WEST HILL ENERGY AND COMPUTING

Vermont Home Performance with Energy Star, Post-Installation Inspection Report

Vermont Department of Public Service

April 29, 2020

Prepared For

Keith Levenson
Energy Programs Specialist
Vermont Department of Public Service
112 State Street
Montpelier, VT 05620-2601

Prepared By

West Hill Energy and Computing
in partnership with Center for
EcoTechnology

Table of Contents

Table of Tables

Table of Figures

Appendices

Vermont Home Performance with Energy Star (HPwES), Post-Installation Inspection Report

1 Introduction

This report covers the supplemental evaluation activities associated with the impact evaluation conducted for Efficiency Vermont's (EVT's) Home Performance with ENERGY STAR (HPwES) program for projects completed in 2014 through 2016.

Efficiency Vermont's (EVT's) HPwES program is a statewide program that provides 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 to advance 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.

The supplemental evaluation activities were conducted to investigate the reasons for the low realization rate (RR) found in the recent evaluation of EVT's Home Performance with ENERGY STAR program (HPwES). The realization rates from the most recent two impact evaluations are shown in Table 1-1 below.

TABLE 1-1: IMPACT EVALUATION RESULTS FOR EVT'S HPWES PROGRAM

Program	State	Program Year Evaluated	Average Pre-Install Use (MMBtu/yr)	Program-Reported Savings (% of Pre Install Use)	Evaluated Savings (% of Pre Install Use)	Overall Realization Rate
HPwES	VT	2014-2016[1]	92.0	25%	16%	65%
HPwES	VT	2008-2010[2]	91.5	35%	18%	51%

[1] West Hill Energy and Computing in partnership with GDS Associates, "Impact Evaluation of Efficiency Vermont's Home Performance with ENERGYSTAR Program." September 10, 2018.

[2] West Hill Energy and Computing in partnership with GDS Associates, "Efficiency Vermont's Home Performance with ENERGY STAR® Program Impact Evaluation Final Report." June 3, 2013.

While the evaluated savings as a percent of pre-install use is consistently in the range of other, similar programs in the Northeast, the reported savings for HPwES are substantially overstated. The realization rate (RR) for unregulated fuels from the earlier impact evaluation was about 50%. Based on the results of this evaluation, EVT applied an adjustment factor of 76% to the HPwES savings as calculated by the contractors for PY 2014 to 2016.

The realization rate for the 2014 to 2016 program years was 65%. Accounting for EVT's adjustment factor, the ratio of the contractor-to-evaluated savings is similar between the two studies and the accuracy of the estimation of savings by contractors has not improved since the previous evaluation.

1.1 Evaluation Objective

The supplemental evaluation activities were designed to assess the possible reasons for the overstatement of savings by the contractors. In specific, on-site inspections were conducted to assess whether performance issues and/or discrepancies in modeling inputs could be reasons that many contractors' analyses seem to consistently overstate savings. While other factors could be influencing the RRs, the supplemental activities were focused on the contractors' use of the EVT's modeling tool, the quality of the installations and site-specific factors that may make estimation of savings more difficult.

1.2 Project Approach

The primary approach was to conduct 10 post-installation site visits, including blower door tests and infrared imaging, for the purpose of determining whether the installation practices and modeling inputs affected the realized savings. The sample frame was 101 homes in the previous billing analysis; 10 sites were visited in 5 southern Vermont counties.

The site visits and data collection were conducted by the Center for EcoTechnology (CET). West Hill Energy reviewed and analyzed the data collected by CET to reach qualitative conclusions.

The goal was to collect details about the pre- and post-install conditions, which included the following:

1. Documenting the measures and other key aspects of the home through photographs and infrared imaging
2. Conducting a brief customer survey on site
3. Visually inspecting installed measures
4. Verifying as many of the contractor inputs as possible
5. Investigating the pre-existing conditions to the extent feasible

CET utilized the data from EVT's HERO tool to fill in pre-installation conditions that could not be determined from the site visit, *e.g.*, the insulation was behind drywall or otherwise inaccessible.

2 Methods

This study consisted of site visits to a sample of 10 homes participating in the HPwES program 2014-2015. The study was not designed to provide statistically significant results, but rather to produce a high-level assessment of whether performance issues may be contributing to the low HPwES realization rates. The following sections describe the sampling and solicitation process, site-specific data collection and analysis.

2.1 Sampling and Solicitation

The sample frame was the 101 homes included in the billing analysis conducted for the previous impact evaluation.[1] To minimize travel costs, homes in the southern half of state were contacted first[2].

West Hill Energy and CET developed the following materials in preparation for the site visits:

- Advance letter
- Solicitation script
- Site visit protocols
- Data collection form
- Brief customer survey

A $100 incentive was offered for participants who completed the site visit.

The advance letter was sent to sixty randomly ordered homes in southern Vermont. The respondents emailed or called West Hill Energy and completed a short screening survey to ensure that no substantial energy efficiency upgrades had been completed subsequent to the HPwES project. Twenty-four participants responded to the survey and ten site visits were completed. The respondents were screened and disqualified if there had been substantial changes made to the structure of the home (such as an addition or further efficiency measures) that would make it difficult to assess the work done by the HPwES program. Others were eliminated due to scheduling availability.

---

[1] West Hill Energy and Computing, Inc. "Impact Evaluation of Efficiency Vermont's Home Performance with ENERGYSTAR Program", September 10, 2018, publicservice.vermont.gov

[2] As the modeling uses weather data for the region, starting with the southern half of the state does not introduce bias into the results.

2.2 Site-specific Data Collection

CET visited ten homes for this evaluation. All 10 homes had oil heating. Extensive information was collected at each site, including the following:

1. Heating system details for all heating equipment, such as type and use of thermostats, type of fuel and heating system type(s), heating system manufacturer/model, distribution type, the efficiency listed on the label, measured steady state efficiency and date of installation
2. Water heater fuel and type, the manufacturer/model and date of installation
3. Location of ductwork, details on insulation type, depth, and coverage, and duct sealing
4. Type of pre-existing and current insulation, depth, R-value, dimensions, framing, depth below grade, attic hatch sealing and year installed
5. Evidence of air sealing in basement, attic and interior areas
6. Types of windows and doors

In addition, CET conducted blower door tests and administered a short customer survey. The main purpose of the customer survey was to identify any major changes to the house, occupancy, heating equipment or supplemental fuel use that could affect the savings from the HPwES measures.

The inspection documentation included both photos and infrared images. The photos covered basement, interior, exterior, and attic of each home. Photos were taken showing insulation depth where possible and areas where air sealing was found or was needed. The data collection form is provided in Appendix A.

2.3 Analysis

Three possible contributors to the RR were defined as follows:

- Modeling inputs
- Performance/on-site issues
- Change in use of supplemental heat

The analysis in each of these areas is described in more detail below.

2.3.1 Modeling Inputs

The modeling inputs were assessed by measure and other key inputs, such as heating system efficiency and percent of heating load provided by oil heat. The documentation of the measures reported by the program were compared to the conditions found during the site inspections. Discrepancies between EVT and CET inputs were identified and evaluated to estimate the likely magnitude of the impact. The modeling inputs were divided into five categories, as described in Table 2-1.

TABLE 2-1: DESCRIPTION OF MODELING INPUT CATEGORIES

Modeling Input Category	Description	Comments
Insulation – Attic	Assess differences in dimensions, pre- and post-R-values	Calculated UA to determine net differences; UA is directly proportional to savings
Insulation –Basement, Rim Joist		
Heating System Efficiency	Compare EVT and CET estimates of seasonal efficiency	Conductive savings were adjusted by the heating system efficiency
Blower Door Test	Compare EVT and CET measurement of post-install air infiltration	Underestimating post-install air infiltration could overestimate air sealing savings
Supplemental Heat	Compare EVT and CET estimates of percent of heat load provided by oil	Original evaluation for oil heat; savings are directly multiplied by the percent of heat load from oil

For insulation, numerous differences in the insulated area and pre- and post-R-values were found; these differences had both upward and downward impacts on savings. EVT's HERO database did not include savings by measure, so a direct comparison could not be conducted.

To assess the net impact of the differences, the pre- and post-installation conductive heat loss coefficients (UA values) and coverage areas for each measure were calculated from the CET inspection and the difference between them was compared to the EVT value. Savings for insulation measures are commonly calculated from the conductive heat loss equation as follows:

$$Savings = (UA_{pre} - UA_{post}) \times HDD_{annual}$$

Where

U is the conductance (reciprocal of the R-value [1/R-value])

A is the area

HDD are the annual heating degree days

Thus, comparing the change in UA incorporates differences in the areas and R-values and should affect the savings proportionally. Table 2-2 shows an example of the UA comparison for two homes.

Table 2-2: Example of Comparison of Insulation Modeling Inputs

	Insulated Attic Area (sf)		Pre-Install Attic R-Value		Post-Install Attic R-Value		Attic UA[1]	
Project ID	**EVT**	**CET**	**EVT**	**CET**	**EVT**	**CET**	**EVT**	**CET**
435569	1,409	1,356	9.7	17.1	30.9	30.5	77.8	29.4
445822	638	771	13.1	13.5	38.9	41.9	26.8	32.2

[1] UA = conductive heat loss coefficient (BTU/h-°F)

In each category, discrepancies between CET and EVT values were ranked on a scale of 1 to 7. The overall magnitude of EVT's savings was also ranked and provided for context. The five (5) categories of modeling inputs with ranking are described in Table 2-3.

Table 2-3: Ranking of Differences between EVT and CET Modeling Inputs

Category	Description	Ranking
Attic Insulation	Compared CET & EVT UA using pre- and post-R-value, square footage of insulation; UA = A/(Rpre - Rpost)	1 = EVT > CET by more than 50% 4 = EVT & CET within 10% 7 = EVT < CET by more than 50%
Basement/ Rim Joist		
Heating System Efficiency	Compared CET & EVT seasonally adjusted efficiency	1 = EVT - CET < 10% 4 = EVT & CET within 1% 7 = EVT - CET > 10%
Blower Door Test	Compared CET blower door cfm50 to EVT test out cfm50	1 = EVT - CET < 10% 4 = EVT & CET within 1% 7 = EVT - CET > 10%
Supplemental Heat	Compared EVT estimate of % load from oil heat to CET estimate	1 = EVT - CET > 25% 4 = EVT & CET within 5% 7 = EVT - CET < 25%
Savings Magnitude[1]	EVT savings per home as a percent of the estimated pre-install use from the bills, provided for context	1 = EVT/Billed Pre Use > 45% >=4 = EVT/Billed Pre Use >25%

[1] The savings magnitude is provided for context only. Program reported savings representing a high percent of the pre-install use indicate that there may be issues with the modeling. See further discussion below the table.

The Savings Magnitude category is included for context. High program reported savings as compared to pre-install use may indicate overstated savings, while low program reported savings may simply indicate that the scope of the project was smaller. In general, residential retrofit programs like HPwES save in the range of 13% to 22% of pre-install use on average, with substantial variation from house to house. In this analysis, the purpose of the Savings Magnitude category is to identify homes with program reported savings that are greater than 25% of the pre-install use. This flag serves to identify homes where the magnitude of the savings suggests that there could be issues with the modeling.

2.3.2 Analysis of Performance Issues

West Hill Energy conducted an extensive review of the data collection forms, inspection reports, and the 50-to-100 photos and infrared images collected at each site to assess potential performance issues. Through this process, West Hill Energy assessed the integrity of the thermal envelope, insulation quality and comprehensiveness, and identified areas with substantial heat loss.

2.3.3 Changes in Supplemental Heat Use

Oil savings may also be affected by changed in the use of supplemental heating fuels. For example, installing a heat pump after the HPwES installation is likely to result in higher electric use and lower oil use during the winter months. Another example is participants who use the wood stove substantially less or substantially more after the installation of measures through HPwES.

A participant survey was conducted as part of the original impact evaluation, which included detailed questions about all heating fuels and changes in use between the pre- and post-period use. In addition, all heating fuels were verified as part of this evaluation.

2.3.4 Final Comparison of Contributors to RRs

For each of the three possible contributors to the RRs (modeling inputs, performance issues, and change in use of supplemental heat), West Hill Energy constructed a rating system and applied it to each home. Based on the analysis within each component, West Hill Energy assigned 1 as a likely strong contributor to the RR, 2 as a moderate contributor, and 3 as a weak contributor or no contribution.

3 Results

The results of the analysis are presented in the following sections: modeling inputs, supplemental heat, performance issues, and synthesis of results.

3.1 Modeling Inputs

CET's on-site data collection identified numerous differences with the EVT inputs. These discrepancies included the square footage insulated as well as the depth and the R-value of insulation. The reasons for these differences are unknown. Measurement error is a likely contributor. Invoices were available for one project and, in that case, it appeared that the final savings were not updated to reflect changes in the scope of the work.

CET performed blower door tests at nine of the ten homes.[3] The highest variation between the tests by CET and EVT was 17%, and for half of the sites, it was a less than a 6% difference. It is important to acknowledge that blower door test results could be affected by other changes after the HPwES work was completed, such as adding more insulation or conducting additional sealing work. These changes were noted where they were identified. The results by home are provided in Table 3-1.

TABLE 3-1: BLOWER DOOR TEST COMPARISON

House	CET	EVT/HERO			
	CFM50 with Basement Door Open	**Reported Post-Improvement CFM50**	**EVT - CET**	**% Difference**	**Notes**
1	3403	3200	-203	-6%	
2	3685	3859	174	5%	
3	1710	1981	271	14%	
4	4380	3892	-488	-13%	
5	4193	3716	-477	-13%	
6	N/A		N/A	N/A	No test, vermiculite present
7	2600	3150	550	17%	Installed additional attic insulation after EVT work
8	1754	1680	-74	-4%	Installed additional wall insulation after EVT work
9	2743	2820	77	3%	
10	4126	4224	98	2%	

The analysis of modeling inputs included the estimate of the heating load provided by the oil heat.

---

[3] One site was not tested due to the presence of vermiculite.

Estimating the percentage of the heat load from the oil system is inexact and largely relies on judgment. CET and EVT estimated the percent of oil heat based on information provided by the participant. We would expect some variation in the estimated use of oil heat; this effect would be expected to be random over the entire population, *i.e.*, estimates of the percent of load of a specific fuel type could be either under- or overstated. With a sample size of only 10 homes, this study does not provide any evidence of systematic over- or under-statement of oil heat by HPwES contractors. However, differences between CET and EVT are included in Figure 3-1 for comparison purposes.

The chart in Figure 3-1 shows the comparison of EVT and CET modeling inputs for the five categories. Each row provides an assessment of the inputs for one house and the chart can be read left to right to provide a sense of possible contributors to the RR for each home. The homes are arranged in ascending order of their realization rates. Red indicates a substantial overstatement of savings in the EVT estimate and green indicates substantial understatement of savings in the EVT estimate. Yellow indicates that the EVT and CET estimates match.[4] The "Savings Magnitude" column on the right contains a rank of the magnitude of EVT's estimated savings as compared to pre-install use and is provided for context.[5]

---

[4] The gray indicates that the category is not applicable to the home; for example, not all homes received attic insulation through HPwES. For the blower door tests, two homes had post-installation work completed that invalidated the blower door test comparison and one home could not be tested.

[5] High program reported savings as compared to pre-install use may indicate overstated savings, while low program reported savings may simply indicated that the scope of the project was smaller. Accordingly, only the homes with program reported savings of over 25% of pre-install use are colored with orange or red. Homes with a red block had program reported savings greater than 45% of pre-install use.

House	RR	Attic	Basement/ Rim Joist	Heating System Efficiency	Blower Door Test	Supple-mental Heat	Savings Magnitude	Possible Contributors to the RR
1	-89%	▩	🟥	🟡	🟧	🟨	🟨	Inputs for basement insulation substantially overstated savings. Basement insulation was the main measure.
2	-29%	🟨	🟥	🟨	🟨	🟨	🟨	Inputs for basement insulation substantially overstated savings. Basement insulation was the main measure.
3	-18%	🟧	▩	🟠	🟠	🟡	🟧	Combination of discrepancies in inputs mostly tend to overstate savings.
4	29%	🟥	🟢	▩	🟧	🟨	🟠	Inputs for attic insulation substantially overstate savings; EVT savings were 37% of pre-install use.
5	37%	🟨	🟥	🟧	🟠	🟡	🟧	Input discrepancies combined to overstate savings, particularly basement; EVT savings were 32% of pre-use.
6	37%	▩	🟥	🟠	▩	🟨	🟨	Inputs for basement insulation substantially overstated savings. Basement insulation was the main measure.
7	45%	▩	🟨	🟡	▩	🟧	🟨	No clear indicator; differences in inputs were minor.
8	55%	🟥	🟨	🟥	▩	🟨	🟥	Inputs for attic and heating system efficiency substantially overstate savings; EVT savings were 55% of pre-install use.
9	120%	🟩	🟡	🟧	🟨	🟨	🟨	Inputs for attic insulation substantially understated savings; inputs for basement also understate savings.
10	253%	🟠	🟥	🟨	🟨	🟩	🟨	Customer switched from oil to wood, resulting in mcuh lower oil use even though inputs overstated savings.

🟩	EVT substantial understatement of savings
🟢	
🟡	
🟨	CET/EVT match
🟧	
🟠	
🟥	EVT substantial overstatement of savings
▩	Not applicable

FIGURE 3-1: COMPARISON OF EVT AND CET MODELING INPUTS

The impact of the modeling inputs varied. Appendix B details the possible overstatements and understatements of savings for each house.

3.2 Pre/Post Changes in Supplemental Heat

The homes inspected all had oil heat as their primary heating fuel. Supplemental heating was found in 8 out of the 10 homes as detailed in Table 3-2. Several homes had multiple sources of supplemental heat including wood stoves, LP inserts/stoves, pellet stoves, and electric space heat.

Of the homes with supplemental heat, four homes were found to have substantial use. The main factor affecting savings is the change in use of supplemental fuels between the pre- and post-periods; although three out of the four participants reported that the use of the supplemental heat was similar during the pre- and post-periods.[6] One participant indicated that he had switched from heating primarily with oil to heating primarily with wood, which explained the very high RR in this home (over 250%).

Five participants reported using wood stoves in some sections or throughout the home. Wood stoves are often located in conditioned space and draw combustion air from interior areas. Cooler air drawn from outdoors or semi-conditioned space may increase oil use. However, the homes were sorted by RR and homes with wood stoves were evenly distributed throughout the ten homes, suggesting that the presence of a wood stove did not necessarily result in a low RR.

The differences between EVT's and CET's estimates are provided in Table 3-2.

TABLE 3-2: SUPPLEMENTAL HEAT DATA FROM EVT AND CET SURVEYS

House	Supplemental Heat	EVT % Oil	CET % Oil	CET Survey	WHEC Survey Pre/Post Change	Comments
1	Wood stove	57%	62%		None	No pre/post changes
2	None	100%	100%	Fireplace for ambience		No supplemental heat
3	Wood stove	65%	75%		None	No pre/post changes
4	Electric space	100%	100%	Wood furnace not used; electric space heat low use	Oil somewhat less, electric same	Very low supplemental use
5	Wood stove, electric space	56%	65%	Sets oil heat at 58F	Oil/wood somewhat less, electric about the same	Very low supplemental use
6	None	100%	100%	Has wood stove but never uses it		No supplemental heat
7	Wood stove, pellet stove	89%	75%		No survey	No survey data about pre/post use
8	Electric radiant heat, LP stove	100%	95%	LP heater for ambience; electric in bathroom	Oil about same, LP/Elec somewhat less	Very low supplemental use
9	LP insert	95%	100%	Does not use LP insert	No survey	LP not used
10	Wood stoves (3)	94%	10%	EVT work allowed him to burn more wood and less oil	Oil somewhat less, wood somewhat more	Substantial pre/post change – oil to wood

3.3 Performance Issues

The photos taken at each site provided evidence of potential performance issues. There were two main types of issues:

---

[6] In some cases, the participant reported that all fuels were used less in the post-period, suggesting that they saw savings across all fuels.

1. Difficulties with defining the thermal envelope
2. Areas that were not properly insulated, either as part of the HPwES work or existing conditions prior to the HPwES work

Three examples are provided below; additional detail is provided in the Appendices.

3.3.1 Defining the Thermal Envelope

This section provides three examples of issues with the thermal envelope. In one home, basement walls were insulated but the basement ceiling had been previously insulated, which reduces the effectiveness of the basement wall insulation. The modeling inputs showed that the R-value of previous insulation was entered, but this approach does not accurately reflect the actual impact of redefining the thermal envelope.

Figure 3-2: Competing Insulation

In the second home, a bulkhead door with single pane glass separates basement from a largely uninsulated bulkhead. While the basement walls are insulated, the door most likely has an R-value of 1 or less, creating a large thermal break in the envelope. The purpose of the insulation on the bulkhead ceiling is unclear.

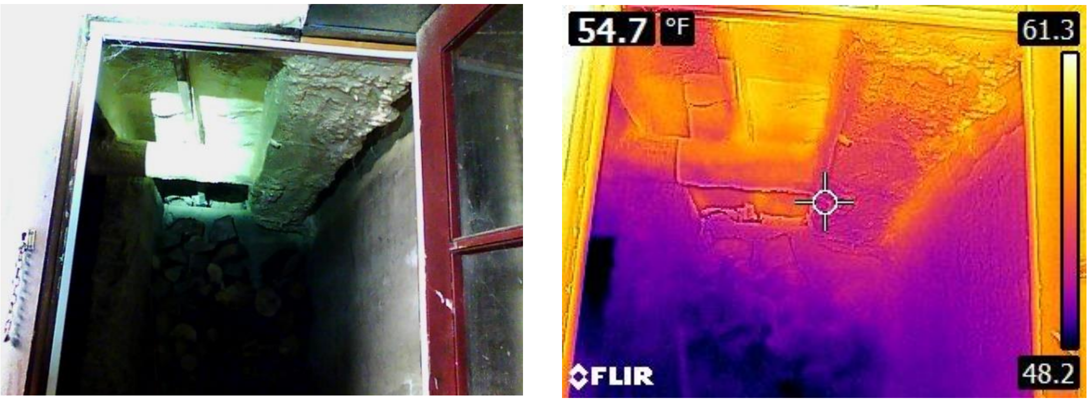


Figure 3-3: Bulkhead Door And Insulation

Some homes had multiple performance issues. One home had thermal envelope issues, under-insulated wall areas, and potentially ineffective attic hatch sealing.[7] The crawlspace in Figure 3-4 was mostly above grade and the wall insulation does not go below the frost line, which makes the insulation largely ineffectual.

Figure 3-4: Basement Wall Insulation

---

[7] Heat is vented into crawlspace to keep pipes from freezing. Crawlspace ceiling was previously insulated with 1" HDF.

3.3.2 Under-Insulated Areas

The infrared imaging showed some un- or under-insulated areas. For example, Figure 3-5 shows the area behind the wainscoting may be poorly insulated as the heat from the register is not reaching an area that is less than 5 feet away.

FIGURE 3-5: POORLY INSULATED WALL

In the home shown below, the attic insulation was installed but the attic was not accessible; this project did not include wall insulation. However, infrared image photos show numerous examples of major heat loss through wall and attic areas. Existing construction may limit effectiveness of insulation in this home.

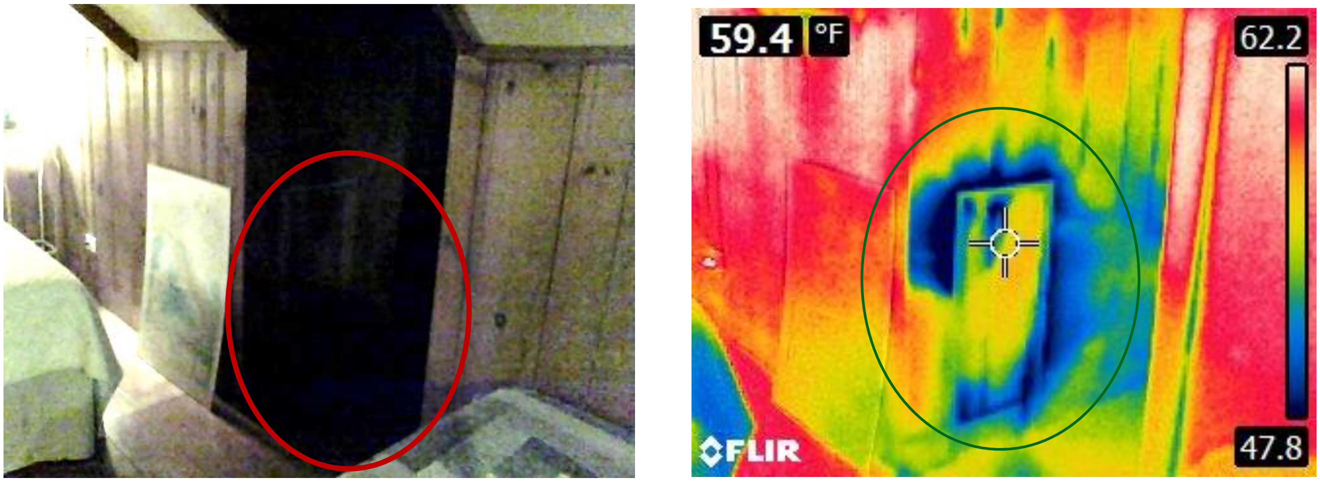
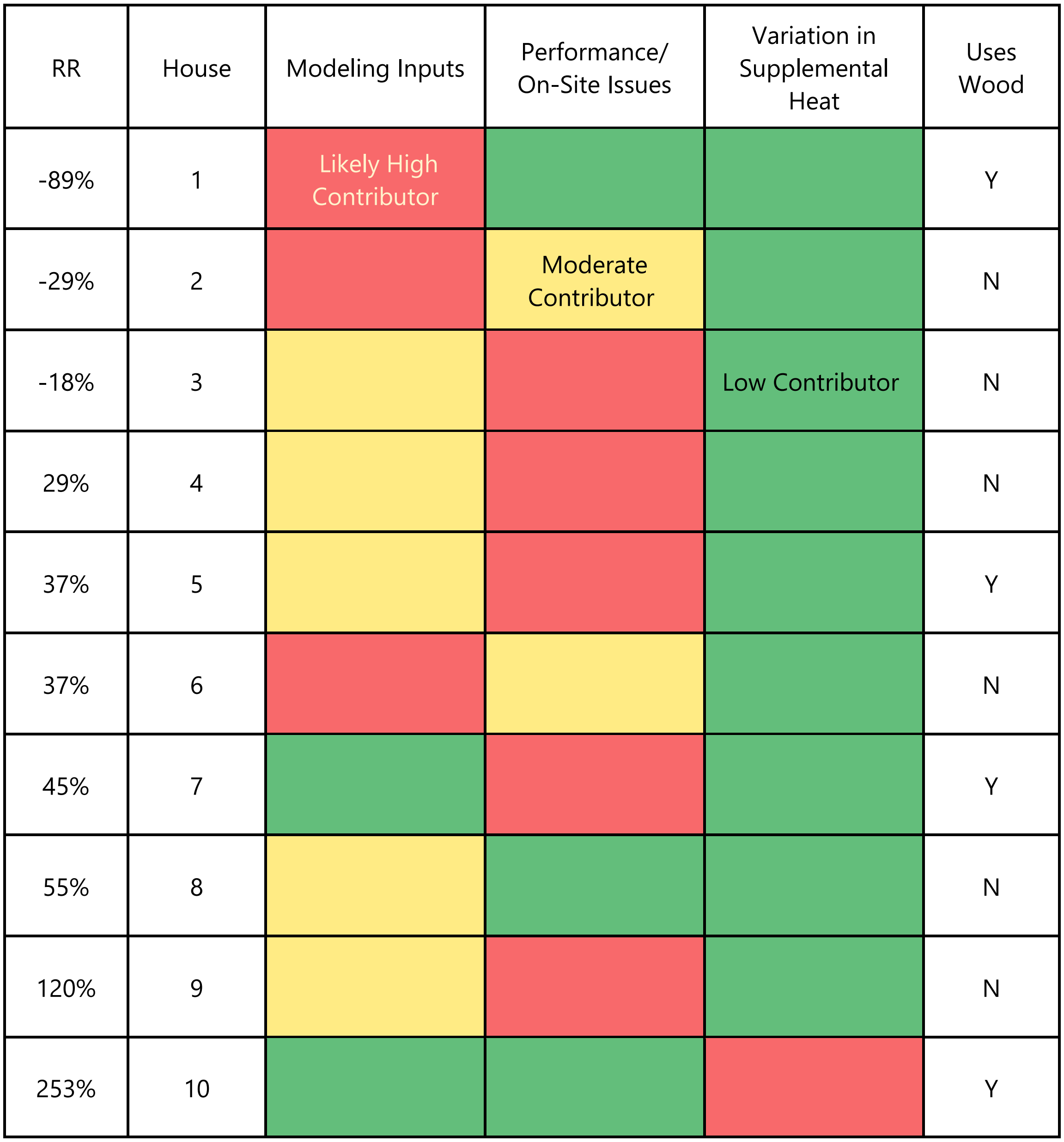


FIGURE 3-6: UNINSULATED HATCH

3.4 Synthesis of Results

The analysis by site gives an overall picture of the largest contributors to the realization rate. Figure 3-7 describes each category with red indicating a likely high contributor, yellow a moderate contributor and green a low contributor. The graphic indicates that the modeling inputs and performance/onsite issues were the largest contributors. Homes with wood heat did not show a consistent pattern of low RR's.



RR	House	Modeling Inputs	Performance/ On-Site Issues	Variation in Supplemental Heat	Uses Wood
-89%	1	🟥 Likely High Contributor	🟩	🟩	Y
-29%	2	🟥	🟨 Moderate Contributor	🟩	N
-18%	3	🟨	🟥	🟩 Low Contributor	N
29%	4	🟨	🟥	🟩	N
37%	5	🟨	🟥	🟩	Y
37%	6	🟥	🟨	🟩	N
45%	7	🟩	🟥	🟩	Y
55%	8	🟨	🟩	🟩	N
120%	9	🟨	🟥	🟩	N
253%	10	🟩	🟩	🟥	Y

Figure 3-7: Contributors to RR

As with other studies of this type, there are sources of uncertainty that could affect the results. The four main areas are the small sample size, the observational nature of the study, and the length of time between the installation and the post-installation inspection. These issues are summarized in Table 3-3.

TABLE 3-3: SOURCES OF UNCERTAINTY

Source of Uncertainty	Description	Actions Taken
Small sample size	Only 10 homes were visited; difficult to draw conclusions	None
Observational study	Possible measurement error; inspectors and contractors may see different things in the same home	Extensive documentation was done on data entry forms and through photos and infrared imaging. Documentation was reviewed by multiple researchers.
Long lag between installation and inspection	Pre-existing conditions are difficult to determine and additional changes may have been made in the interim	Post-HPwES changes were identified and noted. Participants were screened for major changes. Where possible, original layer of insulation was inspected and documented.

In addition, the synthesis of contributing factors to the RR is somewhat subjective, as it is difficult to assess the relative impacts of modeling inputs and performance issues on the RR.

4 Conclusions and Recommendations

This section presents a summary of contributors to the RR and recommendations for program improvement.

4.1 Summary of Contributors to the RR

Figure 4-1 summarizes the findings that contributed to the RRs. In general, errors in modeling inputs and performance issues seem to be the two largest contributors to the low RRs. These are issues that could be improved through additional contractor training and quality control efforts. The variation in supplemental heat is more likely to be random and create errors in both directions, i.e., resulting in both overstated and understated savings. In these ten homes, the single home with a clear and substantial change in supplemental heating use had an extremely high RR.

Of the ten homes visited, eight have an RR of less than 100%. As shown in Figure 4-1, modeling input errors could have a high impact in three homes and moderate impact in four homes. Four homes had potentially high impact performance issues and two had lesser performance issues. Only one of the ten homeowners reported a substantial change in supplemental heat use, which resulted in an RR substantially over 100%.

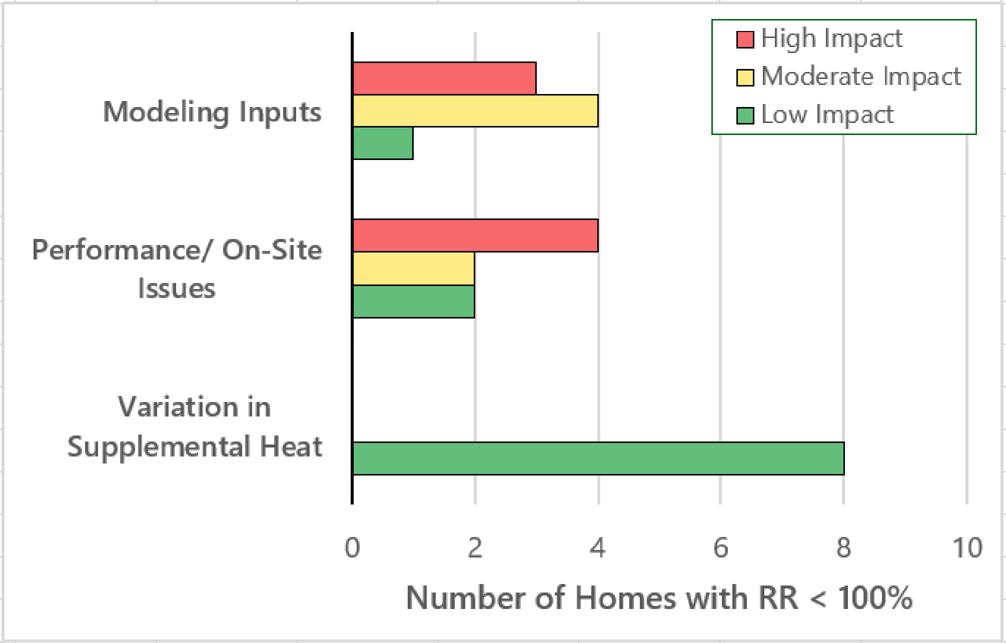


FIGURE 4-1: MODELING INPUTS FOR HOMES WITH RR LESS THAN 100 PERCENT

For one home, invoices were provided and indicated that there was a change in scope between contractor's estimate (used in the program reported savings) and the measures installed. As invoices were not included in the verification process, the prevalence of this issue is unknown. However, further investigation may be warranted.

4.2 Recommendation

Recommendation: Add QC activities to HPwES to verify contractor inputs into the modeling software and ensure that contractors are performing effective installations. QC should include the following items at a minimum:

1. On site pre- and post-install inspections for a sample of homes
2. Thermal imaging to identify performance issues
3. Review of invoices and changes in work scope
4. Follow up with contractors to explain QC results

QC results could be used to develop additional contractor training materials and curriculum.

Appendix A

VT HPwES Post-Installation Inspection: Data Collection Form

Quality Assurance Inspection Form

Project ID: **Date:**

Site Address:

Participant Name: **Inspector:**

Heating, Cooling, and Water Heating

Thermostats programmable ☐ y ☐ n

Weekdays	Start time	Heat temp	Cool temp
Period 1			
Period 2			
Period 3			
Period 4			

Weekends	Start time	Heat temp	Cool temp
Period 1			
Period 2			
Period 3			
Period 4			

Notes:

Heating System Fuel: Heating System Type: Distribution Type:

Heating System Manufacturer: Model #:

Efficiency Label: Year Installed:

Measured Steady State Efficiency:

Water Heater Fuel: Water Heater Type:

Water Heater Manufacturer: Model # Year Installed:

Notes:

Heating Ductwork

Duct location	%	Insulation Type	Depth	Coverage	Duct Sealing / Notes
Basement					
Crawlspace					
Conditioned Space					
Attic					

Supplemental Heating System

Heating System Fuel: Heating System Type: Distribution Type:

Heating System Manufacturer: Model #:

Efficiency Label: Year Installed:

Area of house heated:

How often is this used?

Notes:

Basement/Crawlspace Walls 1

Cavity Insulation Type: Depth: R-Value: Year Installed:
Continuous Insulation Type: Depth: R-Value: Year Installed:
Framing: x x Area:
Rim Joist Insulation Type: Depth:
Basement/crawl depth below grade:
Notes:

Basement/Crawlspace Ceiling 1

Cavity Insulation Type: Depth: R-Value: Year Installed:
Continuous Insulation Type: Depth: R-Value: Year Installed:
Framing: x x Area:
Notes:

Basement/Crawlspace Walls 2

Cavity Insulation Type: Depth: R-Value: Year Installed:
Continuous Insulation Type: Depth: R-Value: Year Installed:
Framing: x x Area:
Rim Joist Insulation Type: Depth:
Basement/crawl depth below grade:
Notes:

Basement/Crawlspace Ceiling 2

Cavity Insulation Type: Depth: R-Value: Year Installed:
Continuous Insulation Type: Depth: R-Value: Year Installed:
Framing: x x Area:
Notes:

Basement/Crawlspace Walls 3

Cavity Insulation Type: Depth: R-Value: Year Installed:
Continuous Insulation Type: Depth: R-Value: Year Installed:
Framing: x x Area:
Rim Joist Insulation Type: Depth:
Basement/crawl depth below grade:
Notes:

Basement/Crawlspace Ceiling 3

Cavity Insulation Type: Depth: R-Value: Year Installed:
Continuous Insulation Type: Depth: R-Value: Year Installed:
Framing: x x Area:
Notes:

Basement Air Sealing

Measure	Sealed	Not Sealed	Notes

Exterior Wall 1

Cavity Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Exterior Wall 2

Cavity Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Exterior Wall 3

Cavity Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Attic Slope 1

Cavity Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Attic Slope 2

Cavity Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Attic Slope 3

Cavity Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Windows / Doors

Notes:

Interior Air Sealing

Measure	Sealed	Not Sealed	Notes

Attic Flat 1

Layer 1 Insulation Type: Depth: R-Value: Year Installed:

Layer 2 Insulation Type: Depth: R-Value: Year Installed:

Layer 3 Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Attic Flat 2

Layer 1 Insulation Type: Depth: R-Value: Year Installed:

Layer 2 Insulation Type: Depth: R-Value: Year Installed:

Layer 3 Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Attic Flat 3

Layer 1 Insulation Type: Depth: R-Value: Year Installed:

Layer 2 Insulation Type: Depth: R-Value: Year Installed:

Layer 3 Insulation Type: Depth: R-Value: Year Installed:

Framing: x x Area:

Notes:

Attic Kneewalls

Location	Insulation Type	Depth	R-Value	Framing	Area	Year Installed
Kneewall						
Kneewall Floor						
Transition						
Kneewall Slope						
Kneewall Gable						

Notes:

Attic Air Sealing

Measure	Sealed	Not Sealed	Notes

Mechanical Ventilation Test

Type of ventilation system: Location:

Manufacturer & Model #: ☐ Bath Exhaust ☐ HRV / ERV

Measured CFM: System Speed Setting:

☐ Continuous ☐ Intermittent For intermittent systems, time setting:

Notes:

Blower Door Test

Verify safety conditions (no asbestos, vermiculite, major mold, fire in fireplace, etc): ☐ OK to test ☐ Not OK to test

Infiltration Volume: Basement Door Configuration:

Fan Model #: BD3 Fan Serial#: Gauge Model #: DG 700 Gauge Serial#:

Indoor Temp: Outdoor Temp: Elevation:

CFM50: Temp Adjusted CFM50: ACH50:

Notes:

Infrared Scan

Notes:

Duct Test - Leakage to Outside (for heating ducts outside the envelope)

Fan Model #: DBB Fan Serial#: Gauge Model #: DG 700 Gauge Serial#:

Measured CFM$_{25}$ to Outside:

Attachment Location: register; air handler Pressure Measurement Location: supply register; main supply trunk line; supply plenum

Notes:

Photo List

Basement

- ☐ Overall: all 4 corners
- ☐ Wall insulation
- ☐ Floor insulation
- ☐ Rim joist insulation
- ☐ Air sealing measures
- ☐ Unsealed openings
- ☐ Mechanical systems (10' away)
- ☐ Mechanical system model #'s
- ☐ Ductwork

Interior

- ☐ Windows
- ☐ Evidence of insulation
- ☐ Wall thickness at door jamb
- ☐ Mechanical systems
- ☐ Mechanical system model #'s

Exterior

- ☐ Overall: all 4 sides
- ☐ Evidence of insulation

Attic

- ☐ Overall: 2 directions
- ☐ Insulation depth
- ☐ Kneewall insulation
- ☐ Slope insulation
- ☐ Air sealing measures
- ☐ Unsealed openings
- ☐ Mechanical systems
- ☐ Mechanical system model #'s
- ☐ Ductwork

☐ Anything that does not match what was expected

Abbreviations

Fuels		Insulation		Rigid foam board	
NG	natural gas	CE	cellulose	EPS	expanded polystyrene
PRO	propane	FGB	fiberglass batt	XPS	extruded polystyrene
OIL	oil	LBF	loose blown fiberglass	ISO	polyisocyanurate
ELEC	electricity	VERM	vermiculite		
WOOD	cord wood	HDF	closed cell spray foam		
PELLET	wood pellet	LDF	open cell spray foam		

Customer Survey

1. Do you know what year the building was constructed? Are you certain or is this an estimate?

2. Do you recall the Home Performance with Energy Star contractor working on your home?

3. Review list of measures completed. Can you confirm that these measures were installed?

Measure	Notes

4. Are you satisfied with the work that was performed?

5. Did you save money on your energy bills due to the work performed?

6. How many people were living here at the time of the work? How many are living here now? When did this change?

7. Have there been any significant changes to the house or heating systems since then? When did this change?

8. Have you changed how you set your thermostats since then? When did this change?

9. How would you describe the comfort of your home **before** the insulation work was completed?

10. How would you describe the comfort of your home **after** the insulation work was completed?

11. Which month do you usually turn your primary heating system on and off each year?

12. Do you ordinarily leave the property for vacation or for a season of the year? If so, when and for how long?

13. How often do you use your supplemental heating system(s) (wood stove, heat pump, electric heater, etc)?

Authorization and Incentive Form

This is a required form. If the site visit was not completed, an incentive may not be paid out.

For the Evaluator:

Project ID	
Date of visit	
Name of inspector	
Customer name	
Customer address	

☐ Site visit is complete – ok to payout incentive

☐ Site visit was not completed – no incentive paid out

If not complete, please give reason: ____

Example: on-site participant was not available

For the Participant:

Site Visit Approval

I authorize the Center for EcoTechnology field team to complete a site visit at my home. This visit will include taking building measurements, inspecting the heating system(s), inspecting the walls and attic, and taking photos of equipment, insulation, and air sealing.

On-Site Participant Name (print): ____

On-Site Participant Signature: ____ Date: _________________

Appendix B

VT HPwES Post-Installation Inspection:

Summary of Modeling Inputs

TABLE 1: SUMMARY OF MODELING INPUT IMPACTS BY HOME

RR	House	Possible Overstatement	Possible Understatement	Comments
-89%	1	High impact: Basement insulation Low impact: Blower door test	Low impact: Heating system efficiency	Modeling inputs alone unlikely to explain the RR.
-29%	2	High: Basement insulation		Modeling inputs alone unlikely to explain the RR.
-18%	3	Medium: heating system efficiency Low: Attic insulation	Low: supplemental heat	Modeling inputs alone unlikely to explain the RR.
29%	4	High: Attic insulation Low: Blower door test	Medium: basement insulation	Overstatements could be major contributor to the RR.
37%	5	High: Basement insulation Medium: Blower door test Low: heating system efficiency	Low: supplemental heat	Overstatements could be major contribution to RR.
37%	6	High: Basement insulation Medium: heating system efficiency		Overstatements could partially explain the RR.
45%	7		High: blower door test Medium: heating system efficiency	Modeling inputs alone do not explain the RR.
55%	8	High: Attic insulation, heating system efficiency		Overstatements could be major contribution to RR.
120%	9	Low: heating system efficiency	High: attic insulation Medium: basement insulation	Understatements are likely to outweigh overstatements.
253%	10	High: Basement insulation Medium: attic insulation	High: supplemental heat	Homeowner switched to almost entirely heating with wood; explains high RR