WEST HILL ENERGY AND COMPUTING

Impact Evaluation of Efficiency Vermont's Home Performance with ENERGYSTAR Program

Program Year 2014-2016

September 10, 2018

Prepared For

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Executive Summary

This report covers the impact evaluation conducted for Efficiency Vermont's (EVT's) Home Performance with ENERGY STAR (HPwES) program for projects completed in 2014 through 2016. This evaluation is the second for EVT's HPwES Program, following the initial impact evaluation completed in 2012.

Efficiency Vermont's HPwES program is a statewide program providing incentives for weatherization measures and services for single family homes. The objective of HPwES is to improve the thermal envelope, heating, and ventilation systems of residential homes, advancing the efficiency, comfort, and health of Vermont residences, in addition to lowering energy bills. The most commonly installed measures are insulation and air-sealing. However, other improvements may include heating system replacement and distribution, domestic hot water, or electric efficiency measures.

Evaluation Objectives

This impact evaluation was designed to determine the evaluated gross energy savings, peak demand reduction, and realization rates for major measures installed in program years 2014 through 2016. Both electric and unregulated fuel energy savings were evaluated.

The gross impact evaluation meets or exceeds industry standards for energy efficiency program evaluation and the requirements of the New England Independent System Operator (ISO) for sales into the Forward Capacity Market (FCM).[1]

Evaluation Approach

The primary method used to estimate program savings was billing analysis. Electric savings from heating-related measures were verified through AMI analysis. All homes with sufficient electric billing data were included in the analysis. Thus, no sampling was necessary and the results were not affected by sampling error.

Verified unregulated fuel savings were estimated using a normalized annualized consumption (NAC) model. All homes with more than 8 MMBtu annual program-reported savings were solicited for participants.[2] As with the AMI analysis, a census attempt was made and no sampling was necessary; thus the results were not affected by sampling error.

Savings from wood were not verified as part of this evaluation. All results were weather-normalized, as appropriate.

Electric Space Heat Savings

The electric billing analysis was conducted using 15-minute AMI data for 47 projects with 600 kWh (or more) of program-reported, annual savings. The majority of the savings were due to

[1] The ISO-NE FCM requires impact evaluation to be conducted by third-party independent qualified evaluators.
[2] Billing analysis is generally considered to be effective when the savings are about 8 to 10% of the pre-install consumption. Eight MMBtu is about 8% of average residential heating use. Homes with lower savings were eliminated, as we did not expect to be able to estimate the savings for many of these homes.

heating-related measures, with 3 domestic hot water (DHW) measures. The homes with DHW measures were dropped from the analysis, as the small number of projects introduced a high amount of uncertainty due to the variation in hot water usage across households.

The results from the analysis are presented in Table ES-1.

TABLE ES-1: ELECTRIC AMI BILLING ANALYSIS RESULTS

Total Program Reported Savings		Total Evaluated Savings		Realization Rate	
Annual kWh	Winter kW	Annual kWh	Winter kW	Annual kWh	Winter kW
400,421	198.687	319,465	72.548	80%	37%

Unregulated Fuel Savings

Billing analysis of unregulated fuels requires an extra layer of data collection, as it is necessary to obtain permission requesting consumption records from the fuel dealers (reflected in the process laid out in the table below).

TABLE ES-2: UNREGULATED FUELS BILLING ANALYSIS PROCESS

Step	Purpose	Method
Data Collection	Collect billing records from fuel dealers and obtain key information about household energy use	Consent forms, fuel dealer requests, participant detailed survey
Data Cleaning/ Attrition	Combine data from various sources, prepare the billing data, and remove households with incomplete or poor quality data	Apply criteria for inclusion in model
Data Preparation	Develop a complete data set with key fields from various sources	Data manipulation
Billing Model	Conduct modeling and determine characteristics of sample	House-by-house, 2-stage regression; final savings using NAC[1]
Verification of Results	Assess the results, identify sources of uncertainty, and provide another level of rigor to our analysis	*Post hoc* stratification, review of outliers and influential data points, domestic hot water separation and sensitivity analysis, other sensitivity analyses
Results	Compare verified savings to program reported savings	Ratio estimation

[1] Normalized Annual Consumption

Initial letters, including consent forms, were sent to 1,576 participants with unregulated fuel savings of more than 10 MMBtu, resulting in a final model with 101 homes. The number of homes at each major step in the process is shown in Table ES-3.

TABLE ES-3: UNREGULATED FUELS DATA COLLECTION OVERVIEW

Step	Number of Homes	Number of Surveys Completed
Consent Forms with Survey Link Sent Out	1,576	N/A
Consent Forms Returned	355	275
Billing Data Requests Sent to Fuel Dealers	330[a]	N/A
Total Billing Records Provided by Fuel Dealers	282[b]	209
Removed Due to Attrition	181	N/A
Final Billing Model	101	70

[a] About 81 fuel dealers were listed to request records for the 355 participants who returned consent forms. Due to budget constraints and the tight evaluation timeline, 25 fuel dealers--with only one customer participating in the study--were not contacted, leaving a total of 330 participants for which fuel records were requested.

[b] Thirty-five (35) of the 56 fuel dealers contacted were willing to provide billing records, for a total of 282 participants.

Extensive review of the results was conducted, including numerous sensitivity analyses. Some of the key topics included the following:

- Separating heating and DHW fuel use
- Assessing impacts of survey data regarding changes in energy use and differences between homes with and without survey data
- Comparing the Normalized Annual Consumption (NAC) calculation method to regressions within homes
- Outliers and influential data points

Through this process, additional homes were removed from the analysis and the method was modified to address the data issues. The results are shown in Table ES-4.

TABLE ES-4: UNREGULATED FUELS BILLING ANALYSIS RESULTS

Variable	Results
Number of Homes in the Model	101
Mean Program Reported Savings (MMBtu)	22.5
Mean Evaluated Savings (MMBtu)	14.6
Realization Rate	65%
Realization Rate 90% Confidence Interval	+/- 10%
Relative Precision at 90%[1]	15%
Mean Evaluated Pre-Install Use (MMBtu)	92.0
Evaluated Savings as Percent of Pre-Install Use	16%
Program Reported Savings as Percent of Pre-Install Use	25%

[1] Relative precision is the error-bound divided by the realization rate. The precision reflects the variability in the model. There is no sampling error, as all homes with sufficient billing data were included in the model.

The results from the evaluation are within the range of other impact evaluations conducted for similar programs in the Northeast. Despite changes in program-reported savings and calculation methods, the evaluated savings, as a percentage of pre-install use between programs and years, are fairly consistent.

Conclusions

Some of the key conclusions from this analysis are explored below.

- The realization rate is 80% for electric heating-related measures and 65% for unregulated fuel savings.
- For winter peak kW reduction, the realization rate is 37% for electric heating-related measures, suggesting the coincident factor (CF) for electric space heating is overstating this metric.
- For unregulated fuels, the realization rate is substantially higher for larger contractors completing at least 50 to 80 projects through the program.
- The results from the evaluation are within the range of other impact evaluations conducted for similar programs in the Northeast. Despite changes in program-reported savings and calculation methods, the evaluated savings, as a percentage of pre-install use between programs and years, are fairly consistent.

Program Recommendations

The following recommendations discuss possible strategies for improving the realization rate.

Program Recommendation #1: Estimating savings in homes with electric space heat

Most of the homes with electric heating savings had multiple heating fuels. Almost a quarter of these homes did not show any savings. Flagging homes with electric space heat and related

heating measures for additional review (if not already done) may help improve the realization rate.

Program Recommendation #2: Focus on smaller contractors

A significant finding from the unregulated fuels *post hoc* analysis was contractors with more than 50 completed projects had a significantly better realization rate than those without. Additional attention on training, ongoing support, and review of savings estimates for contractors completing fewer projects through the program, may help improve the realization rate.

Program Recommendation #3: Adjust the winter coincidence factor for space heating

Previous FCM impact evaluation from program year 2014 and this analysis suggest the coincidence factor for electric space heating measures is too high. The winter peak coincidence factor in Loadshape 5 -- Residential Space Heat -- is about twice as high as the results found from the current billing analysis and the 2014 FCM evaluation. Based on these analyses, we recommend changing the winter coincidence factor for Loadshape 5 in the TRM from 45% to 20%.

Evaluation Recommendations

Evaluation Recommendation #1: Investigate reasons for low realization rate for unregulated fuel heating measures

The realization rate for the 2014 to 2016 program years is similar to the results from the previous evaluation. As this evaluation was based solely on billing analysis, it provided a good indicator of overall program impacts, but did not offer insights into the reasons for the gap between program reports and evaluated savings. Additional evaluation activities, such as a more detailed review of program procedures, combined with an on-site survey, are needed to develop a better assessment of the reasons for the low realization rate for unregulated fuel heating measures.

1 Introduction

This report covers the impact evaluation conducted for Efficiency Vermont's (EVT's) Home Performance with ENERGY STAR (HPwES) program for projects completed in 2014 through 2016. This evaluation was the second for EVT's HPwES Program, following the initial impact evaluation completed in 2012.

Efficiency Vermont's (EVT's) HPwES program is a statewide program providing incentives for weatherization measures and services for single family homes. The objective of HPwES is to improve the thermal envelope, heating and ventilation systems of residential homes, advancing the efficiency, comfort, and health of Vermont residences, in addition to lowering energy bills. The most commonly installed measures are insulation and air-sealing. However, other improvements may include heating system replacement and distribution, domestic hot water, or electric efficiency measures.

1.1 Evaluation Objectives

This impact evaluation was designed to determine the evaluated gross energy savings, peak demand reduction, and realization rates for major measures installed in program years 2014 through 2016. Both electric and unregulated fuel energy savings were evaluated.

The primary outcomes for this study are the gross energy savings, peak demand reduction, and realization rates for the evaluated measures. Homeowners participating in the Vermont HPwES Program commonly use delivered fuels, such as oil, propane or kerosene, to heat their homes and program-reported energy savings included unregulated fuels, as well as electric savings. The impact evaluation measured the savings of both electric and delivered fuels.

The gross impact evaluation meets or exceeds industry standards for energy-efficiency program evaluation and the requirements of the New England Independent System Operator (ISO) for sales into the Forward Capacity Market (FCM).[3]

1.2 Evaluation Approach

Billing was the primary method used to estimate program savings. Electric savings from heating-related measures were verified through AMI analysis. Verified unregulated fuel savings were estimated using a normalized annualized consumption (NAC) model. Savings from wood were not verified as part of this evaluation. All results were weather-normalized, as appropriate. No sampling was necessary, and thus, the results were not affected by sampling error.

The remainder of this section covers the approach to estimating the electric savings, followed by a discussion of strategy for verifying the unregulated fuel savings.

[3] The ISO-NE FCM requires impact evaluation to be conducted by third-party independent qualified evaluators.

1.1.1 Electric

Electric savings were estimated for heating-related measures, with estimated savings of 600 kWh or more. Advanced metering interface (AMI) interval data was used for the analysis. The average kW use was calculated by temperature bin and a house-by-house regression was conducted. The data was checked for issues and sufficiency for both pre- and post-periods.

1.1.2 Unregulated Fuels

Heating fuels such as oil, propane and kerosene are purchased in bulk through a largely unregulated energy market. Due to lack of regulation and bulk delivery process, the key issue with unregulated fuels is collecting and interpreting the delivery records.

Steps completing the unregulated fuels evaluation included the following components:

1. Obtaining participant-signed consent forms requesting billing data from the fuel dealers
2. Requesting fuel dealers to provide the billing records
3. Fielding a participant survey to collect additional information about heating consumption patterns
4. Compiling survey results, program and billing records necessary to conduct the billing analysis
5. Conducting a house-by-house, 2-stage regression of heating degree days on unregulated fuel consumption for the pre- and post-installation periods to assess the energy consumption patterns in each home
6. Estimating savings using a normalized annual consumption (NAC) model

Obtaining billing records required extensive cooperation from both participants and fuel dealers. The final model was comprised of participants with a complete consumption history, compiled from all fuel dealers used during the analysis period.

2 Program Description

The Home Performance with ENERGY STAR (HPwES) program offered through Efficiency Vermont (EVT) is a statewide program providing incentives for weatherization measures and services for single family homes (1-4 units). The objective of HPwES is to improve the insulation, heating, and ventilation systems of residential homes, advancing the efficiency, comfort, and health of Vermont residences, in addition to lowering energy bills. The most commonly installed measures are insulation and air-sealing. However, other improvements may include heating system replacement and distribution, domestic hot water, or electric efficiency measures. Since 2009, participants in the HPwES program have been eligible to earn up to $2,500 in incentives per household.

To be eligible to participate in the HPwES program, participants have to meet the following criteria:

- Homes must be residential properties with fewer than five units, including those using unregulated fuels for heating.
- For buildings with multiple units, all units must participate for incentive eligibility.
- To receive an incentive through the HPwES program, households must, at a minimum, install all recommended health and safety improvements, possibly including carbon monoxide detectors, mechanical ventilation, and reducing air leakage by at least 10% (determined through a pre- and post-blower door test).
- Participating homeowners must work with a participating HPwES contractor to be eligible for measure incentives. This contractor must conduct the test-in and test-out and ensure the work meets the program's standards for quality.

As HPwES is delivered through a participating contractor network, ensuring both the quality of the installations and the satisfaction of participating contractors, is inherent to the value of the program. Contractors who participate in the HPwES program, performing the project testing and reporting, must be certified through the Building Performance Institute (BPI) and must maintain their re-certification every three years. Other requirements to become a participating contractor include speaking with an EVT engineer; confirming their technical ability, and with an EVT customer representative to approve of their customer service.

Contractors receive multiple benefits from their participation in the HPwES program. Advanced training opportunities are provided, for free or at low costs, by the Efficiency Excellence Network (EEN) throughout the year. These training workshops cover technical topics, in addition to marketing, education, and customer service techniques.

2.1 Program Savings

HPwES contractors use Efficiency Vermont's Home Energy Reporting Online (HERO) tool to estimate thermal energy savings. Savings for electric measures, such as LEDs and appliances, are reported based on the VT Technical Resource Manual (TRM) characterization.

HERO uses an asset-based approach to estimate savings for envelope measures. Savings are estimated based on the existing condition of the building assembly being retrofitted, the ending condition of the assembly, and the long-term average annual Heating Degree Days (HDD). The asset-based savings estimates are then adjusted to account for typical internal/-solar gains, modest occupant set-back, and shoulder season energy conservation. In addition, an estimate of annual heating fuel consumption is gathered by contractors through an interview with the homeowner. Estimated annual heating fuel consumption is used by contractors and Efficiency Vermont as a reality check for screening, identifying high-percentage savings estimates, and making subsequent adjustments to inputs.

The tables below provide summaries of program-reported savings for PY2014 through PY2016.

TABLE 2-1: HPWES PROGRAM-REPORTED SAVINGS BY YEAR

Program Year	Participants with Installed Measures	Annual Electric Savings (kWh/year)	Annual Unregulated Fuel Savings (MMBtu/year)[1]	Annual Other Thermal Savings (MMBtu/year)[2]
2014	720	138,825	16,085	4,077
2015	820	120,824	15,677	3,350
2016	742	187,627	13,231	2,774
Total	2,282	447,275	44,992	10,201

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

[2] "Other Thermal Savings" include wood and natural gas savings. These fuels were not evaluated as part of this evaluation.

TABLE 2-2: HPWES PROGRAM-REPORTED SAVINGS BY MEASURE GROUP FOR PROGRAM YEARS 2014 TO 2016

Measure Type	All Participants with Installed Measures	Annual Electric Savings (kWh/year)	Annual Unregulated Fuel Savings (MMBtu/year)[1]	Annual Other Thermal Savings (MMBtu/year)[2]
Insulation and Air Sealing	2,266	783,241	37,695	10,030
Heating System Replacement	181	-350,671	6,308	894
Domestic Hot Water Conservation	18	-2,749	10	7
Domestic Hot Water Replacement	39	11,111	145	-12
Programmable Thermostat	75	450	128	5
Heating System Fuel Switch	78	1,392	-41	-793
Other[3]	472	4,501	748	71
Total	3,129	447,275	44,992	10,201

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

[2] "Other Thermal Savings" include wood and natural gas savings. These fuels were not evaluated as part of this evaluation.

[3] Other category includes duct sealing and insulation, ventilation, window and door improvements.

3 Electric Billing Analysis

Billing analysis was used to evaluate the electric heating portion of the HPwES savings. The electric billing analysis was conducted using 15-minute AMI data for projects with 600 kWh (or more) of program-reported, annual savings. The majority of the savings for these projects were due to heating-related measures.[4]

3.1 Data Cleaning and Preparation

The cleaning and preparation of the data set involved several steps eliminating households with insufficient data and checking for problematic data. This process can be described in three stages: combining the data, data integrity checks, and calculating average kW by temperature bin. Each of these steps is described below in greater detail, followed by a summary of reasons homes were removed from the model.

3.1.1 Combining the Data

The analysis required data from the following sources:

- EVT's central database (measures installed, program-reported savings)
- HERO program-tracking database (heating and water heating fuel types)
- Utility AMI data
- NOAA weather data

Program data was checked to see where the savings were from and only heating measures were included in this analysis. The type of heating fuel from the HERO database was added to the file to check reported fuel savings against the fuel used for heating. AMI data was linked with hourly temperature data. As the AMI data is on a 15-minute interval, all four data points within an hour have the same temperature.

3.1.2 Data Integrity

The data was reviewed to ensure all included homes had sufficient data, without any data-integrity issues. Homes were eliminated from the analysis for the following reasons:

1. More than 5% of reads were 0, indicating possible data issues, as a home very rarely draws no power
2. Sites without at least 90 days of pre- and post-installation AMI data. The threshold of 90 days was used in combination with the check for sufficient heating season data

[4] The savings for three projects were predominantly associated with domestic hot water (DHW) measures. These homes were dropped from the analysis, as these few projects introduced a high amount of uncertainty due to wide variation in hot water usage across households.

3. Discrepancy between the HERO database and the central measure tracking database, regarding the installation of a heat pump; as it was uncertain whether the heat pump was installed, the potential impact on the results is unknown
4. Insufficient heating-season data

3.1.3 Temperature Binning

AMI reads were assigned to 5-degree temperature bins based on the ambient air temperature during the time of the AMI read. Flags for three seasons were generated based on the month: summer was June-August, winter was November-March, and the remaining months were the shoulder season. The 15-minute kW reads were averaged for each temperature bin.

3.1.4 Summary of Attrition

A summary of the attrition due to the issues described above is shown in the table below.

TABLE 3-1: SUMMARY OF ATTRITION

Reason	Number of Homes Removed	Number of Homes Remaining	% of Homes Remaining
Data Received		116	100%
90 days or more of pre-/post-bills	10	106	91%
Less than 5% of reads are 0 kW	36	70	60%
Sufficient heating-season data	20	50	43%
Removed homes with ASHP	3	47	41%
Total homes	69	47	41%

3.2 Analysis

A regression of the electric usage vs temperature bin was conducted for each of the three heating seasons (Fall, Winter and Spring). The winter kWh and kW regressions were used to calculate the savings. If temperature-dependent use was found during a shoulder season, it was also included in the analysis.

Several of the homes had low R^2 values, indicating there was little temperature-dependent load. As heating savings of 600 kWh (or more) was reported in these homes, they were not removed from the analysis. Ten homes showed some extra use (negative savings) during the winter period. These would normally be left in the analysis, as non-program changes in use are random and can result in either additional use or unexpectedly high savings. However, because

of the small number of homes in the analysis and uncertainty of the reasons for the additional use, the savings for these homes were set to 0.

The regression results were normalized using a 6-year average of 2011-2016 temperature data for the appropriate weather stations, as follows[5]:

1. The winter peak was normalized using the percent of hours in each temperature bin during the peak period.
2. The kWh savings were normalized using the hours during the winter and shoulder seasons.

For additional details and an example of the data used in the analysis, see Appendix A.

3.3 Results

The heating fuel type, as recorded in the HERO database, was used to divide the homes into two categories:

1. Homes with all, or part, of their heating provided by electric space heat (ESH), as reported (44 homes)
2. Homes without electric space heat; these homes had some heating-dependent electric use due to secondary loads from unregulated fuel heating systems (3 homes)

None of the homes had summer peak kW savings.

TABLE 3-2: SUMMARY OF RESULTS

Group	Count	Program-Reported Savings Per Site		Verified Savings Per Site		Realization Rate	
		Annual kWh	Winter kW	Annual kWh	Winter kW	Annual kWh	Winter kW
ESH	44	2,407	1.185	1,946	0.437	81%	37%
No ESH	3	1,367	0.709	704	0.200	57%	28%
Total	47	2,340	1.154	1,867	0.422	80%	37%

The realization rate is 80% for energy savings and 37% for the winter peak kW demand reduction.[6] The relative precision at 80% is 16% for the kWh and 18% for the winter kW savings. This relative precision reflects the variability in the model. There is no sampling error, as all homes with sufficient AMI data were included.

[5] Six years is used for normalization to account for recent changes in the climate.
[6] The winter peak period is 5-7pm in December and January for the ISO-NE FCM.

A summary of the program savings is shown in the table below. The low realization rate for peak kW reduction and the substantially higher realization rate for kWh savings suggests the coincidence factor for residential heating is too high. The TRM indicates the residential space heat coincidence factor for winter peak demand is 45.4%. For the homes included in this study, the winter peak coincidence factor is 16.6%, based on the assumed kW-connected load reduction used by EVT. This result is similar to the residential ESH analysis conducted as part of the FCM impact evaluation for PY2014, which found a coincidence factor of about 20%.

TABLE 3-3: SUMMARY OF PROGRAM SAVINGS

Total Program-Reported Savings		Total Evaluated Savings		Realization Rate	
Annual kWh	Winter kW	Annual kWh	Winter kW	Annual kWh	Winter kW
400,421	198.687	319,465	72.548	80%	37%

4 Unregulated Fuels Analysis

In New England, many homeowners use oil, kerosene, propane, or some combination of these fuels, to heat their homes. This billing analysis evaluated the program-reported savings associated with homes heated with these fuels.

Billing analysis was the primary method of verifying the unregulated fuel savings. The process of collecting and analyzing the bills required numerous steps, as it was necessary to contact individual participants and their fuel dealers to acquire billing records. The irregular delivery of fuels required a rigorous analysis to accurately assess savings. An overview of the steps in the billing analysis is provided in the table below.

TABLE 4-1: UNREGULATED FUEL BILLING ANALYSIS OVERVIEW

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

Each of these topics is discussed briefly in the sections below, with additional detail provided in the referenced appendices.

4.1 Data Collection

The data collection process involved the following steps:

1. Sending out advance letters with a consent form and link to the Web-based survey
2. Receiving the consent forms and sending a reminder to those who did not respond
3. Contacting fuel dealers to request records for those participants who sent a consent form
4. Receiving and entering the fuel dealer's billing records

5. Sending incentives to the participants ($20) and the fuel dealers ($40 plus $1 for each customer after the first 10)

The Web-based survey requested information about household characteristics and changes in heating use to improve our understanding of the bulk fuels analysis. West Hill Energy staff conducted the survey by phone upon request.

TABLE 4-2: UNREGULATED FUELS DATA COLLECTION OVERVIEW

Step	Number of Homes	Number of Surveys Completed
Consent Forms with Survey Link Sent Out	1,576	N/A
Consent Forms Returned	355	275
Billing Data Requests Sent to Fuel Dealers	330[a]	N/A
Total Billing Records Provided by Fuel Dealers	282[b]	209
Removed Due to Attrition	181	N/A
Final Billing Model	101	70

[a] About 81 fuel dealers were listed to request records for the 355 participants who returned consent forms. Due to budget constraints and the tight evaluation timeline, 25 fuel dealers--with only one customer participating in the study--were not contacted, leaving a total of 330 participants for which fuel records were requested.

[b] Thirty-five (35) of the 56 fuel dealers contacted were willing to provide billing records, for a total of 282 participants

Additional information on the data collection can be found in Appendix B. The advance letter, consent form, and detailed survey instrument are also attached (Appendices C and D).

4.1.1 Weather Data Collection

Weather data was obtained from the National Oceanographic and Atmospheric Administration (NOAA) for 9 weather stations in Vermont. This weather data was used to calculate heating degree days (HDD). The heating degree days (HDD) were applied to the billing records for each participant, using the weather station nearest to the participant's zip code.

4.2 Data Preparation

To conduct the billing analysis, data from several sources was combined, as shown in the following table.

TABLE 4-3: DATA SOURCES FOR THE UNREGULATED FUELS BILLING ANALYSIS

Source	Data Used
EVT's central database	Measures installed, program-reported savings
HERO program-tracking database	Heating and water heating fuel types
Survey Data	All fuels used in household, estimated percentage heating by fuel, fuels used for DHW, heat pump installed, significant changes in fuel use, thermostat settings
Fuel dealer records	Fuel type, quantity delivered, delivery date, tank number, partial fill flag
NOAA weather data	Hourly outside air temperature, date, hour, station location

4.3 Data Cleaning and Attrition

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

TABLE 4-4: DESCRIPTION OF ATTRITION CATEGORIES

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

Billing records were received for 282 (79%) of the 355 participants with signed consent forms and 36% of these projects were included in the final model. Additional detail on the attrition, data cleaning, and data preparation is provided in Appendices E, F, and G. A summary of the attrition is included in the table below.

TABLE 4-5: ATTRITION SUMMARY

	Number of Homes	Number Removed	% of Total Billing Records	Number of Households with Survey Data
Total Billing Records Received	282	-	100%	209
Not Enough Data	174	108	62%	N/A
Poor Quality Data	107	67	38%	N/A
Outliers or Influential Data Points	101	6	36%	N/A
Accounts in final model	101	-	36%	70

4.4 Analysis

The analysis method involved conducting a house-by-house, 2-stage regression of the heating degree days (HDD) on unregulated fuel consumption for the pre- and post-installation periods and compiling the results. The steps to review the data and determine whether to keep homes in the model were as follows:

1. Conduct pre- and post-regression analysis using the heating degree days (HDD) and consumption in millions of British thermal units (MMBtu) for each home.
2. Identify the correct regression model to be used, based on survey information and regression results
3. Review each project for erratic or inexplicable results and assess whether adjustments were needed
4. Remove projects with problematic data or regression results
5. Conduct verification and sensitivity analyses to assess the validity of the results
6. Assess changes to the method and additional removal of homes based on the results of Step 5

The method of selecting the correct regression model depended on whether the same fuel was used for both space- and water heating.[7]

In Step 3 above, the regression results were reviewed and homes were dropped for the following reasons:

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

[7] For homes with survey data, the intercept regression model was used for homes using the same fuel for space- and water heating and the non-intercept model was used for homes with only space heating. In a few cases, the participant did not complete the detailed survey. In these cases, the intercept and non-intercept regression models were tested and the model with the better fit was used.

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

The savings from the heating measures were determined by calculating the heating energy required per heating degree day separately for the pre- and post-installation period. The difference in the two values was then multiplied by the 6-year annual average HDD for the appropriate weather station.[8] The realization rate was calculated by dividing these savings by the program-reported savings for the same fuel.

4.5 Verification of the Analysis

After savings were estimated, we performed an extensive series of checks and sensitivity analyses to assess the validity of the results. The table below outlines the additional analysis conducted to verify the results. Additional detail on the data-verification process and sources of uncertainty is provided in Appendices E and H.

[8] For some weather stations, there was complete weather data for 5-years and the 5-year average was used.

TABLE 4-6: ADDITIONAL VERIFICATION STUDIES OVERVIEW

Step	Procedure	Finding	Change to Model
Isolate DHW usage from heating	Isolated DHW usage from heating in homes by analyzing fuel use during low heating demand periods.[1] This estimated use was then deducted to get a heating only estimate of energy use.	4% increase in RR	Modify model
Identify suspect DHW usage	Flagged and removed participants when estimated DHW usage was greater than 16 MMBTU *and* varied more than 40% between the pre- and post-.	<1% change in RR	15 participants were removed
DHW sensitivity analysis	Used the max. and min. values of the estimated DHW use to isolate DHW from heating	Sensitivity analysis found < 1% change in RR	No change
Regression-based estimate of savings for homes with DHW	Tested whether there was a bias in our MMBtu/HDD method by comparing the results of the MMBtu/HDD method to the regression estimators only in homes where we had a reliable estimate of the DHW use.[2]	<2% decrease in RR	No change
Changes in heating use from survey responses	Isolated those 6 households identified as having a substantial change in secondary fuel usage in the survey to see if this biased the results downward	93% RR for the group, no downward bias	No change
Homes without survey data	Isolated the 31 homes without survey data to see if the lack of information about changes in heating affected the realization rate	<3% decrease in RR for the group	No change
R^2 sensitivity analysis	The threshold for leaving records in was reduced to an R^2 of 0.6 from 0.65 and also increased to an R^2 of 0.7 from 0.65	Sensitivity analysis found <2% change in RR	No change
Outliers	Identified those with much higher or lower verified savings than all other participants and outside a range that seemed reasonable.[3]	<1% change in RR	3 homes removed
Influential data points	Participants were removed one by one and the overall realization rate was recorded. One record was noted to have a significant impact on the overall results and was removed.[4]	2% increase in RR	1 home removed

[1] Low heating demand was based on periods with less than 4 HDD per day on average. The estimated use from these periods was confirmed by taking the max., min., and average of all those showing DHW usage and by flagging any suspect outliers.
[2] The DHW use was estimated by assessing use during periods of less than 5 HDD on average. This resulted in a consistent, reliable estimate for 19 homes. We substituted the regression estimate for the MMBtu/HDD method for these homes.
[3] One home with very low savings (<-30 MMBTU) and 2 homes with very high savings (>70 MMBTU) were removed.
4 The quality of the data on this record was also near the threshold of our attrition cutoffs on a few indicators.

In aggregate, these additional checks support the validity of the results, as the impacts have both an upward and downward effect on the realization rate.

4.6 Results

The final results of the analysis are shown in the table below. These results included multiple fuel types, with each household's evaluated fuel savings compared to the program-reported savings for the same fuel at the household. The realization rate is 65% +/- 10%.

TABLE 4-7: UNREGULATED FUELS BILLING ANALYSIS RESULTS

Variable	Results
Number of Homes in the Model	101
Mean Program Reported Savings (MMBtu)	22.5
Mean Evaluated Savings (MMBtu)	14.6
Realization Rate	65%
Realization Rate 90% Confidence Interval	+/- 10%
Relative Precision at 90%[1]	15%
Mean Evaluated Pre-Install Use (MMBtu)	92.0
Evaluated Savings as Percent of Pre-Install Use	16%
Program Reported Savings as Percent of Pre-Install Use	25%

[1] Relative precision is the error-bound divided by the realization rate. The precision reflects the variability in the model. There is no sampling error, as all homes with sufficient billing data were included in the model.

Table 4-8 provides the results by fuel type. As the sample sizes are small, particularly for kerosene, these results are presented for informational purposes only.

TABLE 4-8: UNREGULATED FUELS BILLING ANALYSIS RESULTS BY FUEL TYPE

Fuel Type	Number of Homes in the Model	Mean Evaluated Pre-Install Use (MMBtu)	Mean Program-Reported Savings (MMBtu)	Mean Evaluated Savings (MMBtu)	Realization Rate
Fuel Oil	87	105.3	21.4	14.0	66%
Propane	12	104.8	32.8	20.8	63%
Kerosene	2	60.8	9.4	2.3	24%

The total program savings are presented in Table 4-9.

TABLE 4-9: SUMMARY OF UNREGULATED FUELS PROGRAM SAVINGS

Total Program-Reported Savings	Total Evaluated Savings	Realization Rate
MMBTU	MMBTU	%
1,476	2,272	65%

4.6.1 Results by Contractor

As part of our *post hoc* analysis, we investigated the realization rate of contractors based on their volume of work through the program. The realization rate for the larger contractors with over 50 completed projects was substantially higher than smaller contractors. This difference was statistically significant at the 90% confidence interval, as shown in the table below.[9]

TABLE 4-10: RR FOR LARGE AND SMALL CONTRACTORS

Contractors with ...	N	Realization Rate	90% Confidence Interval	Average Number of Projects Completed
More than 50 projects completed	73	73%	62-83%	154
Less than 50 projects completed	28	49%	40-57%	26

4.6.2 Comparison to other programs

The results from the evaluation are within the range of other impact evaluations conducted for similar programs in the Northeast. Despite changes in program-reported savings and calculation methods, the evaluated savings as a percentage of pre-install use between programs and years are fairly consistent.

The results of eight impact evaluations are shown in the table below, with the findings from the current study shown at the top of the table for comparison. The evaluated savings, as a percentage of the pre-install use in this study, are very close to the earlier study of the EVT's HPwES program, and exactly the same as the New York HPwES program (2007-2008) and VGS's low income program (RLI VT 2008-2010).

[9] There was some variation in these results depending on the grouping of contractors by number of projects completed. When we performed this analysis on those contractors with over 80 projects, the results still showed a large gap in RR, but the findings were only statistically significant at the 80% confidence interval.

TABLE 4-11: COMPARISON OF SIMILAR IMPACT EVALUATIONS[5]

Program	State	Program Year of Impact Evaluation	Average Pre-Install Use (MMBtu/yr)	Program-Reported Savings (% of Pre Install Use)	Evaluated Savings (% of Pre Install Use)	Overall Realization Rate
HPwES[1]	***VT***	***2014-2016***	***92.0***	***25%***	***16%***	***65%***
HPwES	VT	2008-2010	91.5	35%	18%	51%
HPwES[6]	NY	2007-2008	105.5	25%	16%	65%
HES[2]	MA	2010-2011	119.5	15%	12%	76%
HPwES[3]	NY	2011-2013	104.0	45%	27%	60%
VGS RMR[4]	VT	2008-2010	125.5	26%	22%	89%
VGS RLI	VT	2008-2010	88.2	26%	16%	62%
EmPower	NY	2007-2008	109.0	13%	9%	70%
EnergyWise	RI	2010	116.8	13%	13%	99%

[1] This impact evaluation, shown for comparison
[2] Includes only insulation and air-sealing measures
[3] The evaluation includes unregulated fuel savings from fuel switches to natural gas. Since unregulated fuels do not include natural gas use, this increased program savings substantially
[4] This program is specifically targeted to high use "residential customers that consume in excess of 50,000 BTU/ft2s per square foot per year," suggesting these homes have a higher potential for savings than many others. Another significant feature of the VGS RMR program is savings estimates are routinely checked against consumption to insure they are reasonable. Bartsch, Danaher, 2014. The Shell Game: Finding Thermal Savings in Residential Retrofit Programs, p.6 and 8.
[5] All program results are from the paper referenced here except where noted. Bartsch, Danaher, 2014. The Shell Game: Finding Thermal Savings in Residential Retrofit Programs, p.6 and 8.
[6] Energy & Resource Solutions, West Hill Energy, 2012. Home Performance with Energy Star: Unregulated Fuels Impact Evaluation, prepared for the New York State Energy Research and Development Authority.

5 Conclusions and Recommendations

This section presents the conclusions and recommendations.

5.1 Conclusions

Some of the key conclusions from this analysis are explored below.

- The realization rate is 80% for electric heating-related measures and 65% for unregulated fuel savings.
- For the winter peak kW reduction, the realization rate is 37% for electric heating-related measures, suggesting the coincident factor for electric space heating measures is overstating this metric.
- Most of the homes with electric heating-related measures used multiple heating fuels.
- For unregulated fuels, the realization rate is substantially higher for larger contractors who completed at least 50 projects through the program.
- The realization rate for the 2014 to 2016 program years (65%) is somewhat higher than the results from the previous impact evaluation covering program years 2008 through 2010 for unregulated fuels (50%).
- It does not appear the accuracy of the estimation of savings by contractors has improved since the previous evaluation, as EVT began applying an adjustment factor to the HPwES savings following the completion of the prior study.[10]
- The results from the evaluation are within the range of other impact evaluations conducted for similar programs in the Northeast. Despite changes in program-reported savings and calculation methods, the evaluated savings as a percentage of pre-install use between programs and years are fairly consistent.

5.2 Program Recommendations

The following recommendations discuss possible strategies for improving the realization rate.

5.2.1 Estimating savings in homes with electric space heat

Most of the homes with electric heating savings had multiple heating fuels. Almost a quarter of these homes did not show any savings. In some cases, it appeared the secondary electric heating usage in those homes was very small, prior to the program work done and any change was indistinguishable from the noise of the other electric loads. Flagging homes with electric space heat and related heating measures for additional review (if not already done) may help improve the realization rate.

[10] The adjustment factor was 76% for the program years covered in this evaluation.

5.2.2 Focus on smaller contractors

A significant finding from the unregulated fuels *post hoc* analysis is contractors with more than 50 completed projects had a significantly better realization rate than those without. This finding suggests contractors with more project experience are better able to achieve savings, and/or estimate them more appropriately. Additional attention on training, ongoing support, and review of savings estimates for contractors that complete fewer projects through the program may help to improve the realization rate.

5.2.3 Adjust the winter coincidence factor used for space heating

This analysis and the previous FCM impact evaluation from program year 2014 suggest the coincidence factor for electric space heating measures is too high. The winter peak coincidence factor in Loadshape 5 -- Residential Space Heat -- is about twice as high as the results found from the current billing analysis and the 2014 FCM evaluation. Based on these analyses, we recommend changing the winter coincidence factor for Loadshape 5 in the TRM from 45% to 20%.

5.3 Evaluation Recommendations

This recommendation relates to additional evaluation activities, providing insight into the reason(s) for the low realization rate.

5.3.1 Investigate reasons for the low realization rate for unregulated fuel heating measures

The previous HPwES evaluation concluded the realization rate for unregulated fuel heating measures was about 50%. EVT subsequently began applying an adjustment factor to the program savings to address the overstatement of savings. During the period covered in this evaluation, EVT applied an adjustment factor of 76%. The realization rate from the current evaluation is 65%, to be applied to the savings already adjusted by EVT, indicating the realization rate for the 2014 to 2016 program years is similar to the results from the previous evaluation.

As this evaluation was based solely on a billing analysis, it provides a good indicator of overall program impacts, but does not offer insights into the reasons for the gap between program reports and evaluated savings. Additional evaluation activities, such as a more detailed review of program procedures, combined with an on-site survey, are needed to develop a better assessment of the reasons for the low realization rate for unregulated fuel heating measures.

6 References

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