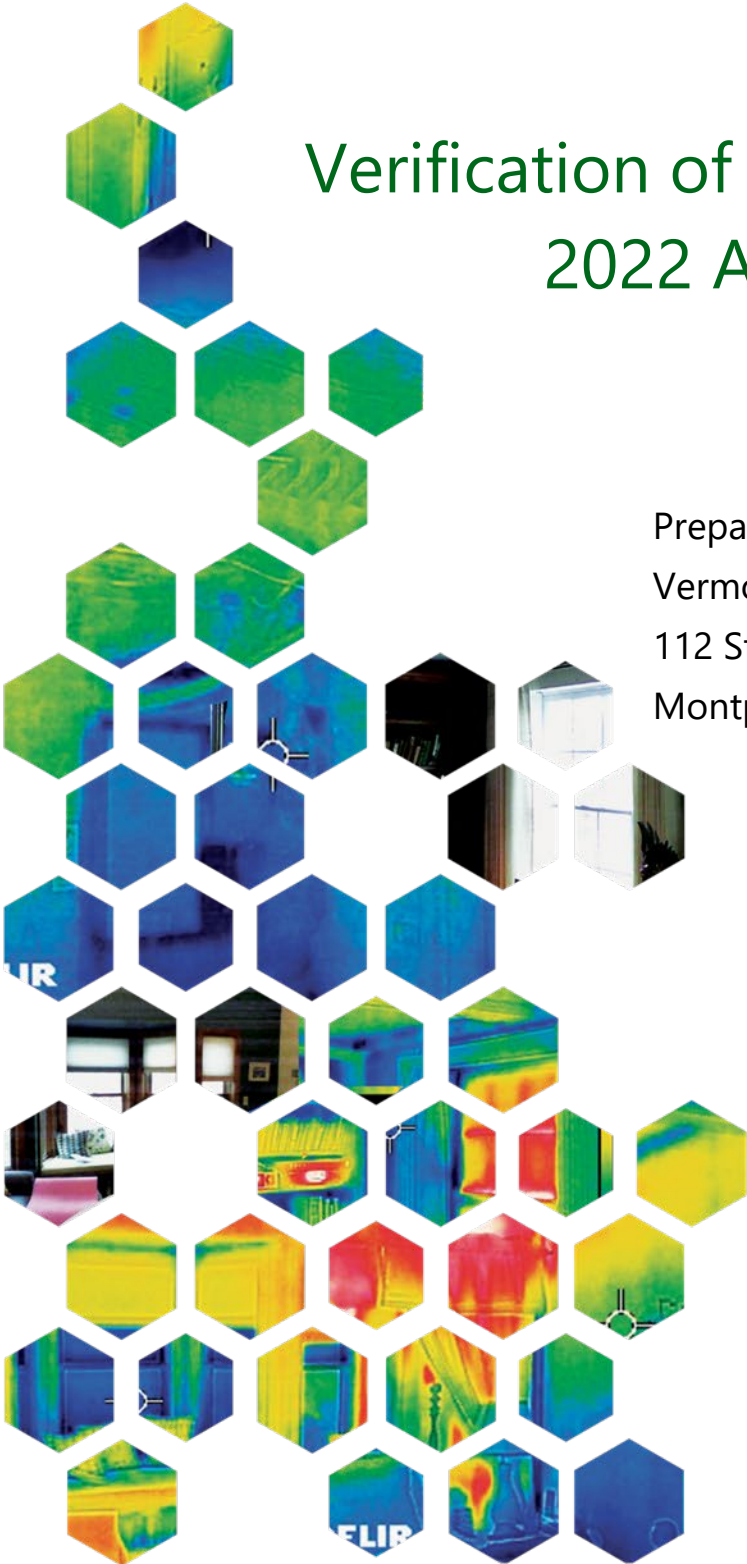# WHEC

Verification of Vermont Gas Systems 2022 Annual Savings

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Final Report

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ES Executive Summary

This report covers savings verification for Vermont Gas Systems (VGS) energy efficiency programs for program year (PY) 2022. The 3-year verification cycle covers PY2021 through PY2023. The Vermont Department of Public Service (PSD) contracted with West Hill Energy and Computing (West Hill Energy) to provide independent verification of VGS's energy efficiency portfolio. The West Hill Energy Team, consisting of West Hill Energy and Cx Associates, implemented this evaluation, which covers VGS's residential and commercial energy efficiency programs.

The primary objective of this evaluation was to estimate the program and portfolio annual and peak day Mcf realization rates (RRs) associated with VGS reported savings. The West Hill Energy Team also reviewed VGS's progress in meeting the quantifiable performance indicators (QPIs) established by the Vermont Public Utilities Commission (PUC) and provided recommendations to address ongoing issues with project documentation and analyses in order to streamline verification efforts.

ES.1 Methods

This evaluation verified the annual incremental Mcf saving, peak day savings, and lifetime natural gas savings for PY2022. The West Hill Energy Team also determined VGS's progress toward several QPIs, as described in the Vermont PUC order.

The main savings verification method was to conduct engineering desk reviews for a sample of sites. Where applicable, a billing analysis was conducted to estimate actual savings or to inform the results of the desk review. Sample sizes were designed to meet 80/10 confidence and precision for the gross annual Mcf savings at the program level. Error ratios were informed by prior PY2020 and PY2021 savings verification results. Table ES-1 provides a summary of the sampling and evaluation approach by program.

TABLE ES-1: SUMMARY OF VGS PY2022 SAMPLING AND EVALUATION APPROACH

Program	Sampling Approach	Evaluation Approach
Commercial and Industrial (C&I) Programs	Stratified random sample by unique site to capture interactive effects	Engineering desk review and billing analysis for select projects, where appropriate.
Residential Multifamily Programs	Stratified projects by project size	
Residential Equipment Replacement (RER) Single Family	Stratified random sample	The West Hill Energy Team conducted sampling and the PSD and West Hill Energy conducted desk reviews for this program.
Residential Single-Family Retrofit	Census	RRs from the previous impact evaluation were applied.[1]
Residential Single Family New Construction	Census	RR for the RNC program from EVT's 2022 Annual Savings Verification was applied.[2]

[1] Impact Evaluation of Vermont Gas System's Residential Retrofit Program. Prepared by West Hill Energy and Computing. September 2018. Page 7.
[2] Report to Verify Efficiency Vermont 2022 Savings Claim. Prepared by Cadmus Group. June 2023. Page 19.

The West Hill Energy Team completed desk reviews for each project in the sample. The steps in evaluating each project across all programs were similar and included multiple steps of initial project file review, data requests, analysis, and review. The evaluation process is shown in Figure ES-1.
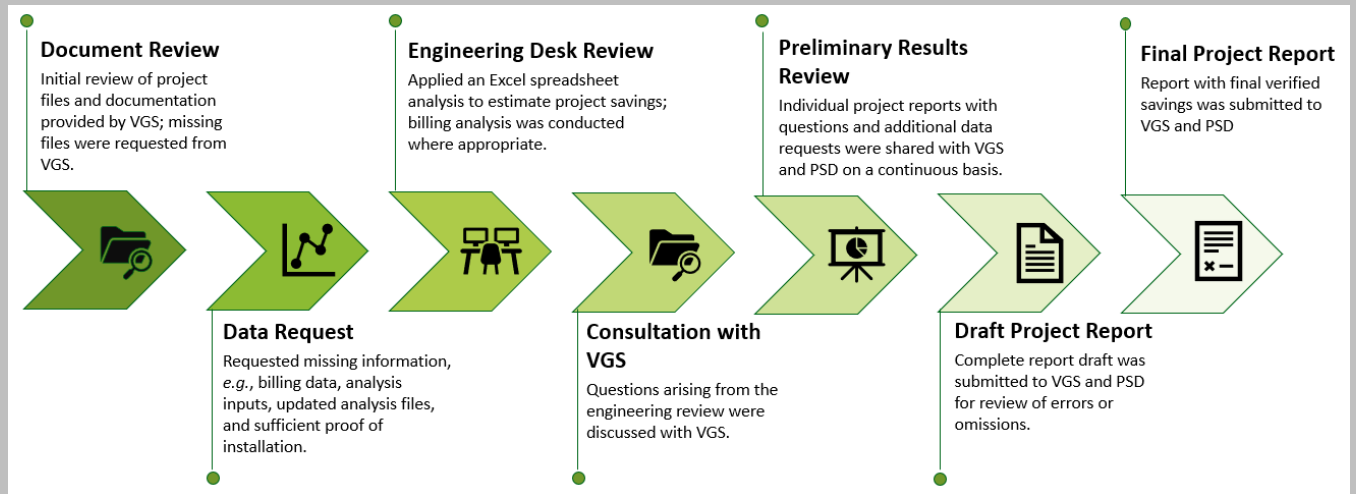
FIGURE ES-1: EVALUATION DESK REVIEW APPROACH

The West Hill Energy Team was in regular communication with VGS and the Vermont PSD staff to ensure verified savings were based on a complete understanding of what happened with each project.

ES.2 Results

The West Hill Energy Team developed verified savings estimates for each project in the sample. The ratio of these verified results to the program reported savings is the RR, which was then applied to the total population to determine the 2022 verified savings. For the residential single family Residential Retrofit (RIR) and Residential New Construction (RNC) programs, the RR from other studies were applied, as specified in Figure ES-1.

ES.2.1 Annual Mcf Savings

The RRs and relative precision for VGS's annual Mcf savings are provided in Table ES-2. The portfolio RR is 94% with a relative precision of 2.0% at the 80% confidence level.

TABLE ES-2: SUMMARY OF PROGRAM REPORTED AND VERIFIED PY2022 ANNUAL MCF SAVINGS

Program	Total Sites	Sampled Sites	Reported Annual Savings (Mcf)	PSD Verified Annual Savings (Mcf)	Realization Rate	Relative Precision
Commercial Sector						
Equipment Replacement	31	2	5,172	2,792	54%	0.9%
New Construction	13	4	3,837	2,645	69%	18.9%
Retrofit	19	6	27,368	30,344	111%	1.8%
Total Commercial Sector	63	12	36,377	35,781	98%	2.4%
Residential Sector						
Equipment Replacement	1,361	21	12,203	10,902	89%	6.0%
New Construction	30	4	4,682	3,494	75%	5.7%
Retrofit	500	5	6,534	6,185	95%	4.8%
Total Residential Sector	1,891	30	23,419	20,581	88%	3.6%
Portfolio Total	1,954	42	59,795	56,362	94%	2.0%

The most common reasons for differences in realized savings are listed below.

- **Incorrect inputs –** Errors included efficiencies, annual hours, boiler capacity, pipe length, and heat loss. Several measures used a lifetime that did not match the Vermont Technical Reference Manual (TRM) defaults.

- **Baseline usage -** Baseline usage was overestimated in several analyses; billing data was used to verify the baseline consumption where possible.

- **Mismatch to billing data –** Several projects had lower heating loads than the TRM assumptions when compared to billing data and one retrofit site showed almost no reduction in usage compared to the reported measures although the exact reason for the difference is unknown.

- **Energy Code baseline errors –**VGS did not consistently apply the correct energy code baseline for energy recovery ventilation (ERV) measures. VGS also applied the Commercial Building Energy Standards (CBES) 2015 energy code rather than the CBES 2020 baseline for air sealing.

- **Conversion and unit errors –** Other unit errors included incorrectly converting from CFM75 to CFM50 and from ccf to therm.

- **Measure not installed –** One measure was included in VGS's program reported savings but the measure was not installed.

Some errors, such as using a custom tool with equipment specifications from a previous project, could have been identified with additional quality control.

ES.2.2 Peak Day Mcf Savings

The RRs and relative precision for VGS's peak day Mcf savings are provided in Table ES-3. The portfolio RR is 88% with a relative precision of 2.5% at the 80% confidence level.

TABLE ES-3: SUMMARY OF PROGRAM REPORTED AND VERIFIED PY2022 PEAK DAY MCF SAVINGS

Program	Total Sites	Sampled Sites	Reported Peak Day Savings (Mcf)	PSD Verified Peak Day Savings (Mcf)	Realization Rate	Relative Precision
Commercial Sector						
Equipment Replacement	31	2	53.3	27.4	51%	1.7%
New Construction	13	4	38.5	26.2	68%	23.9%
Retrofit	19	6	84.5	100.9	119%	0.6%
Total Commercial Sector	63	12	176.2	154.4	88%	5.3%
Residential Sector						
Equipment Replacement	1,361	21	93.9	90.6	97%	1.2%
New Construction	30	4	54.1	38.3	71%	6.8%
Retrofit	500	5	89.1	78.8	89%	1.8%
Total Residential Sector	1,891	30	237.0	207.8	88%	1.8%
Portfolio Total	1,954	42	413.2	362.2	88%	2.5%

The peak savings are based on the verified annual Mcf multiplied by the peak day factor for each measure depending on the end use. Therefore, findings that affect annual Mcf savings also proportionally affect peak day Mcf savings. There were also some commercial and residential measures where the peak savings factor was adjusted to match the measure end use. For example, VGS applied the heating system peak savings factor for a boiler that served domestic hot water (DHW) loads rather than the DHW peak savings factor.

ES.2.3 Lifetime Mcf Savings

The RRs and relative precision for VGS's lifetime Mcf savings are provided in Table ES-3. The portfolio RR is 87% with a relative precision of 2.8% at the 80% confidence level.

TABLE ES-4: SUMMARY OF PROGRAM REPORTED AND VERIFIED PY2022 LIFETIME MCF SAVINGS

Program	Total Sites	Sampled Sites	Reported Lifetime Savings (Mcf)	PSD Verified Lifetime Savings (Mcf)	Realization Rate	Relative Precision
Commercial Sector						
Equipment Replacement	31	2	94,388	45,055	48%	7.1%
New Construction	13	4	70,437	44,986	64%	25.5%
Retrofit	19	6	387,557	395,633	102%	1.9%
Total Commercial Sector	63	12	552,381	485,674	88%	3.7%
Residential Sector						
Equipment Replacement	1,361	21	227,940	210,207	92%	5.2%
New Construction	30	4	107,947	74,875	69%	15.0%
Retrofit	500	5	153,689	138,169	90%	0.4%
Total Residential Sector	1,891	30	489,576	423,251	86%	4.1%
Portfolio Total	1,954	42	1,041,958	908,924	87%	2.8%

To determine lifetime savings, the West Hill Energy Team multiplied the verified annual Mcf savings by the lifetime for each measure; therefore, findings that affect annual Mcf savings also affect the lifetime Mcf savings. The variation in lifetimes across measure type results in some differences in the final RR. In addition, for several commercial and residential measures, VGS used a lifetime that did not match the Vermont TRM defaults for the measure. These were adjusted to match the TRM, which resulted in lower lifetime savings as the values used by VGS were higher than the TRM value.

ES.3 Recommendations

The West Hill Energy Team offers the following recommendations to improve future VGS programs RRs and streamline future verification processes. Addressing ongoing issues will reduce the amount of time spent on each project review and provide transparency into VGS calculations and assumptions.

TABLE ES-5: SUMMARY OF PROGRAM RECOMMENDATIONS

Recommendation	Description
Improve Project-level Documentation*	Provide more detailed description of the project, identify permit data and applicable code where appropriate, list sources of all inputs, and include invoices.
Review Heat Load Estimation	Check heat loads calculated using engineering calculations to billing data whenever possible. VGS and the PSD should work together to improve estimation of the heat load for the RER program.
Establish Criteria for Selecting Methods, Inputs and/or Use of the TRM*	Establish written criteria for using the VGS TRM, the Vermont TRM, site-specific inputs and/or custom approaches or alternative TRM approaches, and establish protocols for clear documentation in the project files.
Update Normalization to Use Average Weather Values Rather than Typical Meteorological Year (TMY)3*	PY2022 verification used TMY3 weather as it was the basis for developing VGS's goals. West Hill Energy recommends updating weather normalization to the 6-to-10-year average for future uses to better reflect the impacts of global climate change.
Improve Internal Savings Calculation Quality Control (QC)*	Improve internal QC processes to include a comprehensive review of project documentation, savings calculations, application of the correct peak savings factor, and comparison to consumption records (if appropriate).
Timing of Project Completion	Finalize project reported savings and complete the project after the equipment or systems are tested and operational to ensure full savings are being achieved.

*These recommendations were also made in whole or in part in the PY2020 savings verification report prepared by NMR and/or the PY2021 savings verification report prepared by the West Hill Energy Team.

1   Introduction

This report documents the savings verification of VGS's energy efficiency programs during PY2022. Vermont PSD contracted with West Hill Energy to provide independent verification of VGS's energy efficiency portfolio. The West Hill Energy Team, consisting of West Hill Energy and Cx Associates, conducted the evaluation. The evaluation included the following VGS programs:

- Commercial Equipment Replacement (CER)
- Commercial Retrofit (CSR)
- Commercial New Construction (CNC)
- Residential Equipment Replacement (RER)
- Residential New Construction (RNC)
- Residential Retrofit (RIR)

VGS offers incentives for a variety of measures including space heating (boilers, furnaces), heating systems controls, hot water replacement, building shell improvements, pipe insulation, cooking equipment, faucet, and shower aerators.

The primary goal of this evaluation was to verify the Mcf annual and peak day savings for PY2022. The West Hill Energy Team also determined VGS's progress toward several QPIs as described in the Vermont PUC order of October 22, 2020. The West Hill Energy Team provides recommendations to address ongoing issues with project documentation and analyses in order to streamline future verification efforts.

The following sections provide details on VGS PY2022 program activity and previous evaluation history.

1.1   Program Activity

The West Hill Energy Team reviewed VGS PY2022 program tracking database to determine program and sector level savings. Table 1-1 provides a summary of the overall portfolio savings at the program level as reported by VGS. As shown in Table 1-1, about 63% of the portfolio annual Mcf savings are from the commercial and industrial (C&I) programs.

TABLE 1-1: SUMMARY OF PROGRAM REPORTED PY2022 SAVINGS

Program	Number of Projects	Reported Annual Savings (Mcf)	Reported Peak Day Savings (Mcf)
Commercial Sector			
Equipment Replacement (CER)	31	5,172	53.3
New Construction (CNC)	13	3,837	38.5
Retrofit (CSR)	19	27,055	84.5
Total Commercial Sector	63	36,064	176.2
Residential Sector			
Equipment Replacement (RER)	1,361	12,203	93.9
New Construction (RNC)	30	4,682	54.1
Retrofit (RIR)	500	6,534	89.1
Total Residential Sector	1,891	23,419	237.0

1.2   Evaluation History

The PSD has conducted annual savings verification for VGS for the past several years. From PY2018 through PY2020, the NMR Group was the evaluator. The West Hill Energy Team was contracted to conduct savings verification for PY2021 through PY2023. This report is the second savings verification report for the 3-year cycle.

VGS operates the single family RNC in conjunction with Efficiency Vermont (EVT). The PSD has conducted annual savings verification for EVT from its inception in 2000. Cadmus conducted the most recent verification cycle.[1]

The PSD also oversaw impact evaluations of the components of VGS's residential portfolio for PY2014 to 2016. [2]

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[1] Report to Verify Efficiency Vermont 2022 Savings Claim. Prepared by Cadmus Group. June 2023.
[2] Impact Evaluation of Vermont Gas System's Residential Retrofit Program. Prepared by West Hill Energy and Computing. September 2018.

2   Methods

The primary goal of this evaluation was to estimate annual Mcf and peak day natural gas savings for PY2022. The main verification method was to conduct desk reviews on a sample of sites. Where applicable, a billing analysis was conducted to estimate actual savings or to inform the results of the desk review. Table 2-1 provides a summary of the evaluation approach by program.

TABLE 2-1: SUMMARY OF VGS PY2022 EVALUATION APPROACH BY PROGRAM

Program	Evaluation Approach
Commercial & Industrial Programs	Engineering desk review and billing analysis for select projects, where appropriate.
Residential Multifamily Programs (MER, MNC, MIR/MLI)	
RER Single Family	The West Hill Energy Team conducted sampling and the PSD and West Hill Energy conducted desk reviews for this program.
RIR Single Family	VGS applied RR from the previous impact evaluation was applied.[1]
RNC Single Family	The RR for the RNC program from the EVT's 2022 Annual Savings Verification was applied.[2]

[1] Impact Evaluation of Vermont Gas System's Residential Retrofit Program, page 7. Prepared by West Hill Energy and Computing. September 2018.
[2] Report to Verify Efficiency Vermont 2022 Savings Claim. Prepared by Cadmus Group. June 2023. Page 19.

The following sections describe the sampling and analysis.

2.1   Sampling

VGS programs were divided into three groups of programs for sampling purposes: C&I, residential MF, which includes the Multifamily Equipment Replacement (MER), Multifamily Retrofit/Multifamily Low Income (MIR/MLI), and Multifamily New Construction (MNC), and RER single family. The sampling plans were designed to address program specifics.

TABLE 2-2: SAMPLING OVERVIEW

VGS Program	Number of Sites/ Projects	Sample Size	Sampling Group	Notes
Commercial				
CER	31	6	CER/CNC	Sampling was done by site. *Post hoc* stratification was conducted to determine RRs by program.
CNC	13			
CSR	19	6	CSR	Sampling was done by site.
Residential Multifamily				
RER	7	2	Residential MF	Sampling was done by site. *Post hoc* stratification was conducted to determine RRs by program.
RIR	11	5		
RNC	9	4		
Residential Single Family				
RER	1,354	19	SF RER	The West Hill Energy Team conducted the sampling. The PSD conducted the reviews for this program.
RIR	490	0	SF RIR	RR from the previous impact evaluation were applied.
RNC[1]	61	0	SF RNC	The RR for the RNC program from the EVT's 2022 Annual Savings Verification was applied.

[1]VGS operates this program in conjunction with Efficiency Vermont.

The following sections provide the sampling plan for each of the three programs.

2.1.1   Commercial and Industrial

C&I programs account for 61% of VGS's PY2022 portfolio annual Mcf. The projects in this category include equipment replacement, new construction, and retrofit projects completed at C&I facilities. The West Hill Energy Team employed stratified ratio estimation and sample sizes were calculated to meet or exceed 80/10 confidence/precision level. A summary of the sampling approach is provided in Table 2-3.

TABLE 2-3: CER AND CNC SAMPLING APPROACH

Sampling Component	Description	Comments
Population Size	44 sites	All CER and CNC sites were included in the population. VGS's database had some sites under more than one program. The unique site was used for sampling.
Sample Frame	30 sites	The smallest projects accounting for less than 3% of the program reported annual Mcf savings were excluded from the sample frame.
Stratification	Annual Mcf reported savings	Projects were divided into three strata based on the size of the annual Mcf savings and sample sizes were calculated using an error ratio of 0.30.
Primary Sampling Unit	Site	The unique site was the sampling unit to account for interactive effects.
Target Sample Size	6	Random selection was applied to small projects (stratum 1) and a census of the largest projects (strata 2 and 3) was reviewed.

TABLE 2-4: CSR SAMPLING APPROACH

Sampling Component	Description	Comments
Population Size	19 sites	All CSR sites were included in the population. VGS's database had some sites under more than one program. The unique site was used for sampling.
Sample Frame	12 sites	The smallest projects accounting for less than 3% of the program reported annual Mcf savings were excluded from the sample frame.
Stratification	Annual Mcf reported savings	Projects were divided into two strata based on the size of the annual Mcf savings and sample sizes were calculated using an error ratio of 0.30.
Primary Sampling Unit	Site	The unique site was the sampling unit to account for interactive effects.
Target Sample Size	6	Random selection was applied to small projects (stratum 1) and a census of the largest projects (stratum 2) was reviewed.

Table 2-5 provides a summary of the C&I savings by stratum and the sample sizes.

TABLE 2-5: C&I SAMPLE SIZES FOR PY2022

Program	Strata	% Annual Mcf Commercial Savings	% Peak Day Mcf Commercial Savings	Total Number of Sites	Sampled Sites
CSR	0	3%	9%	7	0
CSR	1	40%	91%	9	3
CSR	2	57%	0%	3	3
CER/CNC	0	3%	3%	14	0
CER/CNC	1	46%	43%	26	2
CER/CNC	2	51%	56%	4	4
	Total	100%	100%	63	12

2.1.2   Residential Multifamily

The residential MF projects account for approximately 10% of VGS's PY2022 portfolio annual Mcf. The projects in this category include retrofit, equipment replacement, and new construction projects completed in MF facilities.

The West Hill Energy Team stratified projects by project size. Sample sizes were calculated to meet or exceed 80/10 confidence/precision level at the program level.

TABLE 2-6: RESIDENTIAL MULTI-FAMILY SAMPLING APPROACH

Sampling Component	Description	Comment
Population Size	27 projects	All MER, MIR/MLI, and MNC multi-family projects were included in the population.
Sample Frame	18 projects	Projects accounting for 3% or less of the program reported annual Mcf savings were excluded from the sample frame.
Stratification	Annual Mcf reported savings	Projects were divided into two strata based on the size of the annual Mcf savings and sample sizes were calculated using an error ratio of 0.30.
Primary Sampling Unit	Project	The project was the sampling unit.
Target Sample Size	7 projects	Random selection was applied to small projects (stratum 1) and a census of the largest projects (strata 2) was reviewed.

TABLE 2-7: RESIDENTIAL MULTIFAMILY SAMPLE SIZES FOR PY2022

Strata	% of Total Annual Mcf Residential MF Savings	% of Total Peak Day Residential MF Savings	Total Number of Sites	Sampled Sites
0	3%	3%	4	0
1	42%	43%	13	2
2	55%	55%	5	5
Total	100%	101%[1]	22	7

[1] Rounding error resulting in a total of 101%

2.1.3   RER Single Family

RER single family projects account for 19% of VGS's PY2022 annual savings portfolio. VGS calculated savings for these measures using the VGS TRM. Sample sizes were calculated to meet or exceed 80/18 confidence/precision level. A summary of the sampling approach is provided in Table 2-8.

TABLE 2-8: RESIDENTIAL SINGLE-FAMILY SAMPLING APPROACH

Sampling Component	Description	Comment
Population Size	1,354 projects	All RER single family projects were included in the population.
Sample Frame	1,163 projects	Projects accounting for 3% or less of the program reported annual Mcf savings were excluded from the sample frame.
Stratification	Annual Mcf reported savings	Projects were divided into seven strata, 2 strata with Controls-only projects, 5 with all other measures to ensure control measures were included in the sample. The strata were then based on the size of the annual Mcf savings. The largest strata were for Controls only; all others were census strata. Sample sizes were estimated using an error ratio of 0.30.
Primary Sampling Unit	Project	The project was the sampling unit.
Target Sample Size	19 projects	Random selection was applied to small projects (strata 1-4 and 6) and a census of the largest projects (strata 5 and 7) was reviewed. Six of these projects were controls only and 13 projects were all other non-controls measures.

Table 2-9 provides a summary of the RER single family savings and sample sizes by stratum.

TABLE 2-9: RER SINGLE FAMILY SAMPLE SIZE

Group	Strata	% Annual RER SF Mcf	% Peak Day RER SF Mcf	Total Number of Projects	Sampled Sites
All Measures	0	3%	3%	191	0
All Non-Controls	1	19%	25%	437	2
All Non-Controls	2	22%	21%	232	2
All Non-Controls	3	24%	21%	172	2
All Non-Controls	4	24%	19%	113	2
All Non-Controls	5	2%	2%	5	5
Controls Only	6	3%	4%	127	3
Controls Only	7	3%	5%	77	3
Total	Total	100%	100%	1,354	19

2.2 Review Process

The West Hill Energy Team conducted desk reviews for all sampled commercial and residential MF projects and the Vermont PSD conducted desk reviews on the single-family RER projects. The verification process is shown in Figure 2-1.

Document Review
Initial review of project files and documentation provided by VGS; missing files were requested from VGS.

Data Request
Requested missing information, *e.g.*, billing data, analysis inputs, updated analysis files, and sufficient proof of installation.

Engineering Desk Review
Applied an Excel spreadsheet analysis to estimate project savings; billing analysis was conducted where appropriate.

Consultation with VGS
Questions arising from the engineering review were discussed with VGS.

Preliminary Results Review
Individual project reports with questions and additional data requests were shared with VGS and PSD on a continuous basis.

Draft Project Report
Complete report draft was submitted to VGS and PSD for review of errors or omissions.

Final Project Report
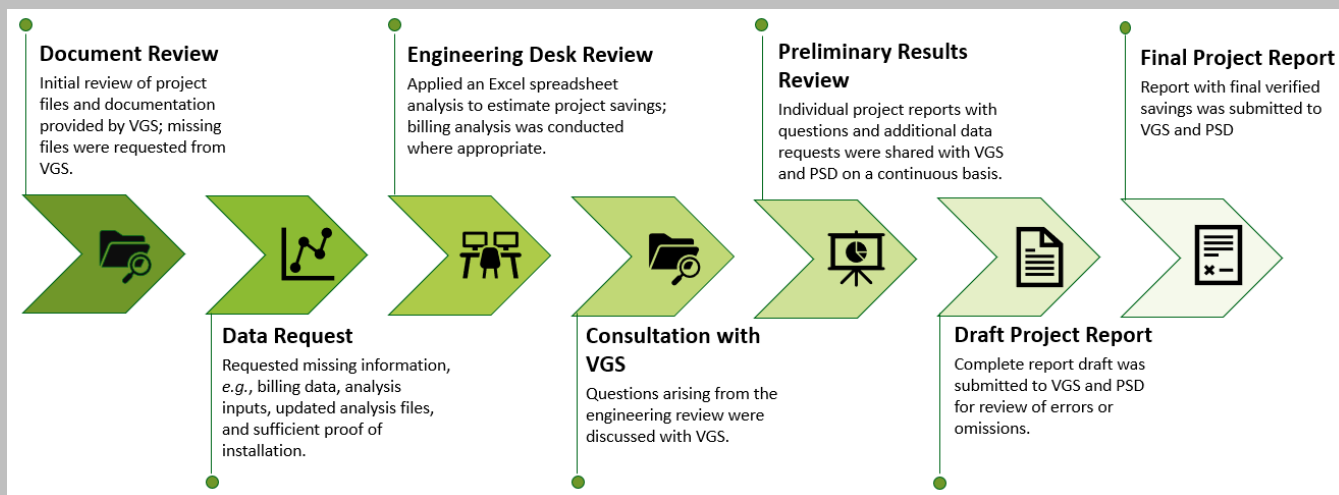Report with final verified savings was submitted to VGS and PSD

FIGURE 2-1: EVALUATION OF DESK REVIEW APPROACH

2.2.1 Documentation Review

Documentation review was the initial step in the evaluation process for all projects in the evaluation sample. This was done to determine if any project files were missing and if there was

adequate information to calculate energy savings and verify proof of installation. The West Hill Energy Team sent data requests to VGS for projects with missing or insufficient documentation.

2.2.2   Engineering Desk Reviews

Engineering desk reviews were completed for all projects in the evaluation sample. The review included verifying annual energy and peak day savings for each measure installed at the sampled site. The engineering desk review included a review of the inputs, calculations, and proof of installation, as shown in Figure 2-2.
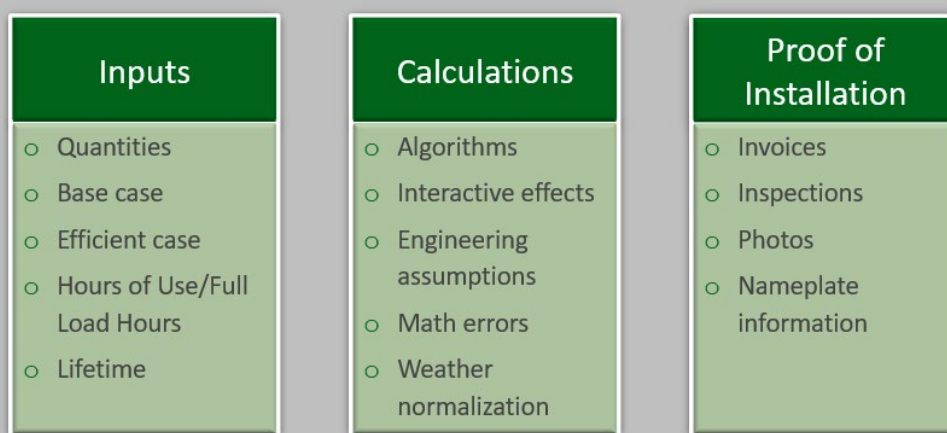

FIGURE 2-1: ENGINEERING REVIEW DETAIL

The desk reviews focused on verifying energy savings for each measure within the sampled project. The reviews focused on the following:

- **Calculation methods -** Identify if methods rely on deemed or custom analysis approach and if the methods are accurate and applied correctly.

- **Data sources -** Identify basis for savings calculations (*e.g.*, manufacturer specification sheets, site-specific data, billing data, energy code, audits).

- **Baseline and efficient case -** Identify project type (new construction, retrofit, equipment replacement) and analysis inputs for baseline and efficient conditions.

- **Proof of installation -** Check if each project has itemized invoices, inspection forms, photos, and nameplate information.

The VGS analyses generally used TRM methods and/or VGS standardized tools, which the West Hill Energy Team reviewed to determine whether the inputs matched the best available information and that the appropriate TRM algorithm was used. For projects using custom analysis approaches, the PSD team reviewed the analysis approach and algorithm to determine if they met industry standards and used the best available information. The West Hill Energy Team also reviewed billing data when available and, if appropriate, used billing analysis to calculate the savings, inputs into the savings algorithms, or to inform the desk review.

2.2.3 Continuous Feedback

The evaluation timeline for this project was constrained; therefore, the West Hill Energy Team had biweekly check-in calls and regular email communication with VGS and the PSD throughout the evaluation. These calls provided the opportunity to discuss project-specific details and to ensure that the West Hill Energy Team had a complete understanding of each project.

The West Hill Energy Team sent data requests to VGS for clarification and additional documentation on a rolling basis. Preliminary and draft project reports were sent upon completion to provide enough time for VGS to review the analyses for errors and omissions.

2.3 Realization Rate

The RR is the ratio of verified energy savings to the program's reported savings. The RR represents the percentage of program reported savings that is achieved based on the results of the savings verification. The RR was calculated as follows:

$$RR = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i x_i}$$

Where,

      RR = Realization rate (ratio estimator)

      i = The site

      n = Total number of verified sites in the sample

      w_i = Expansion weight (the total number of sites in the stratum divided by the number of verified sites in the stratum)

      y_i = Verified savings for site i

      x_i = Original claimed savings for site i

Results from each stratum were rolled up to program-, sector-, and portfolio-level using expansion weights as appropriate.

2.3.1 Residential MF *Post Hoc* Stratification

Residential MF projects were sampled by site to verify all measures associated with each site. This approach allowed the West Hill Energy Team to account for possible interactive effects. A few sites in the sample had projects in more than one program.

As the savings verification goal was to estimate the savings and provide RRs by program, the West Hill Energy Team conducted *post hoc* stratification by program to meet the verification goals. Table 2-10 shows the distribution of projects across the strata for the population and the sample.

Table 2-10: Residential MF Distribution Among Programs (Population and Sample)

Strata	Sites in Population				Sites in Sample			
	MER	MIR/MLI	MNC	Total	MER	MIR/MLI	MNC	Total
0	2	1	1	4	0	0	0	0
1	4	6	5	13	1	2	1	2
2	1	3	3	5	1	3	3	5
Totals	7	10	9	22	2	5	4	7

3 Results

This section provides the results from VGS PY2022 programs savings verification. Results are provided for annual, peak day, and lifetime savings. Site- or project-level results for the sample are summarized in Appendix A and site- or project-level reports are included as Appendix B.

3.1 C&I Annual Mcf Savings

The RRs and relative precision for VGS's annual Mcf savings are provided in Table 3-1. The portfolio RR is 98% with a relative precision of 2.4% at the 80% confidence level. The relative precision for the CNC program was 18.5%, due to the high variability of the verified savings.

TABLE 3-1: SUMMARY OF C&I REPORTED AND VERIFIED PY2022 ANNUAL MCF SAVINGS

Program	Total Sites	Sampled Sites	Program Reported Annual Savings (Mcf)	PSD Verified Annual Savings (Mcf)	Realization Rate	Relative Precision
Commercial Equipment Replacement	31	2	5,172	2,792	54%	0.9%
Commercial New Construction	13	4	3,837	2,645	69%	18.9%
Commercial Retrofit	19	6	27,368	30,344	111%	1.8%
Commercial Total	63	12	36,377	35,781	98%	2.4%

There were 12 C&I sites included in the desk review and 5 had verified annual savings within 10% of the VGS reported savings. Three of the remaining sites had over a 50% reduction in verified savings. Some of the key issues that influenced the RR are described below.

- **Incorrect inputs –** Analyses for two projects used incorrect equipment specifications from a previous project, resulting in more than a 50% reduction in savings. Other projects had smaller issues such as boiler capacity, pipe length, and heat loss that did not match the project documentation.

- **Baseline usage -** Baseline usage in a new construction project was greatly overestimated. Other projects had smaller adjustments to baseline use based on billing data. The West Hill Energy Team used billing data to verify the baseline consumption where possible.

- **Conversion and unit errors –** Several projects had minor adjustments due to conversion errors between therms and ccf resulting in a small overstatement of savings. There were other unit errors such as a project that appeared to incorrectly convert from CFM75 to CFM50 when using the code baseline.

  o **Measure not installed –** VGS included one measure in its program-reported savings that
     was not installed.

Other issues and additional details are included in the project-level reports.

3.2   Commercial and Industrial Peak Day Mcf Savings Results

The RRs and relative precision for VGS's peak day Mcf savings are provided in Table 3-2. The
C&I RR is 88% with a relative precision of 5.3% at the 80% confidence level.

TABLE 3-2: SUMMARY OF C&I REPORTED AND VERIFIED PY2022 PEAK DAY MCF SAVINGS

Program	Total Sites	Sampled Sites	Program Reported Peak Day Savings (Mcf)	PSD Verified Peak Day Savings (Mcf)	Realization Rate	Relative Precision
Commercial Equipment Replacement	31	2	53	27	51%	2%
Commercial New Construction	13	4	38	26	68%	24%
Commercial Retrofit	19	6	84	101	119%	0.6%
Commercial Total	63	12	176	154	88%	5.3%

To determine verified peak day savings, the West Hill Energy Team multiplied the verified
annual Mcf savings by the peak day savings factor for the end use; therefore, findings that affect
annual Mcf savings also affect peak day Mcf savings. There were several measures where the
peak savings factor was adjusted. For example, a boiler that served DHW loads but the VGS
savings used the heating peak savings factor.

3.3   Commercial and Industrial Lifetime Mcf Savings Results

The RRs and relative precision for VGS's lifetime Mcf savings are provided in Table 3-3. The
C&I RR is 88% with a relative precision of 3.7% at the 80% confidence level.

TABLE 3-3: SUMMARY OF C&I REPORTED AND VERIFIED PY2022 LIFETIME MCF SAVINGS

Program	Total Sites	Sampled Sites	Program Reported Lifetime Savings (Mcf)	PSD Verified Lifetime Savings (Mcf)	Realization Rate	Relative Precision
Commercial Equipment Replacement	31	2	94,388	45,055	48%	7.1%
Commercial New Construction	13	4	70,437	44,986	64%	25.5%
Commercial Retrofit	19	6	387,557	395,633	102%	1.9%
Commercial Total	63	12	552,381	485,674	88%	3.7%

To determine lifetime savings, the West Hill Energy Team multiplied the verified annual Mcf savings by the lifetime for each measure; therefore, findings that affect annual Mcf savings also affect the lifetime Mcf savings. The variation in lifetimes across measure type results in some differences in the final RR.

There were several measures that used a lifetime that did not match the Vermont TRM for the measure. These were adjusted to match the TRM resulting in lower lifetime savings as the values used by VGS were typically higher than the TRM value.

3.4　Residential Program Annual Mcf Savings

The RRs and relative precision for VGS's annual Mcf savings are provided in Table 3-4. The residential portfolio RR is 88% with a relative precision of 3.6% at the 80% confidence level.

TABLE 3-4: SUMMARY OF RESIDENTIAL PROGRAM REPORTED AND VERIFIED ANNUAL MCF SAVINGS

Program	Total Sites	Sampled Sites/ Projects	Program Reported Annual Savings (Mcf)	PSD Verified Annual Savings (Mcf)	Realization Rate	Relative Precision
Residential Sector						
Equipment Replacement	1,361	21	12,203	10,902	89%	6.0%
New Construction[1]	30	4	4,682	3,494	75%	5.7%
Retrofit[2]	500	5	6,534	6,185	95%	4.8%
Total Residential Sector	1,891	30	23,419	20,581	88%	3.6%

[1] The RNC RR for single family projects was from the Report to Verify Efficiency Vermont 2022 Savings Claim, June 2023.
[2] VGS applied the RR from the 2018 impact evaluation of VGS residential, which was applied to all 490 single family retrofit projects.

All seven of the reviewed MF sites had over 10% difference between the verified annual savings and reported savings with 2 having over 50% reduction in savings. The most common reasons for differences in realized savings for the residential sector are discussed below.

- o **Incorrect inputs -** For RER measures, VGS used an "existing" AFUE/UEF and a "base" AFUE/UEF for calculating the heat load from the consumption and calculating the savings, respectively. These values were adjusted to both match the base AFUE/UEF as that is consistent with the value used in previous years. For MF projects, there were few errors in inputs including annual hours, measure lifetime, and air sealing CFM75 that did not match the project documentation.

- o **Mismatch to billing data –** Several projects had lower heating loads than the TRM assumptions when compared to billing data. One retrofit site showed almost no reduction in savings compared to the reported measures although the exact reason for the difference is unknown. In addition, five of the RER projects in the sample had input heating or DHW loads that did not match the loads from the billing data with two showing substantially different consumption, one much higher and one much lower billing use.

- o **Code baseline errors –** Two MF custom sites did not apply the correct energy code baseline for ERV measures resulting in large reductions in savings. One site used the CBES 2015 energy code rather than the CBES 2020 baseline for air sealing due to a misinterpretation of the timing to determine the applicable code.

Reasons for project-level adjustment and related issues are described in the project level reports.

3.5 Residential Peak Day Annual Mcf Savings

The RRs and relative precision for VGS's peak day Mcf savings are provided in Table 3-5. The residential RR is 88% with a relative precision of 1.8% at the 80% confidence level.

TABLE 3-5: SUMMARY OF PROGRAM REPORTED AND VERIFIED PY2022 PEAK DAY MCF SAVINGS

Program	Total Sites	Sample Sites	Reported Peak Day Savings (Mcf)	PSD Verified Peak Day Savings (Mcf)	Realization Rate	Relative Precision
Residential Sector						
Equipment Replacement	1361	21	93.9	90.6	97%	1.2%
New Construction[1]	30	4	54.1	38.3	71%	6.8%
Retrofit[2]	500	5	89.1	78.8	89%	1.8%
Total Residential Sector	1891	30	237.0	207.8	88%	1.8%

[1] The RNC RR for single family projects was from the Report to Verify Efficiency Vermont 2022 Savings Claim, June 2023.
[2] VGS applied the RR from the 2018 impact evaluation of VGS residential, which was applied to all 490 single family retrofit projects.

For several residential MF measures, the West Hill Energy Team found a few discrepancies with VGS's application of peak day multipliers including pipe insulation measures that served both heating and hot water where the heating savings factor was used. The peak savings factor for those was adjusted to use weighted average of the heating and DHW peak factors. There were no adjustments to the RER peak day multipliers for the single-family projects.

3.6 Residential Lifetime Mcf Savings

The RRs and relative precision for VGS's lifetime Mcf savings are provided in Table 3-6. The residential portfolio RR is 86% with a relative precision of 4.1% at the 80% confidence level.

TABLE 3-6: SUMMARY OF PROGRAM REPORTED AND VERIFIED PY2022 LIFETIME MCF SAVINGS

Program	Total Sites	Sample Sites	Reported Lifetime Savings (Mcf)	PSD Verified Lifetime Savings (Mcf)	Realization Rate	Relative Precision
Residential Sector						
Equipment Replacement	1,361	21	227,940	210,207	92%	5.2%
New Construction[1]	30	4	107,947	74,875	69%	15.0%
Retrofit[2]	500	5	153,689	138,169	90%	0.4%
Total Residential Sector	1,891	30	489,576	423,251	86%	4.1%

[1] The RNC RR for single family projects was from the Report to Verify Efficiency Vermont 2022 Savings Claim, June 2023.
[2] VGS applied the RR from the 2018 impact evaluation of VGS residential, which was applied to all 490 single family retrofit projects.

To determine lifetime savings, the West Hill Energy Team multiplied the verified annual Mcf savings by the lifetime for each measure; therefore, findings that affect annual Mcf savings carry over to lifetime Mcf savings proportionally, although the variation in lifetimes across measure type results in differences in the final RR.

There were several measures that used a lifetime that did not match the Vermont TRM value for the measure. These were adjusted to match the TRM resulting in lower lifetime savings as the values used by VGS were higher than the TRM value.

3.7 Quantifiable Performance Indicators

The West Hill Energy Team also reviewed VGS's progress toward selected QPIs for PY2021-PY2023, as described in the Vermont PUC order from October 22, 2020. These QPIs were designed to assess whether efficient energy utilities (EEUs) are meeting established goals on schedule and at levels set by the PUC. As verification of some of the QPIs were either part of the

verification process or could be easily added, the West Hill Energy Team reviewed VGS's progress toward meeting these selected QPIs.

Table 3-7 provides a summary of VGS's progress toward the portfolio-level savings and greenhouse gas emissions QPIs.

TABLE 3-7: SUMMARY OF PORTFOLIO-LEVEL QPIS

QPI	Sector	QPI Description	3-year Goal	PY2021 Verified Savings[1]	PY2022 Verified Savings	Achieved vs 3-Year Goal
QPI1a.	Portfolio	Annual net Mcf savings	239,650	43,771	56,362	42%
QPI1b.	Portfolio	GHG metric tons emissions	13,214	2,587	3,108	43%
QPI2b.	Portfolio	Lifetime Mcf Savings	4,196,753	840,812	908,932	42%
QPI3.	Portfolio	Peak day Mcf savings	1,356	364	362	54%

[1] PY2021 savings from Verification of Vermont Gas Systems 2021 Annual Savings Claims. Prepared by West Hill Energy and Computing, July 2022.

Table 3-8 provides a summary of the selected residential QPIs. The goals for the whole territory are on track, although due to the small number of audits in Addison (3), it is unclear if the conversion goal will be met in Addison County.

TABLE 3-8: SUMMARY OF RESIDENTIAL AND RESIDENTIAL SINGLE FAMILY QPIS

QPI	Sector	QPI Description	3-year Goal	PY2021 Results	PY2022 Results	Progress Towards 3-Year Goal
QPI4a.	Residential Single Family[1]	Percent of home energy audits converted to a measure installation within 12 months (Existing)	30%	53%	38%	On Track as of PY2022
		Percent of home energy audits converted to a measure installation within 12 months (Addison)	30%	50%	35%	On Track as of PY2022
QPI5.	Residential	Energy Audits Completed	600 (Annually)	707	642	On Track as of PY2022

[1] VGS Note: Will be based on prior year's number of audits that had cost effective measures. For example, for calendar year (CY) 2018 results, the denominator will be single family audits completed in CY2017 that had cost effective measures, and the numerator will be how many of those became completions within 365 days of the audit.

Table 3-9 provides a summary of the selected commercial retrofit (CSR) QPIs. As shown in Table 3-9, VGS is on track to meet the three-year requirements for diversity of measures

implemented in the C&I retrofit program and lagging on meeting the requirements for controls and process-related measures for Addison County.

TABLE 3-9: SUMMARY OF C&I QPIS

QPI	Sector	QPI Description	3-year Goal	PY2021 Results	PY2022 Results	Progress Towards 3-Year Goal
QPI.7	C&I Retrofit	Diversity of measures implemented in CSR projects (Existing)				
		Controls	5%	12%	14%	On Track
		Heating systems, heat recovery or domestic hot water (DHW) system	20%	21%	6%	In Progress
		Process	5%	12%	14%	On Track
		Shell or other-related	15%	55%	66%	On Track
QPI.7	C&I Retrofit	Diversity of measures implemented in CSR projects (Addison)				
		Controls	5%	0%	0%	In Progress
		Heating systems, heat recovery or DHW system	20%	14%	0%	In Progress
		Process	5%	0%	33%	On Track
		Shell or other-related	15%	86%	67%	On Track

4　Recommendations

This section provides recommendations to improve future VGS programs' RRs and streamline future verification processes.

4.1　Improve Project-level Documentation

Issue: The PY2021 and PY2020 savings verification reports identified issues with missing project-level documentation. While the West Hill Energy Team has noted some progress, there is room for further improvement. For 9 of the 19 C&I and MF sites with custom projects selected for desk review, the West Hill Energy Team had to request additional documentation to determine key inputs into the saving algorithms. Six (6) of the 19 sites were missing proof of installation for some measures.

Recommendation: The PSD recommends that VGS continue its efforts to improve project-level documentation by providing more detailed description of the project files and analysis tools. Specific items to include in the project files include the following:

- A project overview that describes the installed energy efficiency measures, the baseline and efficient operating conditions, and project timeline. While a few projects included a narrative description, most did not.

- Where Vermont energy code applies, the date of the permit and the applicable building energy code should be clearly stated. For several projects, additional documentation was required to determine the applicable code. For a couple of the selected projects, the incorrect code was applied (2015 rather than 2020). More attention to documenting these details may avoid these issues.

- Sources of all inputs to the savings algorithm in the analysis spreadsheet; this is especially important for any inputs that are different from the TRM defaults. While references were documented for some projects, they were not consistently provided.

- Proof of installation such as itemized invoices, inspection reports, and clear photos of nameplate information and installation photos. The West Hill Energy Team noted substantial improvements in photo documentation; however, invoices were generally lacking.

In addition, analysis files should be in an editable and readable format such as a spreadsheet rather than password protected files or pdfs where values cannot be reviewed. This issue occurred in three projects in PY2022.

Addressing these documentation issues will reduce the amount of time spent on each project review and provide transparency into VGS assumptions.

4.2   Heat Load Estimation

Issue: The West Hill Energy Team noticed substantial progress in correcting previous errors related to the estimation of heat loads, as discussed in the PY2021 savings verification report. A few issues still remain.

1.   The TRM often uses engineering calculations to determine the heat load. Without grounding in actual consumption, engineering calculations are often highly inaccurate.

2.   For RER equipment replacements, VGS adjusted the pre-install billing consumption to reflect the average actual efficiency of the existing equipment, which was higher than the baseline efficiency. West Hill Energy Team adjusted the efficiency to be consistent with the PY2021 adjustment.

Recommendation: Whenever possible, heat loads calculated using engineering calculations should be checked against billing data to verify that the heat load is reasonable and the savings are realistic. The West Hill Energy Team recommends that VGS work with the PSD to improve the approach to estimating the heat load for the RER program.

4.3   Establishing Methods, Inputs, and TRM Use

Issue: VGS appears to be using a combination of the VGS TRM, EVT TRM, TRMs from other jurisdictions, custom tools, and TRM algorithms with custom inputs. The PSD is prepared to review projects using a variety of analysis tools and methods; however, it is often unclear why specific methods or out-of-state TRMs were selected. For example, the PSD does not support the use of out-of-state TRMs for measures that are in the Vermont TRM or the VGS TRM without a specific justification as to why the Vermont or VGS TRM does not apply. In addition, VGS has in some cases used part of a TRM measure characterization and rejected other components of the same TRM measure characterization (such as the measure life).

Recommendation: The PSD fully supports using site-specific inputs and/or custom approaches where appropriate and when the sources of the inputs can be properly documented. The PSD recommends that VGS develop a clear, written strategy for selecting among the alternative approaches, including when an out-of-state TRM may be applied. TRM measure characterizations should be fully adopted or rejected, but not partially adopted without a strong and defensible reason.

4.4   Update Weather Normalization

Issue: Currently VGS uses TMY3 weather data to normalize all weather dependent calculations. Due to climate change, TMY3 30-year data (1976-2005) is not the best available information that represents future climate conditions for measures going forward. VGS current goals are based on TMY3, and thus, the PSD evaluation team has used the TMY3 weather normalization for the PY2022 savings verification.

Recommendation: The West Hill Energy Team recommends using the most recent 6-to-10 years for the nearest National Oceanic Atmospheric Administration (NOAA) weather station to estimate

the future heating loads more accurately. The average heating degree days for the selected period could be calculated at the beginning of the program year and used throughout the year.

4.5   Improve Internal Savings Calculation Quality Control

Issue: Some of the errors in the calculations appear to result from simple errors that could be prevented with additional quality control (QC).

Recommendation: The internal QC process should be improved to include a comprehensive review of project documentation and savings calculations. Topics to cover could include the following:

- o   Check that the analysis file savings match the program tracking database.
- o   Reality checks on the magnitude of savings, using billing data if available.
- o   Check that the peak day factor matches the end use and/or standardize the approach to assigning the peak day multiplier to the end use.

Improving the internal QC is likely to improve RRs. This recommendation was also made in the PY2021 savings verification report and the PY2022 review indicated ongoing issues.

4.6   Timing of Project Completion

Issue: For some projects, commissioning or other fine-tuning of the equipment or systems seems to be conducted after the savings have been calculated and the project is marked as complete. Savings verification is based on a desk review and billing analysis (where appropriate), which may not take into account ongoing efforts on site to improve the operation of the equipment especially if it is still ongoing during the verification process.

Recommendation: The PSD recommends that VGS calculate savings after the equipment or systems are completely operational and only then change the project status to complete. This approach may require some changes to program procedures, such as holding out a part of the incentive until proof of commissioning has been provided.

4.7   Savings Verification Process

Issue: VGS reviews the PSD's project-level verification results for errors and omissions, which is an important part of the process. Late delivery of the program data, slow responses to requests for clarification and confusion about the review process led to delays.

Recommendation: The West Hill Energy Team recommends that the PSD and VGS agree on a framework for VGS's review process, including, for example, a scheduled date for VGS to deliver the program reported savings, a time frame for the PSD to provide the project-level reports, turn-around times for VGS to respond to data requests and to provide comments on project-specific reports, a limit on how many times the same issues are raised and addressed, and other guidelines for VGS's review process.