



WEST HILL ENERGY AND COMPUTING

# Impact Evaluation of Vermont Gas System's Residential Retrofit Program

## Program Year 2014-2016

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## 1 Introduction

This report covers the impact evaluation conducted for Vermont Gas Systems's (VGS) Residential Retrofit program for projects completed between 2014 and 2016. The object of this impact evaluation was to determine the evaluated gross natural gas savings for the Residential Retrofit program. This is the second evaluation of the program, following one completed in 2012.

Billing analysis was the method used to estimate the program savings. A fixed effects, cross-sectional, time series model was conducted to estimate the normalized annual savings. No sampling was done as all projects with sufficient data were included in the analysis.

This report covers the data sources used for the analysis, the data cleaning and attrition process and the methods used for the billing analysis. The final section presents the results includes a comparison to other similar program evaluation results.

## 2 Program Description

The Residential Retrofit program provides incentives for weatherization measures installed in both single and multifamily homes to reduce natural gas usage. The majority of measures installed are insulation and air sealing, and were installed in almost all participating homes. Other measures installed include heating system replacement, domestic hot water (DHW) equipment replacement, windows, doors, and duct sealing. The program offers an incentive of one-third of the project cost for eligible retrofits to homeowners who pay the gas bill directly, with higher incentives (half of project costs) available for owners of rental properties where the tenant pays the gas bill. Vermont Gas also supports a loan offering to allow participants to finance the remaining project cost at a reduced interest rate. To participate in the Residential Retrofit program, homeowners must be Vermont Gas customers and must meet a minimum energy usage threshold (at least 50,000 BTUs per square foot per year). This requirement may be waived at VGS' discretion.

Vermont Gas markets the Residential Retrofit program to both existing and potential natural gas customers. Vermont Gas staff review the energy consumption of the customer's building for eligibility and conduct energy audits for eligible participants at no cost. Residential Retrofit program energy audits include a comprehensive review of the building shell and heating equipment, including a blower door test and infrared imaging, and gather inputs to model an energy profile of the home, which the auditor uses to recommend cost-effective efficiency improvements. The auditor generates a report that includes the recommended measures' energy savings<sup>1</sup>, estimated measure installation costs, financing and incentive options, overview of historical usage and an overview of the buildings performance. Auditors follow-up with the home owner to answer any questions and provide any support needed after the audit.

Vermont Gas maintains a list of FastTrack contractors that provide standard pricing for insulation and air sealing services. Using this standard pricing, auditors can provide the building owners with accurate cost estimates for the recommended upgrades. If the home

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<sup>1</sup> Audit reports that contain projected savings are adjusted to reflect results of the most recent evaluation of the program. This is to ensure the customer is able to make an informed decision regarding the benefits to the costs.

owner chooses to make upgrades using a FastTrack contractor, the auditor will select a contractor from the list that is best suited to the project's needs. Home owners also have the option of selecting a contractor on their own or installing the recommended measures themselves. VGS conducts quality assurance inspections of completed projects. In addition, it is common for VGS auditors to be present during measure installation, providing an opportunity to give informal feedback to contractors.

The program reported savings for PY2014-PY2016 are summarized in Table 1.

**TABLE 1: PROGRAM REPORTED SAVINGS BY YEAR**

<b>Year</b>	<b>Total Annual CCF Savings</b>	<b>Number of Projects</b>
2014	23,221	115
2015	31,064	156
2016	32,109	155
Total	86,395	426

## 3 Methods

This section includes an overview of the methods and data sources, followed by a description of the data cleaning and attrition.

### 3.1 Overview of the Methods and Data Sources

Billing analysis was the primary method of verifying the natural gas savings. Billing data was provided by Vermont Gas. Both a house-by-house regression and a fixed effects regression model were used in the analysis. Three data sources were used for the analysis: program data, billing data, and weather data, as explained in Table 2.

**TABLE 2: DATA SOURCES**

Source	Description	Purpose
Program (VGS)	Measures installed and program reported savings for each project	Define pre/post period for each home and the installed measures
Billing (VGS)	Monthly billing records for participating homes	Connect to program data to estimate savings
Weather (NOAA <sup>1</sup> )	Hourly temperature data for Burlington and Franklin County	Calculate the heating degree days for each billing cycle and the annual normalized heating degree days

<sup>1</sup>National Oceanographic and Atmospheric Administration

Model details are provided in Appendix A.

### 3.2 Data Cleaning and Attrition

The billing records received from VGS were reviewed and participants were removed from the billing model through a two step process:

1. Initial review of the billing and program data to identify homes with insufficient billing records in the pre- or post-periods
2. Secondary review using a house-by-house regression to assess homes with erratic or unusual usage patterns

The criteria for removal are described in Table 3 and additional details of the initial and secondary reviews are provided in the following sections.

TABLE 3: DESCRIPTION OF ATTRITION CATEGORIES

Step	Attrition Category	Description
1 Initial Review	Not Enough Data	The data provided for the household had less than 80% of the normalized annual HDD at 60 °F.
	Multifamily Homes	Homes with more than 4 units were removed as there were relatively few in the model
2 Detailed Review	Unusual Consumption Patterns	Homes with erratic consumption patterns or heating use that is outside the normal range of residential use
	Multiple Premises	These are projects with multiple premises where one of the premises was removed due to a data problem, the remaining premises were removed.

### 3.2.1 Initial Review

Before the start of the attrition process the billing data was reviewed and a cleaned. The data cleaning included identifying billing periods with overlapping dates and combining the corrected reads. The data was also checked for short billing periods with less than 20 days, which were combined with the shorter of the two adjacent billing periods.

The first stage of attrition was to check for sufficient billing data, particularly in the heating season, for an accurate analysis. The final criteria use for this was each home included in the analysis must have at least 80% of the total heating degree days in the year in both the pre and post-installation period. Homes were also checked for less than 6 reads in the pre or post-installation period, however there were no homes removed due to this criteria.

Multifamily homes with more than 4 units were also identified based on the program data collected and removed from the analysis. They were removed as there were only a few of these buildings included in the analysis.

### 3.2.2 Secondary Review

The house-by house regression was conducted using the heating degree days (HDD) and MMBtu consumption for each home with and without an intercept to capture non-heating usage. The regression results were reviewed and homes were dropped for the following reasons:

1. Heating slope was negative
2. R<sup>2</sup> less than 0.65
3. Consumption levels outside of a normal range of residential heating use

Premises with multiple meter premises associated with one program project were left in the model. This situation could occur when a 2 to 4 unit building is individually metered but the home was treated as a single project; the savings for the project were divided among the premises, and if any one premise had a data issue as described in Table 3 above, all premises were removed from the model.

A summary of the attrition is included in table below. Of the 478 participants with billing data provided, 59% were included in the final model.

**TABLE 4: ATTRITION SUMMARY**

<b>Reason for Removal</b>	<b>Number of Participants</b>	<b>Number Removed</b>	<b>% of Total Billing Records Remaining</b>
Total Billing Records Received	478	-	100%
Not Enough Data	417	61	87%
Multifamily Homes	366	51	77%
Unusual Consumption Patterns	320	46	67%
Multiple Premises	282	38	59%
Accounts in final model	282	-	59%

### 3.3 Billing Model

A fixed effects, cross-sectional, time series model was used to estimate the program savings. The fixed effects model addresses the energy-related characteristics of the home that do not change over time, such as the size of the home and the presence of natural gas appliances.

The regression model included weather and efficiency installations through the program as predictor (independent) variables. The response (dependent) variable was the monthly energy consumption, and the regression coefficients for program variables were used to estimate the program savings. Additional details and the model equation are provided in Appendix A. The final version of the regressions were calculated using the 60°F base HDD for all homes, as a review of the household level regression results indicated that the 60°F base HDD provided more reliable results for the majority of homes.

The final pooled model used site-specific intercepts and heating slopes and had separate variables for DHW measures and heating related measures. Only the heating measures were verified due to the small (21) number of homes with DHW related measures installed in the homes in the model. The savings from heating-related measures were bundled together as multiple heating-related measures were commonly installed at the same home, which introduces collinearity into the model and affects the ability to estimate savings for the individual measures.

Regression output and diagnostic test results are included in Appendix A.

## 4 Results

This section covers the results of the analysis and potential sources of uncertainty.

### 4.1 Analysis Results

The final results of the analysis are shown in the table below. The results are by gas meter premise, and thus will be slightly lower than the savings per project or building as a number of the projects in the analysis have multiple premises. The realization rate is 85% +/- 10% at the 90% confidence level.

**TABLE 5: BILLING ANALYSIS RESULTS**

<b>Variable</b>	<b>Results</b>
Number of Premises	282
Mean Program Reported Savings (MMBtu) by Premise	19.2
Mean Evaluated Savings (MMBtu) by Premise	16.4
Realization Rate	85.2%
Realization Rate 90% Confidence Interval	+/- 9.6%
Relative Precision at 90% <sup>1</sup>	11%
Mean Evaluated Pre Installation Period Use (MMBtu)	101.6
Program Reported Savings Percent of Pre Use	19%
Evaluated Savings Percent of Pre Use	16%

<sup>1</sup> Relative precision is the error bound divided by the realization rate.

The results are applied to the savings claimed by the entire program for project years 2014 to 2016 in Table 6. As the DHW measures are only 2% of the total program reported savings, the realization rate for the heating measures was applied to the savings for the entire program.

**TABLE 6: PROGRAM RESULTS SUMMARY**

<b>Units</b>	<b>Program Reported Savings</b>	<b>Realization Rate</b>	<b>Evaluated Savings</b>
ccf	86,395	85.2%	73,609
MMBtu	8,959		7,633



## 4.2 Sources of Uncertainty

There are two primary sources of uncertainty in the savings calculation.

- Occupancy changes during the analysis period
- Variable balance points from home to home
- Exogenous (nonprogram) effects on energy use

These sources of uncertainty are discussed in more detail below.

### 4.2.1 Occupancy Changes during the Analysis Period

Many homes in the VGS program had turn over of occupants during the analysis period. Premises where a change in accounts indicated a change in occupancy were left in the final model.

These changes in occupancy are nonprogram effects that could introduce bias in the model if the change in occupancy consistently results in higher or lower use during the post-installation period; however, there is no evidence to suggest a systematic impact on the result as changes in energy use are expected to be randomly distributed. Consequently, we would not expect the inclusion of these homes to introduce bias to the results.

### 4.2.2 Variable Balance Points

The balance point of a home is the outside temperature at which the heating system turns on. Thermostat settings and internal gains are contributing factors and the balance point often varies between homes. A pooled billing analysis, however, treats all homes as if they have the same balance point.

The house-by-house regression was run for each project using a HDD base of 60°F and 65°F. The regressions were compared and about three quarters of the homes had a higher R<sup>2</sup> with the base 60°F HDD. As the base 60°F HDD produced a better fit for most homes, it was used in the final model. A sensitivity analysis was performed by running the regression model with a base of 65°F. This adjustment decreased the realization rate by 2.7%, a small impact on the results.

### 4.2.3 Exogenous Effects

Energy use may be affected by widespread economic changes or other factors that are outside of the program activities. In a two-stage model, a comparison group is sometimes used to account for exogenous effects; however, a comparison group may introduce additional uncertainty in the model as it includes naturally-occurring efficiency and the end result cannot be clearly interpreted as either gross or net savings.<sup>2</sup>

In the pooled model used for this analysis, time-specific parameters are explicitly included to capture nonprogram changes in use over time. As our analysis covers multiple program years, later participants perform the function of a comparison group without introducing net effects.<sup>3</sup>

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<sup>2</sup> Randazzo, 2017

<sup>3</sup> Agnew, 2017, page 27

## 5 Conclusions

The realization rate of 85% shows that heating-related savings are being slightly overstated, which is an excellent result compared to other, similar programs. As a percent of pre-installation use, the evaluated savings are within the range of savings seen across similar programs in the Northeast, as shown in Table 7.

**TABLE 7: COMPARISON OF SIMILAR IMPACT EVALUATIONS<sup>5</sup>**

<b>Program</b>	<b>State</b>	<b>Program Year of Impact Evaluation</b>	<b>Average Pre Install Use (MMBtu/yr)</b>	<b>Program Reported Savings (% of Pre Install Use)</b>	<b>Evaluated Savings (% of Pre Install Use)</b>	<b>Overall Realization Rate</b>
<b>VGS RR<sup>1</sup></b>	<b>VT</b>	<b>2014-2016</b>	<b>101.6</b>	<b>19%</b>	<b>16%</b>	<b>85%</b>
HPwES <sup>2</sup>	VT	2014-2016	92.0	25%	16%	65%
HPwES	VT	2008-2010	91.5	35%	18%	51%
HPwES <sup>2</sup>	NY	2007-2008	105.5	25%	16%	65%
HES <sup>3</sup>	MA	2010-2011	119.5	15%	12%	76%
HPwES <sup>4</sup>	NY	2011-2013	104.0	45%	27%	60%
VGS RMR <sup>5</sup>	VT	2008-2010	125.5	26%	22%	89%
VGS/CVOEO <sup>6</sup>	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%

<sup>1</sup> This impact evaluation of the VGS Residential Retrofit program, shown for comparison purposes.

<sup>2</sup> This evaluation is in the process of being finalized and published.

<sup>3</sup> 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.

<sup>4</sup> Includes only insulation and air sealing measures

<sup>5</sup> 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

<sup>6</sup> This program is specifically targeted to high use "residential customers that consume in excess of 50,000 BTUs per square foot per year," suggesting that these homes have a higher potential for savings than many others. Another significant feature of the VGS RMR program is that savings estimates are routinely checked against consumption to insure that they are reasonable. Bartsch, Danaher, 2014. The Shell Game: Finding Thermal Savings in Residential Retrofit Programs, p.6 and 8.

<sup>7</sup> This program is managed by the Champlain Valley Office of Economic Opportunity with part of the incentives contributed by VGS.

<sup>8</sup> 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.

This comparison shows that VGS's RR is slightly lower than found in the previous evaluation for program years 2008 to 2010 (85% as compared to 89%). However the annual average heating consumption of the homes in the model is about 20% lower in the current evaluation (102 MMBtu as compared to 126 MMBtu in the previous evaluation). As VGS has been offering efficiency programs for over twenty years and previous programs targeted high use homes, it is likely that many of the least efficient homes were previously weatherized and the remaining housing stock has lower consumption and fewer opportunities for energy efficiency improvements

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