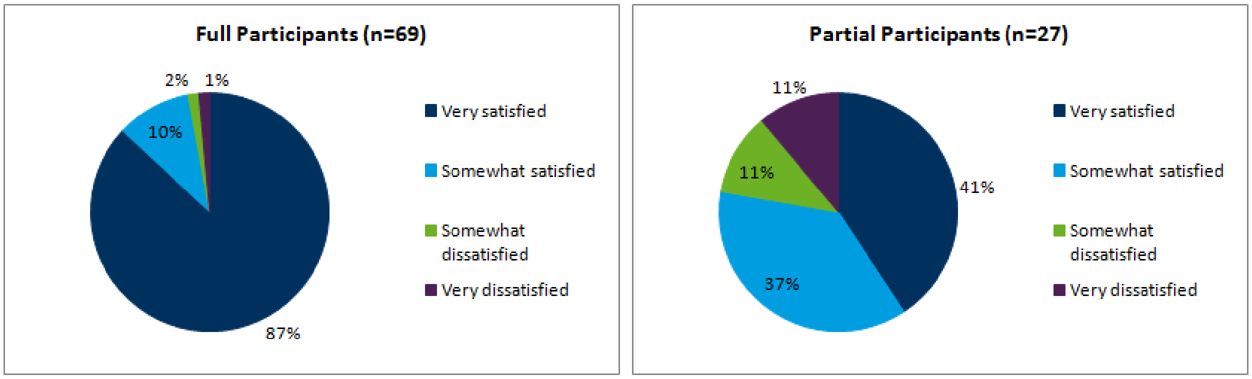
A significantly greater number of full participants (87%) expressed high satisfaction with the program than partial participants (41%). Nearly all (92%) participants said they would recommend the program to a friend.

Nearly all full participants (91%) said their homes became more comfortable following improvements (i.e., most noticed more consistent temperatures throughout their homes, and found they needed to run their heating systems less frequently). Most (82%) said the program met their expectations.

This section and a few of the appendices present topics covered by the survey, and the major survey results and conclusions.

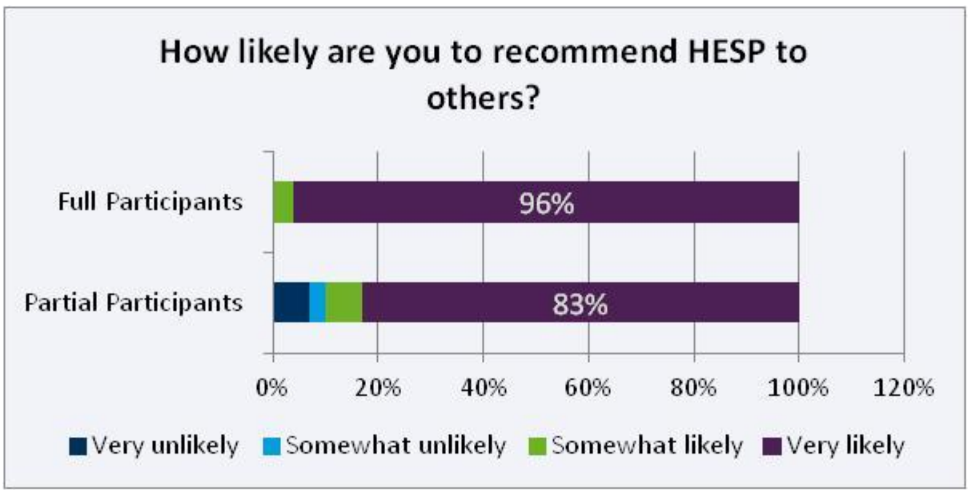
Participants expressed strong satisfaction levels with their overall program experience. Most full participants (87%) reported being "very satisfied" with their program experience overall. Although less than one-half (41%) of partial participants were "very satisfied," over three-quarters (78%) reported some satisfaction level with the program. Figure 35 depicts differences at full and partial participant satisfaction levels.

Figure 35. Overall Program Satisfaction



High satisfaction levels also emerged when participants were asked whether they would recommend the program to others. Almost all full participants (96%) and most partial participants (83%) would be "very likely" to recommend the program to someone else.

Figure 36. Likeliness to Recommend



The survey also explored reasons behind dissatisfaction with the program. As shown in Figure 35, partial participants reported higher dissatisfaction levels than full participants, with 22% of partial participants dissatisfied with their program experiences. Reasons partial participants cited for dissatisfaction included:

- *"I think it's too complicated, too much paperwork, and the incentives are not enough."*
- *"They set a bad tone to start by not letting me know how to prepare for the audit."*
- *"[There were] problems with the contractors, scheduling, and materials."*

Dissatisfaction reasons helped inform program recommendations, discussed at greater length in this report's Conclusions and Recommendations section.

Satisfaction with Program Administration

To further investigate participant satisfaction, the survey asked about participants' experiences regarding administrative aspects of the program. Questions addressed topics such as: lengths of time between application submissions and payment receipts (rebate turnaround times), application processes, contractor performance, and paperwork.

Full participants expressed strong satisfaction with contractors and their work: 84% reported being "very satisfied" with the level of customer service and professionalism provided by contractors. As shown in Table 30, 79% of full participants reported being "very satisfied" with the quality of work performed by their contractors to make the energy-saving improvements to their home.

Table 30. Contractor Work Performance

Response	Full (n=68)	
	Frequency	Percent
Very satisfied	54	79
Somewhat satisfied	10	15
Somewhat dissatisfied	4	6
Very dissatisfied	0	0

Once participants completed installation of the efficient measures, they were required to submit a rebate claim form to Efficiency Maine before they could receive the rebate payments. Reported rebate turnaround times varied from one week to four months. More than three-quarters (76%) of full participants found HESP paperwork "very easy" to complete. As shown in Table 31, most full participants (43%) waited three to four weeks from the time they submitted their rebate claims form to receipt of a rebate, and 87% received their rebate within eight weeks.

Table 31. Rebate Turnaround Times

Response	Full (n=61)	
	Frequency	Percent
1 to 2 weeks	8	13
3 to 4 weeks	26	43
5 to 8 weeks	19	31
More than 8 weeks	8	13

As shown in Table 32, 83% of full participants were "very satisfied" with the time required to receive rebate payments from Efficiency Maine.

Table 32. Satisfaction with Rebate Turnaround Times

Response	Full (n=69)	
	Frequency	Percent
Very satisfied	57	83
Somewhat satisfied	5	7
Somewhat dissatisfied	0	0
Very dissatisfied	7	10

Analysis indicated no correlation between the amount of time required to receive the rebate and the satisfaction level, as half of respondents in the "more than eight weeks" category reported being "very satisfied," and the other half reported dissatisfaction.

Almost all (99%) full participants reported satisfaction with the rebate payment amount.

Satisfaction with Program Results

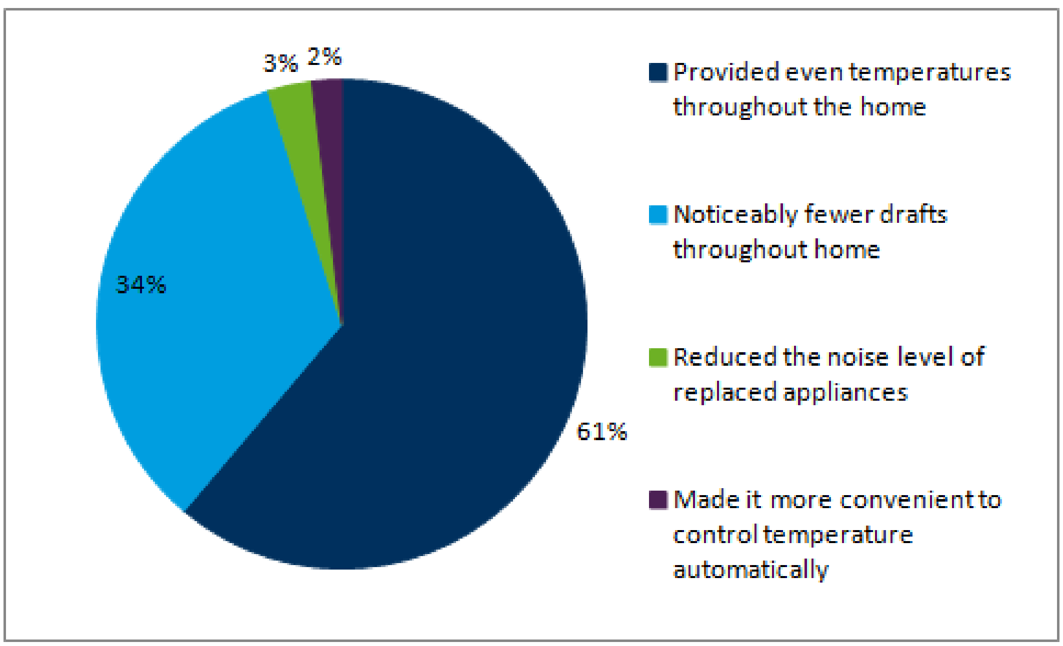
As shown in Table 33, 91% of full participants reported their homes were more comfortable after energy-savings improvements, and none reported them as less comfortable.

Table 33. Home Comfort Level Changes

Response	Full (n=70)	
	Frequency	Percent
More comfortable	64	91
Less comfortable	0	0
About the same	2	3
Don't know/Not enough time to notice a difference	4	6

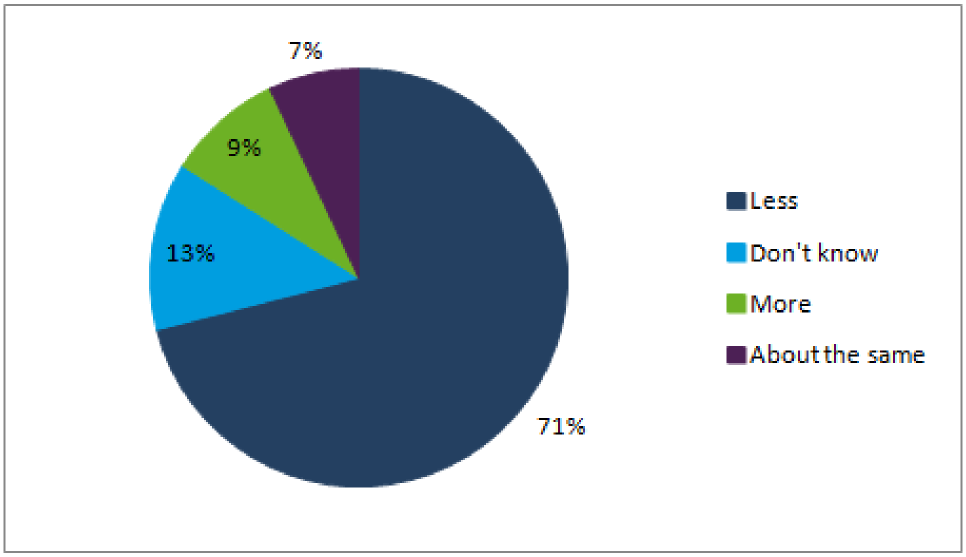
Figure 37 lists ways participants found their homes more comfortable after completing the improvements. Most cited consistent temperatures and fewer drafts throughout homes (61% and 34%, respectively).

Figure 37. Post-Program Home Comfort Level Improvements (Multiple Responses Allowed)



Further, most participants (71%) reported they ran their heating systems less frequently after energy-saving improvements to their homes (as shown in Figure 38).

Figure 38. Post-Program Heating System Usage



In addition, nearly two-thirds (64%) of participants reported their energy bills decreasing after making energy improvements. Three percent reported their energy bills increased, and 11% said they stayed the same (as shown in Table 34).

Table 34. Post-Program Energy Bill Changes

Response	Full (n=70)	
	Frequency	Percent
Bills have gone down	45	64
Bills have gone up	2	3
About the same	8	11
Haven't noticed	9	13
Don't know	6	9

As shown in Table 35, most participants (82%) said their energy bills changed as expected through participating in the program.

Table 35. Post-Program Energy Bill Expectations

Response	Full (n=45)	
	Frequency	Percent
Expectations met	37	82
No	2	4
Don't know	6	13

Nearly all (91%) participants cited increased comfort in their homes as the primary benefit to the program, followed by a decreased need to run heating systems, and lower bills.

6. Recommendations and Conclusions

6.1 Energy-Efficiency Recommendations

The Efficiency Maine HESP reported savings and program verified savings for the 41 houses examined were similar, resulting in a realization rate of 90%. Table 36 and Figure 39 and Figure 40 show energy savings results for the 41 evaluated sites.

Table 36. Final Gross Realization Rate and Savings—By Measure

Measure Type	Reported Savings	Verified Savings	Realization Rate
Air Sealing	566	585	103%
Attic Hatch	29	18	62%
Basement Insulation	381	305	80%
Ceiling Insulation	568	328	58%
Wall Insulation	462	584	127%
Furnace/Boiler	82	51	62%
Total (41 Sites)	**2,087**	**1,871**	**90%**

Figure 39. 41 Site Total Energy Savings: HESP Database

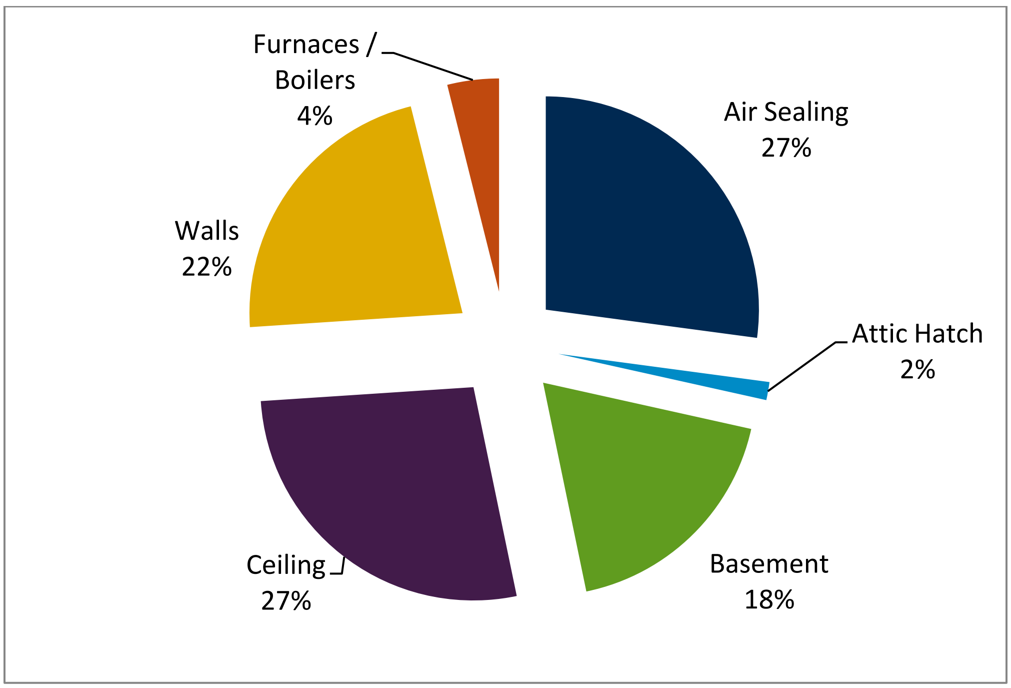
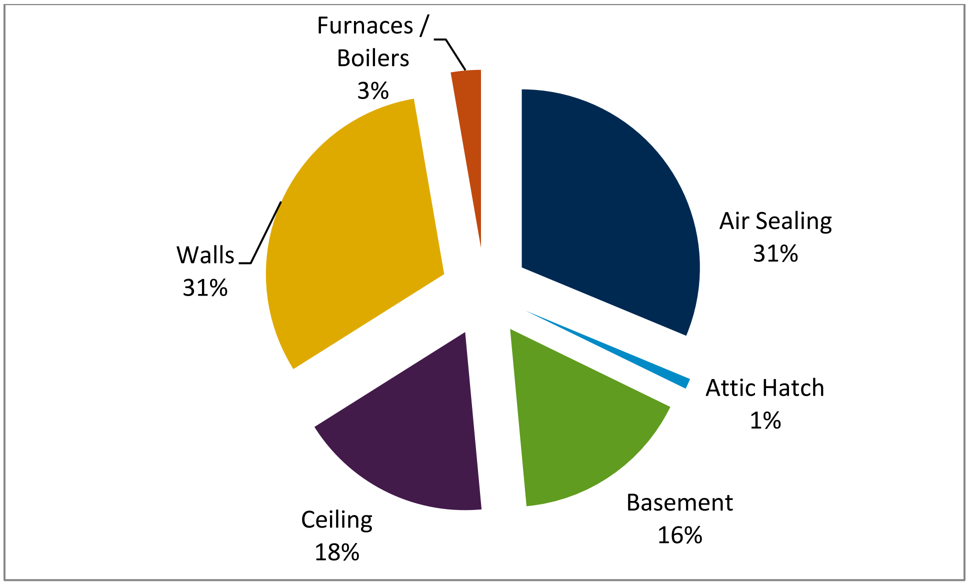


Figure 40. 41 Site Total Energy Savings: Cadmus Observations



The proportion of boiler savings is small in the charts above because there were a small number of retrofits in the sample. The proportion in the population is roughly twice as high.

Table 37 shows the overall, annual program-level savings by verified measure type.

Table 37. Annual Energy Savings by Measure Type in MMBTUs

Measure Type	Reported Gross MMBTU Savings	Verified Gross MMBTU Savings	Gross Realization Rate	NTG	Verified Net Savings (Verified Gross x NTG)	Verified Net Savings	Measures (n)
Air Sealing	42,993	44,467	103%	0.86	38,242	89%	1,846
Attic Access: Existing (Hatch)	2,107	1,310	62%	0.86	1,127	53%	1,248
HVAC: System (Furnace/Boiler)	14,649	9,139	62%	0.86	7,859	54%	730
Insulation: Attic	30,732	17,756	58%	0.86	15,270	50%	2,849
Insulation: Basement/Floors	20,353	16,309	80%	0.86	14,026	69%	2,656
Insulation: Walls	18,394	23,271	127%	0.86	20,013	109%	967
Remaining Measures	12,257	12,257	100%	0.86	10,540	86%	2,765
Total (1780 Sites)	**141,485**	**124,509**	**88%**	**0.86**	**107,077**	**76%**	**13,061**

Overall program-reported savings and Cadmus-verified energy savings were similar, resulting in an 88% gross realization rate and a 76% net realization rate. The verified program savings are slightly different from the verified measure-level savings due to a slightly different measure mix.

Cadmus draws the following conclusions and makes the following recommendations, based on the HESP evaluation:

1. **Reported savings from air sealing measures were corroborated by Cadmus' analysis (103% realization rate). Efficiency Maine should continue to emphasize the importance of thorough air sealing practices.** Air sealing and wall insulation measures made up the majority of the energy savings among homes reviewed by Cadmus. Stopping air leakage is arguably the most important energy conservation action, as leaky insulation does not impede heat. Also, in heating season, houses tend to breathe in through their basements and out through their top floor ceilings; so these two areas are important areas to air seal.

2. **Efficiency Maine should work with its energy advisors to ensure they target areas within the home that will lead to the greatest energy savings achievements (e.g., empty wall cavities).** Improving the product of (the lowest R-value) times (largest area) has the most benefit, as insulation experiences diminishing returns—a little insulation, added to an area with none and over a large area, provides a substantial benefit, while a great deal of insulation added to existing insulation over a similar or smaller area has lower benefits. Filling existing empty wall cavities tends to show greater savings than ceilings, as ceilings most often have some insulation as a starting point, and, therefore, lower savings relative to walls.

3. To allow future comparisons with actual bills, **we recommend Efficiency Maine collect customer billing data as part of the application process, both to assess the need for efficiency upgrades, and to obtain pre- and post-participation information on a larger set of homes**. Due to the difficulty of obtaining utility billing data after the fact, Cadmus was ultimately unable to compare our modeling results with billing data for most sites.

   a. Additionally, resident responses and our observations indicate around half of inspected residences burned wood.

4. **Cadmus recommends, in future evaluations, Efficiency Maine consider placing temperature loggers in homes to see how homes are actually heated, and to obtain accurate data on heating and water temperatures**. We suspect residents may set temperatures lower on their HVAC and hot water systems than reported.

6.2 Program Recommendations

1. **Promotion**: Efficiency Maine's program outreach efforts have successfully reached residents. Program materials were cited as the primary source of program awareness, and the Website was identified as a primary source for identifying energy advisors. **Cadmus recommends the Trust continue using the effective marketing methods currently in place to promote HESP related efforts**. As contractors provide another primary program gateway, **Cadmus also recommends the Trust continue building partnerships, and supplying contractors with information they can use to help promote program offerings**.

2. **Motivations:** The HESP rebate and the potential to reduce home energy bills served as the primary motivators for program participation during the evaluation period. While federal tax credits (available in 2011 for energy improvements) provided added incentives, most HESP participants reported they would have participated had only the program rebate been offered but not the tax credit. This was further evidenced by the 99% satisfaction rate for the rebate amount. While the Trust's ARRA funding for HESP rebates has been exhausted, rebate amounts provided offer a good benchmark for future rebates, if additional funding becomes available.

3. **Barriers:** Concerns about upfront costs of home energy improvement projects and timing issues (availability of contracts to perform work) present potential barriers to partial participants making recommended improvements to their homes. Given the high level of full participants' satisfaction with the program, success stories from full participants completing the process could be used to address these types of concerns. As the program's Website already features participant experiences through the "Homeowner Stories" section**, Cadmus recommends Efficiency Maine consider using these stories in program promotional channels beyond the Website**.

4. **Application Materials:** As full and partial participants indicated the forms very easy to fill out, preassessment concerns about paperwork and "too many hoops" appear to have been assuaged. Efficiency Maine should **consider developing marketing messages that inspire trust with residents, and highlight participants' very positive experiences with program paperwork.**

5. **Measures**: Most energy advisors recommended—and full participants completed—improvements associated with insulation, HVAC equipment, and air sealing. Very few participants, however, reported installing low-cost measures, such as CFLs and low-flow showerheads, as part of the HESP project. We recommend Efficiency Maine **consider enhancing the "ROI" appeal for low-cost measures to increase uptake on these recommended improvements.** This approach may be particularly effective when federal tax credits become unavailable for higher-cost measures.

6. **Satisfaction**: Based on survey results for program satisfaction, it appears program design and implementation was effective for participants. Higher satisfaction levels among full participants suggest that, when something less than satisfactory occurs in the participation process, participants may be less likely to follow through with completing improvements and submitting required paperwork to receive the rebate. **We recommend Efficiency Maine consider addressing causes of participant dissatisfaction by providing an additional Website FAQ and/or pre-assessment information about "how to prepare for an energy audit**." This will help set expectations, and help residents prepare for the energy audit or assessment. As some participants expressed concerns about waiting on contractors and trusting them to complete paperwork, Efficiency Maine should consider adding additional information to the Website, or providing information for call center staff to assist participants on how to follow-up with contractors.

7. **Value**: Participants who made home energy improvements under HESP highlight increased comfort in their homes as a program benefit. They also cite lower bills and lower energy usage. As these benefits mirror motivations for participating in the program, most participants indicated their expectations have been met. **We recommend Efficiency**

Maine consider using customer reported energy and cost saving benefits to provide testimonial endorsements for program promotions.

Appendix A: Net-to-Gross Evaluation Overview

Net-to-gross (NTG) estimates serve as a critical part of demand-side management (DSM) program impact evaluations as they allow utilities to determine the portion of gross energy savings influenced by and attributable to their DSM programs, free from the result of other influences. Freeridership and spillover comprise NTG's two components. Freeriders are customers who would have purchased the measure without any program influence. Spillover is the amount of additional savings obtained by customers investing in additional energy-efficient measures or activities due to their program participation. Various methods can be used to estimate program freeridership and spillover. Our baseline evaluation approach uses self-reports through participant surveys to estimate freeridership for the HESP program. We did not quantify spillover because the responses received did not indicate a high incidence of spillover.

Survey Design—Freeridership

Cadmus designed survey questions to determine why customers installed a given measure and the program's influence over those decisions. The survey goal was to establish what the decision maker might have done in the program's absence. Five core freeridership questions are used to address this:

- Would the participant have installed the measure without the program incentive?
- Would the participant have installed the same quantity of measures without the program incentive?
- Would the participant have installed the measure to the same efficiency level without the program incentive?
- In the absence of the program incentive, when would the respondent have installed the measures?
- Before they requested the energy audit, had the participant ever previously had an energy audit done on their home?

Freeridership Survey Questions

Five specific questions were included in the HESP survey instrument's freeridership portion to capture the four core freeridership concepts listed above:

1. If only the federal tax credit was available and the HESP rebate was not, would you have made the same improvements?
2. Let me make sure I understand. When you say you would not have made the same improvements, do you mean you would not have made any of them or you would have made only some?
3. And would any of the improvements you would have made been less energy efficient?
4. And when would you have made the improvements? (timing)
5. Before you requested the energy audit, had you ever previously had an energy audit done on your home?

Cadmus developed a transparent, straightforward matrix approach to assign a score to participants, based on their objective responses to these targeted survey questions. Question response patterns were assigned freeridership scores using a rules-based approach that decremented a respondent's freeridership score if a response to a question was not indicative of freeridership. This specific approach is cited in the NAPEE Handbook on DSM Evaluation, 2007 edition, page 5-1.

The response patterns and scoring weights remain explicit: they can be discussed, changed and results shown in real time. Our approach provided other important features, including:

- Derivation of a partial freeridership score, based on the likelihood of a respondent taking similar actions in the incentive's absence.
- Use of a rules-based approach for consistency among multiple respondents.
- The ability to change weightings in a "what if" exercise, testing the response set's stability.

The Cadmus method offers a key advantage by introducing the concept of partial freeridership. Experience has taught us that program participants do not fall neatly into freerider and not-freerider categories. For example, partial freeridership scores were assigned to participants with plans to install the measure; though the program exerted some influence over their decision, other market characteristics beyond the program also proved influential. In addition, with partial freeridership, we could utilize "don't know" and "refused" responses by classifying them as partial credit, rather than removing the entire respondent from the analysis.

Freeridership was assessed at three levels. First, each participant survey response was converted into freeridership matrix terminology. Each participant's combination of responses was then assigned a score from the matrix. Finally, all participants were aggregated into an average freeridership score for the entire program category.

Convert Responses to Matrix Terminology

We independently evaluated each survey question's response to assess participants' freeridership level for each question. Each survey response option was converted into a value of "yes," "no," or "partial," which refers to whether the respondent's answer for the question was indicative of freeridership or not.

Table 38 lists five survey questions, their corresponding response options, and the value which we converted them to (in parentheses). "Don't know" and "refused" responses were converted to "partial" for all questions.

Table 38. Assignments of HESP Survey Response Options into Matrix Terminology

28. And, how about if only the federal tax credit was available and the program rebate was not, would you have made the same improvements?	33. Let me make sure I understand. When you say you would not have made the same improvements, do you mean you would not have made any of them or you would have made only some?	30 / 34. And would any of the improvements you would have made been less energy efficient?	31 / 35. And would you have made the improvements: [Read list]	32 / 36. Before you requested the energy audit, had you ever previously had an energy audit done on your home?
Yes (Yes)	Would not have made any (Yes)	Yes (No)	At the same time or within three months of when you actually made the upgrades (Yes)	Yes (Yes)
No (No)	Only some (No)	No (Yes)	Within three to six months (Partial)	No (No)
Don't Know (Partial)	Don't Know (Partial)	Don't Know (Partial)	Six to 12 months (Partial)	Don't Know (Partial)
Refused (Partial)	Refused (Partial)	Refused (Partial)	More than a year (No)	Refused (Partial)
			Never (No)	
			Don't Know (Partial)	
			Refused (Partial)	

Participant Freeridership Scoring

After converting survey responses into matrix terminology, we created a freeridership matrix, so the combination of each participant's responses to the four questions could be assigned a freeridership score. To create the matrix, we determined every combination of possible responses to the four survey questions, and then assigned a freeridership score of 0 to 100% to each combination. Using these matrices, every participant combination of responses was assigned a score of 0 to 100%.

Program Category Freeridership Scoring

After assigning a freeridership score to every survey respondent, Cadmus calculated an average freerider score for the program category. For the purposes of this analysis, a simple average was taken of the individual respondent level freeridership scores to arrive at the program freeridership estimate. If accurate program savings information becomes available for these surveyed participants, the individual freeridership scored can be weighted by measure savings to arrive at a savings weighted freeridership estimate.

The Cadmus Freeridership Scoring Model

Cadmus has developed an Excel-based model to assist with freeridership calculation and improve consistency and quality of results. Our model translates raw survey responses into matrix terminology, and then assigns each participant's response pattern a score from the matrix.

Program participants in the sample can be then aggregated by program category to calculate the average freerider score.

The model incorporates the follow inputs described in this methodology:

- Raw survey responses for each participant, along with the program category for their rebated measure, and energy savings from that measure, if applicable.
- Table A2 above represents the converting of the raw survey responses into scoring matrix terminology (“Yes”, “No”, “Partial”) for each program category.
- Custom freeridership scoring matrices for each unique survey type.

The model uses a simple interface, allowing users to quickly reproduce a scoring analysis for any program category. It displays each participant’s combination of responses and corresponding freeridership score, and then produces a summary table, providing the average score.

Table 39 contains the full freeridership scoring matrix developed for the HESP program.

Table 39. Full HESP Freeridership Scoring Matrix

28. And, how about if only the federal tax credit was available and the program rebate was not, would you have made the same improvements ?	33. Let me make sure I understand. When you say you would not have made the same improvements , do you mean you would not have made any of them or you would have made only some?	30 / 34. And would any of the improvement s you would have made been less energy efficient?	31 / 35. And would you have made the improvements …	32 / 36. Before you requeste d the energy audit, had you ever previousl y had an energy audit done on your home?	Combo	Freeridershi p Score
Yes	x	Yes	Yes	Yes	YesxYesYesYes	100.00%
Yes	x	Yes	Yes	Partial	YesxYesYesPartial	100.00%
Yes	x	Yes	Yes	No	YesxYesYesNo	75.00%
Yes	x	Yes	Partial	Yes	YesxYesPartialYes	75.00%
Yes	x	Yes	Partial	Partial	YesxYesPartialPartial	75.00%
Yes	x	Yes	Partial	No	YesxYesPartialNo	50.00%
Yes	x	Yes	No	x	YesxYesNox	0.00%
Yes	x	Partial	Yes	Yes	YesxPartialYesYes	75.00%
Yes	x	Partial	Yes	Partial	YesxPartialYesPartial	75.00%
Yes	x	Partial	Yes	No	YesxPartialYesNo	50.00%
Yes	x	Partial	Partial	Yes	YesxPartialPartialYes	50.00%
Yes	x	Partial	Partial	Partial	YesxPartialPartialPartial	50.00%
Yes	x	Partial	Partial	No	YesxPartialPartialNo	25.00%
Yes	x	Partial	No	x	YesxPartialNox	0.00%
Yes	x	No	Yes	Yes	YesxNoYesYes	50.00%
Yes	x	No	Yes	Partial	YesxNoYesPartial	50.00%
Yes	x	No	Yes	No	YesxNoYesNo	25.00%
Yes	x	No	Partial	Yes	YesxNoPartialYes	25.00%

28. And, how about if only the federal tax credit was available and the program rebate was not, would you have made the same improvements?	33. Let me make sure I understand. When you say you would not have made the same improvements, do you mean you would not have made any of them or you would have made only some?	30 / 34. And would any of the improvements you would have made been less energy efficient?	31 / 35. And would you have made the improvements …	32 / 36. Before you requested the energy audit, had you ever previously had an energy audit done on your home?	Combo	Freeridership Score
Yes	x	No	Partial	Partial	YesxNoPartialPartial	25.00%
Yes	x	No	Partial	No	YesxNoPartialNo	12.50%
Yes	x	No	No	x	YesxNoNox	0.00%
Partial	x	Yes	Yes	Yes	PartialxYesYesYes	75.00%
Partial	x	Yes	Yes	Partial	PartialxYesYesPartial	75.00%
Partial	x	Yes	Yes	No	PartialxYesYesNo	50.00%
Partial	x	Yes	Partial	Yes	PartialxYesPartialYes	50.00%
Partial	x	Yes	Partial	Partial	PartialxYesPartialPartial	50.00%
Partial	x	Yes	Partial	No	PartialxYesPartialNo	25.00%
Partial	x	Yes	No	x	PartialxYesNox	0.00%
Partial	x	Partial	Yes	Yes	PartialxPartialYesYes	50.00%
Partial	x	Partial	Yes	Partial	PartialxPartialYesPartial	50.00%
Partial	x	Partial	Yes	No	PartialxPartialYesNo	25.00%
Partial	x	Partial	Partial	Yes	PartialxPartialPartialYes	25.00%
Partial	x	Partial	Partial	Partial	PartialxPartialPartialPartial	25.00%
Partial	x	Partial	Partial	No	PartialxPartialPartialNo	12.50%
Partial	x	Partial	No	x	PartialxPartialNox	0.00%
Partial	x	No	Yes	Yes	PartialxNoYesYes	25.00%
Partial	x	No	Yes	Partial	PartialxNoYesPartial	25.00%
Partial	x	No	Yes	No	PartialxNoYesNo	12.50%
Partial	x	No	Partial	Yes	PartialxNoPartialYes	12.50%
Partial	x	No	Partial	Partial	PartialxNoPartialPartial	12.50%
Partial	x	No	Partial	No	PartialxNoPartialNo	0.00%
Partial	x	No	No	x	PartialxNoNox	0.00%
No	Yes	Yes	Yes	Yes	NoYesYesYesYes	50.00%
No	Yes	Yes	Yes	Partial	NoYesYesYesPartial	50.00%
No	Yes	Yes	Yes	No	NoYesYesYesNo	25.00%
No	Yes	Yes	Partial	Yes	NoYesYesPartialYes	25.00%
No	Yes	Yes	Partial	Partial	NoYesYesPartialPartial	25.00%
No	Yes	Yes	Partial	No	NoYesYesPartialNo	12.50%
No	Yes	Yes	No	x	NoYesYesNox	0.00%
No	Yes	Partial	Yes	Yes	NoYesPartialYesYes	25.00%
No	Yes	Partial	Yes	Partial	NoYesPartialYesPartial	25.00%
No	Yes	Partial	Yes	No	NoYesPartialYesNo	12.50%
No	Yes	Partial	Partial	Yes	NoYesPartialPartialYes	12.50%
No	Yes	Partial	Partial	Partial	NoYesPartialPartialPartial	12.50%
No	Yes	Partial	Partial	No	NoYesPartialPartialNo	0.00%
No	Yes	Partial	No	x	NoYesPartialNox	0.00%

28. And, how about if only the federal tax credit was available and the program rebate was not, would you have made the same improvements ?	33. Let me make sure I understand. When you say you would not have made the same improvements , do you mean you would not have made any of them or you would have made only some?	30 / 34. And would any of the improvement s you would have made been less energy efficient?	31 / 35. And would you have made the improvements …	32 / 36. Before you requeste d the energy audit, had you ever previousl y had an energy audit done on your home?	Combo	Freeridershi p Score
No	Yes	No	Yes	Yes	NoYesNoYesYes	12.50%
No	Yes	No	Yes	Partial	NoYesNoYesPartial	12.50%
No	Yes	No	Yes	No	NoYesNoYesNo	0.00%
No	Yes	No	Partial	Yes	NoYesNoPartialYes	0.00%
No	Yes	No	Partial	Partial	NoYesNoPartialPartial	0.00%
No	Yes	No	Partial	No	NoYesNoPartialNo	0.00%
No	Yes	No	No	x	NoYesNoNox	0.00%
No	Partial	Yes	Yes	Yes	NoPartialYesYesYes	25.00%
No	Partial	Yes	Yes	Partial	NoPartialYesYesPartial	25.00%
No	Partial	Yes	Yes	No	NoPartialYesYesNo	12.50%
No	Partial	Yes	Partial	Yes	NoPartialYesPartialYes	12.50%
No	Partial	Yes	Partial	Partial	NoPartialYesPartialPartial	12.50%
No	Partial	Yes	Partial	No	NoPartialYesPartialNo	0.00%
No	Partial	Yes	No	x	NoPartialYesNox	0.00%
No	Partial	Partial	Yes	Yes	NoPartialPartialYesYes	12.50%
No	Partial	Partial	Yes	Partial	NoPartialPartialYesPartial	12.50%
No	Partial	Partial	Yes	No	NoPartialPartialYesNo	0.00%
No	Partial	Partial	Partial	Yes	NoPartialPartialPartialYes	0.00%
No	Partial	Partial	Partial	Partial	NoPartialPartialPartialParti al	0.00%
No	Partial	Partial	Partial	No	NoPartialPartialPartialNo	0.00%
No	Partial	Partial	No	x	NoPartialPartialNox	0.00%
No	Partial	No	Yes	Yes	NoPartialNoYesYes	0.00%
No	Partial	No	Yes	Partial	NoPartialNoYesPartial	0.00%
No	Partial	No	Yes	No	NoPartialNoYesNo	0.00%
No	Partial	No	Partial	Yes	NoPartialNoPartialYes	0.00%
No	Partial	No	Partial	Partial	NoPartialNoPartialPartial	0.00%
No	Partial	No	Partial	No	NoPartialNoPartialNo	0.00%
No	Partial	No	No	x	NoPartialNoNox	0.00%
No	No	x	x	x	NoNoxxx	0.00%

Table 40 shows the unique response combinations from the HESP participant survey sample, and the number of responses for each combination.

Table 40. Frequency of Freeridership Scoring Combinations

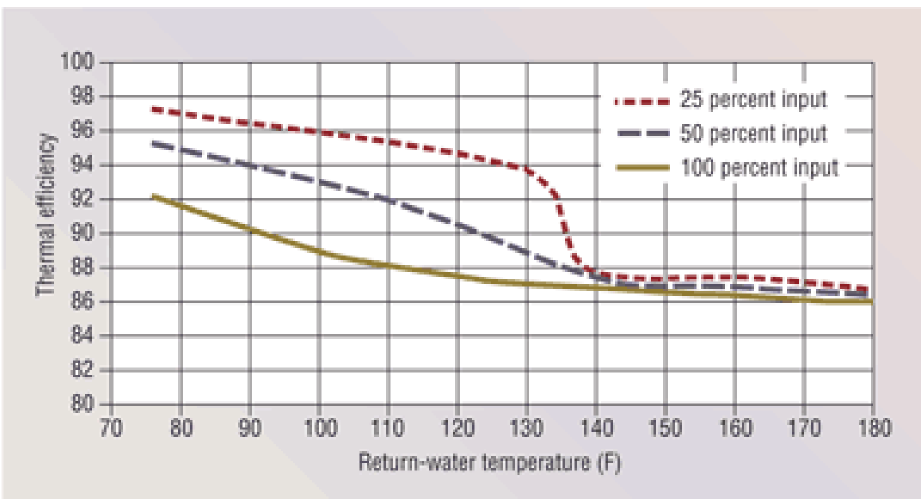
Q28. And, how about if only the federal tax credit was available and the program rebate was not, would you have made the same improvements?	Q33. Let me make sure I understand. When you say you would not have made the same improvements, do you mean you would not have made any of them or you would have made only some?	Q30 / Q34. And would any of the improvements you would have made been less energy efficient?	Q31 / Q35. And would you have made the improvements: [Read list]	Q32 / Q36. Before you requested the energy audit, had you ever previously had an energy audit done on your home?	Freeridership Score	Frequency of Response String
Yes	x	Yes	Yes	No	75.00%	5
Yes	x	Yes	Partial	No	50.00%	6
Yes	x	Yes	No	x	0.00%	7
Yes	x	No	Yes	No	25.00%	5
Yes	x	No	Partial	Yes	25.00%	1
Yes	x	No	Partial	No	12.50%	3
Yes	x	No	No	x	0.00%	6
Partial	x	Yes	Partial	No	25.00%	1
Partial	x	Partial	Partial	No	12.50%	3
Partial	x	Partial	No	x	0.00%	1
Partial	x	No	No	x	0.00%	2
No	Yes	Yes	Yes	No	25.00%	3
No	Yes	Yes	No	x	0.00%	6
No	Yes	No	Yes	No	0.00%	3
No	Yes	No	Partial	Yes	0.00%	1
No	Yes	No	Partial	No	0.00%	3
No	Yes	No	No	x	0.00%	5
No	No	x	x	x	0.00%	9

Appendix B: Limitations of Increasing Heating System Efficiency with Existing Distribution Systems

Replacing mechanical equipment in existing homes can be a simple way to improve efficiency and reduce fuel costs, especially if a heating system is nearing the end of its useful life. However, the overall system efficiency does not necessarily reach the nameplate Annual Fuel Utilization Efficiency (AFUE) rating if the heating appliance is not operating under the same circumstances used during the AFUE testing. AFUE testing conditions are below the condensation temperature of natural gas exhaust streams: therefore, nameplate ratings assume operational conditions are below the condensing point of natural gas, which is in the 135°F range.

High-efficiency condensing gas or propane appliances can reach thermal conversion efficiencies into the mid 90% AFUE range, when operating in a condensing regime, but if return temperatures are above the condensing temperature of the flue gas, the additional efficiency boost of condensing the moisture from the flue gas is not realized. Figure 41 is a typical efficiency curve for condensing boilers.

Figure 41. Condensing Boiler Efficiency Curve



With condensing gas furnaces, the return air temperature is the low end of room temperature, which might be in the 60-70°F range for most of the population of typical residences—obviously well below the condensing temperature of natural gas. Thus, condensing gas furnaces can be relied on to operate in a condensing regime throughout the season.

With gas boilers, the return water temperature is a function of the design of the distribution system and piping, and in the past has typically been designed around temperatures well above the condensing temperature of natural gas, most often 180°F LWT, 160°F EWT. Replacing an 85+/-% AFUE boiler with a condensing boiler without reviewing and/or modifying the distribution system characteristics may mean that the new condensing boiler will condense only under certain conditions (e.g., light loading, which occurs when a boiler has short firing cycles with extended off-periods where boiler return water temperatures do not rise above condensing temperatures), potentially forfeiting the 5-10% AFUE savings being sought.

In some cases, a homeowner may be willing to experiment with boiler water temperatures to empirically determine the lowest functional hot water delivery temperature, and incorporate that information into an outdoor reset controller, but it is more likely settings will be chosen by an installing contractor based on a rule of thumb that does not lead to insufficient heat call-backs, and does not condense for a significant amount of the heating season.

Appendix C. Insulating Basements

From the standpoint of a building enclosure surface area, insulating basement walls increases exterior surface area and total building heat loss over insulating ceilings, but, functionally, attaining an effective air seal and insulation layer at basement walls is typically easier than for basement ceilings. Insulating basement walls makes a quasi-outdoor basement space into a known indoor space, and clarifies the plan for that space, while the typical insulated ceiling does not. Note that when bringing the mechanical equipment into the conditioned space, there is a new concern that combustion products are being properly exchanged with outdoors, and not left to linger indoors.

Basement spaces most often are left to “float” thermally (not directly controlled with a thermostat), and are quasi-indoors and quasi-outdoors, the exact proportion depending on the particular basement under review. While insulating the ceiling of the basement might appear to be a good approach to limit heat loss from upstairs conditioned spaces to the basement, there tend to be many unsealed penetrations through the floor, and the commonly seen fiberglass batting provides no resistance to air flow; so drafts into basements tend to warm up and rise up into the spaces above, bypassing the insulation. Further, most often the heating system resides in the basement, and complicates the question of the basement being indoors or outdoors, since, with few exceptions, the heating system loses a noticeable amount of heat to the basement.

Appendix D. Contacting Fuel Providers

During the Efficiency Maine HESP evaluation, Cadmus contacted the following fuel providers on behalf of Efficiency Maine and HESP participants.

McKusick	Colby & Gale
Dead River	MW Sewall
Ness Oil	Bangor Hydro
RH Foster	Gary's Fuel
Crowley	North Village
Downeast	AmeriGas
Bragdon	Harvest
Mount Blue	Community Energy
Pitt Stop	Atlantic Heating Company
Fielding's	Lampron Energy
Fabian	Deer Pond
J&S Oil	Maritime Energy

Cadmus began by calling the aforementioned fuel providers to locate a contact within the company who could approve of the distribution of energy usage information, and could obtain the necessary energy usage information. Once the connection was made, Cadmus either faxed or e-mailed the participant's signed authorization form to the contact with the hopes of receiving the necessary data in response.

For participants that were customers of Unitil, Cadmus followed a different process. Unitil was unwilling to provide the energy usage information for its customers – even with a signed authorization form. As a result, Cadmus relied on the participants themselves to provide their energy bills. This proved to have a lower than average success rate with two out of five Unitil customers providing complete bills.

Cadmus made multiple attempts to reach out to fuel providers and customers if the fuel usage data was not supplied. In some instances, one participant had multiple fuel providers and, if one fuel provider did not send in the data, that customer fuel usage information was not able to be used in the comparison. Table 41 shows the results of our attempts to receive fuel usage information.

Table 41. Fuel Bill Receipt

Fuel Provider	Received	Not Received	Total
Unitil (only)	2	3	5
Dead River (only)	6	0	6
Downeast (only)	4	1	5
Other/Incomplete	9	7	16
No Viable Form	N/A	N/A	9
Total	**21**	**11**	**41**