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Weatherization Impact Evaluation

EnergyWise Single Family Program
Rhode Island Energy

For

Rhode Island Energy

By

Cadeo

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Executive Summary

This report details the findings of Cadeo's impact evaluation of Rhode Island Energy's EnergyWise Single Family (EWSF) program, which focused on updating the gross energy savings for EWSF's weatherization (i.e., air sealing, duct sealing, and insulation) measures.[1] This evaluation accounts for the full range of weatherization energy impacts including savings associated with primary heating fuel and, when relevant, secondary heating, cooling, and furnace fan usage.

In 2021, weatherization represented the overwhelming majority of EWSF program savings (88%) across all measures and fuel types.

To estimate weatherization savings for primary heating, Cadeo completed a billing analysis for participants that primarily heated with natural gas. Cadeo applied a series of engineering adjustments to leverage the results of the natural gas billing analysis to estimate savings for weatherized participants that primarily heat their homes using electricity or a delivered fuel (i.e., heating oil or propane).

To estimate the impact of weatherization on participant's secondary electric heating usage (i.e., a primarily gas heated home using a plug-in space heater in a bathroom), Cadeo conducted an additional electric billing analysis focused on primary gas heated participants that self-identified as using secondary electric heating via a participant survey.

The results of this evaluation replace the program's previous (i.e., ex ante) savings estimates, which were based on 2017 and 2018 participants. The evaluation includes savings estimates for participants that heat with natural gas, electricity, or a delivered fuel (heating oil or propane).

Key Findings

The evaluation found higher weatherization savings than the previous evaluation for participants that heat their homes with natural gas or a delivered fuel[2], which collectively represent over 90% of weatherized EWSF participants. On average, 2021 natural gas weatherization participants installed more types of insulation (i.e., attic, wall, and floor each counting as 1.0 insulation type) in their home relative to participants in 2017-2018. For example, the average 2021 participant installed 2.11 types of insulation – up from 1.88 in 2017-2018. Most of the difference comes from a jump in percentage of participants that installed wall insulation, which increased from 43% to 62%. The evaluation team found slightly lower savings – again relative to the previous evaluation – for the small number of electrically heated weatherization participants.

The evaluation also found weatherization had small but observable decreases in participants' use of secondary electric heating sources (e.g., plug-in electric space heaters), which was not assessed as part of the previous evaluation. The evaluation also estimated the impact of weatherization on EWSF as well as cooling and furnace fan/pumps usage.

[1] This evaluation focused exclusively on weatherization and did not estimate updated gross energy savings for non-weatherization EWSF measures (e.g., high efficiency showerheads, aerators), which were assessed as part of the previous EWSF impact evaluation. (Cadeo and Illume, *Impact & Process Evaluation: EnergyWise Single Family Program, National Grid Rhode Island*, September 2020.) http://rieermc.ri.gov/wp-content/uploads/2020/10/ng-ri-ewsf-impact-and-process-comprehensive-report_final_04sept2020.pdf

[2] The team opted to combine and report heating oil and propane participants together since so few delivered fuel participants (1%) heated with propane.

Table 1. Average Annual Savings Per Weatherization Participant by Fuel Type

Type of Savings	Ex Ante	Ex Post	RR
Natural Gas			
Primary Heating (therms/MMBtu)	96/9.6	131/13.1	136%
Secondary Electric Heating (kWh/MMBtu)	-	52.3/0.18	-
Cooling (kWh/MMBtu)	16/0.05	23/0.08	144%
Furnace Fan/Pump (kWh/MMBtu)	32/0.11	47/0.16	147%
Total (MMBtu)	**9.8**	**13.5**	**138%**
Electric			
Primary Heating (kWh/MMBtu)	803/2.7	732/2.5	91%
Secondary Electric Heating (kWh/MMBtu)		N/A*	
Cooling (kWh/MMBtu)	27/0.09	24/0.08	89%
Furnace Fan/Pump (kWh/MMBtu)	10/0.03	9/0.03	90%
Total (MMBtu)	**2.9**	**2.6**	**91%**
Delivered Fuels			
Primary Heating (MMBtu)	9.8	12.2	124%
Secondary Electric Heating (kWh/MMBtu)	-	52.3/0.18	-
Cooling (kWh/MMBtu)	16/0.05	21/0.07	131%
Furnace Fan/Pump (kWh/MMBtu)	32/0.11	43/0.15	134%
Total (MMBtu)	**10.0**	**12.6**	**126%**

* Included in primary heating electricity savings.

To improve future impact evaluations, the evaluation team recommends that Rhode Island Energy collect and provide evaluators with the following data not available to our team:

- Pre-program R-value by location (e.g., attic, wall, floor)
- Pre- and post- CFM-50 data for air sealing
- Type of primary heating equipment by fuel type
- Presence and type of secondary electric heating equipment
- Seasonal occupancy flag (e.g., number of months unoccupied, when relevant)

We recommend collecting this information as part of the EWSF program so that it can be consistently reviewed and compared year over year using the same time period as the evaluation time period.

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Section 1 Introduction

The goal of this study was to update the gross per-unit energy savings for air sealing, duct sealing, and insulation (collectively referred as "weatherization") for all fuels using the most recent cohort of Rhode Island (RI) Energy's EnergyWise Single Family (EWSF) program participants.[3] Due to the need for a full year of post-program energy consumption data to support robust billing analysis, this study evaluated savings for customers that participated in 2021. The previous impact study,[4] completed in 2020, established the current gross savings based on customers participating in the EWSF program in 2017 and 2018.

In addition to using billing analysis to estimate savings associated with participants' primary heating fuel, this study addressed the impact of EWSF weatherization on secondary heating usage, which was not part of the previous impact evaluation. Examples of secondary heating are wide ranging and include electric options like portable/plug-in space heaters, wall mounted space heaters, electric resistance baseboards, ductless heat pumps and non-electric heating sources like fireplaces and woodstoves. Accounting for secondary heating is important because homes weatherized through EWSF may change how they use their secondary heating sources too. Reviewing the program's impact on primary and secondary heating sources, as well as cooling sources, ensured that we evaluated the full impact of EWSF weatherization.

About EnergyWise Single Family

EWSF is the flagship in-home comprehensive energy efficiency offering for all Rhode Island Energy residential customers in a single-family residences (up to 4-unit residential buildings) that are not candidates for Income Eligible Services. All market rate customers with either an electric or gas account (including those using delivered fuels for heating), homeowners, renters, and landlords are eligible to participant.

EWSF uses a whole-house approach to identify energy saving opportunities in all major energy systems including heating and water heating systems, appliances, lighting[5], water saving measures, plug loads, and building envelope leaks. This program is facilitated by RISE Engineering who is responsible for conducting home energy assessments (HEA) and coordinating weatherization and heating system upgrades.

EWSF's in-home services start with no cost HEA, during which energy specialist(s) evaluate the whole-house energy systems while providing direct installation of efficiency measures related to lighting, plug load, and water heating savings. In 2020, the COVID-19 pandemic prompted innovation of a virtual home energy assessment (VHEA), and in 2021 EWSF continued to offer customers both HEA and VHEA options. The program tracking data provided to Cadeo included a field to indicate the relevant assessment type.

[3] This evaluation focused exclusively on weatherization and did not estimate updated gross energy savings for non-weatherization EWSF measures (e.g., high efficiency showerheads, aerators), which were assessed as part of the previous EWSF impact evaluation. (Cadeo and Illume, *Impact & Process Evaluation: EnergyWise Single Family Program, National Grid Rhode Island*, September 2020.) http://rieermc.ri.gov/wp-content/uploads/2020/10/ng-ri-ewsf-impact-and-process-comprehensive-report_final_04sept2020.pdf

[4] Cadeo and Illume, *Impact & Process Evaluation: EnergyWise Single Family Program, National Grid Rhode Island*, September 2020. http://rieermc.ri.gov/wp-content/uploads/2020/10/ng-ri-ewsf-impact-and-process-comprehensive-report_final_04sept2020.pdf

[5] EWSF has scaled back its lighting offer over the years. As of 2023, the program limited lighting to 6-pack LED bulbs provided at the time of the assessment.

However, the data field was largely unpopulated (~2/3 missing). Of the entries populated, the overwhelming majority (95%) indicated the assessment happened in-person.[6]

Regardless of the assessment type, the energy specialist presents the customer with an energy action plan at the end of the assessment that summarizes their findings and provides the customer a roadmap for upgrading their home. When relevant, the energy action plan includes a recommended path to weatherization, including associated costs and incentives[7], qualified contractors, 0% interest HEAT loan opportunities and information to overcome any barriers that must be addressed before weatherization can be addressed. The plan also includes additional energy saving opportunities with other RI Energy's programs (including HVAC and Hot Water, Consumer Products, and Connected Solutions, etc.) when appropriate.

EWSF's second phase of in-home service is the weatherization upgrade for the participants who decide to move forward. Customers choose their insulation contractor from a list provided by RI Energy or elect to have a contractor assigned to them. Participants and contractors coordinate scheduling their insulation retrofit. RISE assigns an internal inspector to work with the contractor to assist with weatherization project management and be a liaison between the selected contractor and the EWSF participant.

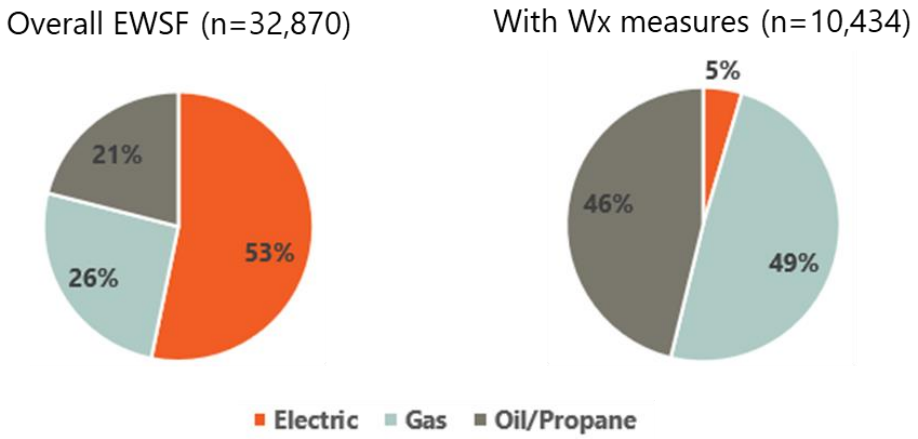
In 2021, RISE facilitated over 16,000 assessments and more than 6,200 weatherization projects across all heating fuel types.

Program Summary

Figure 1 shows EWSF program's overall 2021 participation and participants that installed weatherization measure(s) by primary heating fuel type. While customers with electric heating consisted more than half of the overall EWSF participants (53%), most participants that installed weatherization measures heat their home with gas or oil/propane.

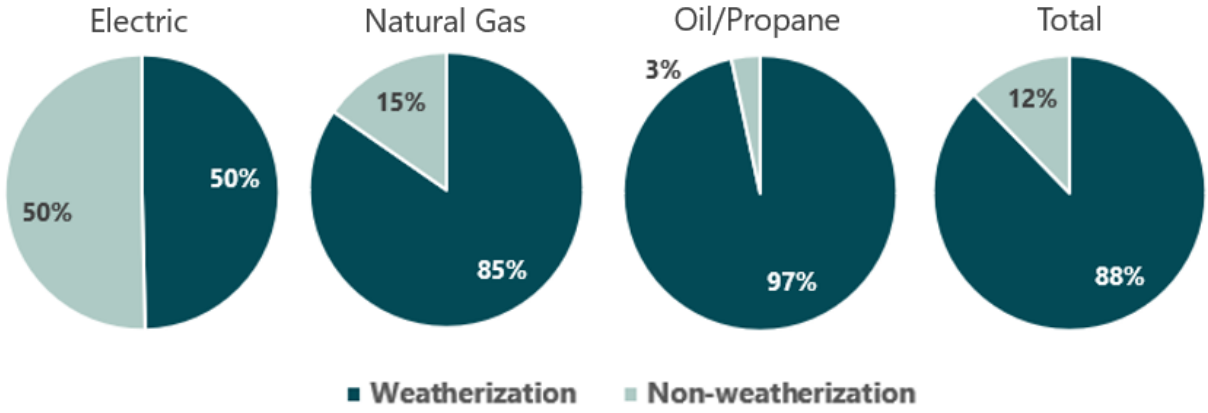
[6] Given the limited number of identified VHEA participants, Cadeo was unable to reliably estimate any VHEA-specific savings values or provide any direct comparisons between VHEA and HEA participants as part of this study.
[7] EWSF covers a large portion of the upfront cost for weatherizing participants (in 2021 typically 75% up to $4,000, with a portion of carry-over customers from 2020 who received 100% up to $15,000).

Figure 1. Overall EWSF Participation and Participants with Weatherization Measures by Primary Heating Fuel (2021)



This evaluation focuses on weatherization measures – again, air sealing, duct sealing, and insulation[8] – because weatherization is responsible for the majority of EWSF lifetime energy savings. As shown in Figure 2, weatherization represented 88% of EWSF total ex ante net lifetime savings (in MMBTUs) across all heating fuel types in 2021.

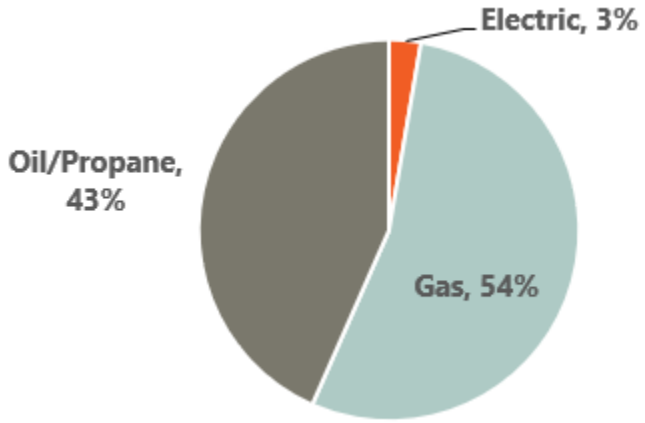
Figure 2. EWSF Lifetime Ex Ante Net Savings by Fuel by Measure Group (2021)



[8] While almost all the participants that installed weatherization measures installed insulation and air sealing, only 19% of them received duct sealing.

As shown in Figure 3, gas savings (54%) were the largest source of EWSF weatherization lifetime ex ante net savings in 2021, followed by oil/propane (43%)[9] and electricity (3%).

Figure 3. EWSF Weatherization Lifetime Ex Ante Net Savings by Fuel (2021)



Study Objectives

Rhode Island Energy established the following objectives for this impact evaluation:

- What is the change in natural gas, electric, and delivered fuel consumption as well as the change in total energy use (across all relevant fuels) associated with EWSF weatherization when accounting for:
    - Primary heating usage
    - Secondary heating usage (e.g., plug-in electric space heaters), when relevant
    - Cooling (i.e., central air conditioners or room air conditioners), when relevant
- How do the evaluated savings from this study compare to the previous evaluation's findings (2017–2018), as well as recent evaluations of comparable programs in neighboring states?

To meet these objectives, Cadeo used a combination of billing analysis and technical reference manual-based (TRM) engineering algorithms.

[9] For weatherization measures, there was zero propane savings in 2021. For non-weatherization measures, propane savings constituted 0.68% of the total non-weatherization lifetime net savings.

Key Terminology

The evaluation team uses the language defined in Table 2 throughout the report to explain key impact evaluation concepts.

Table 2. Summary of Key Evaluation Terminology

Term	Definition
EWSF Participant	An individual or household (also identified by a unique account number) who received a home energy assessment through the EWSF program.
Weatherization Participant	An individual or household (also identified by a unique account number) who received air sealing, duct sealing and/or insulation measure installation through the EWSF program.
Primary Heating	A primary heating system provides most of the heating needs of a house, often centrally located and connected to ductwork or pipes that distribute heat throughout the building. Common types include furnaces boilers, heat pumps, and electric baseboards.
Secondary Heating	A secondary heating system serves as a supplementary or backup source of heat to complement the primary heating system. It is typically used to provide localized heating to specific areas or rooms within a building where additional warmth is desired or in case the primary system is unable to meet the entire heating demand.
Ex Ante Savings	Savings assumed by Rhode Island Energy prior to an evaluation, usually based on the prior EWSF impact evaluation and/or the Rhode Island Energy TRM.
Ex Post Savings	Savings determined through this evaluation.
Gross Savings	Savings generated by the program without consideration for whether the participant would have taken the same/similar actions absent EWSF (i.e., freeridership). This evaluation focuses on gross savings.
Net Savings	Savings generated by the program after consideration of whether the participant would have taken the same/similar action absent EWSF (i.e., freeridership), additional actions attributable to EWSF (i.e., spillover), and any program induced market changes (i.e., market effects). The evaluation did not estimate net savings.
Treatment Group	The EWSF participants for whom the team estimated ex post savings: customers who received EWSF weatherization measures in program year 2021.
Control Group	The set of customers used in a billing analysis to serve as a counterfactual for estimating the program's impact. The control group accounts (or controls) for exogenous factors such as moves and rate changes that can otherwise obscure program-generated savings. In the context of this evaluation, the team used future EWSF participants (i.e., EWSF participants in 2022) as the control group.
Weatherization	A general term used to describe air sealing, duct sealing, and/or insulation (one or more of attic, wall, or floor insulation). References to air/duct sealing or insulation in the report are specific to that measure, whereas weatherization refers to one or both measures.

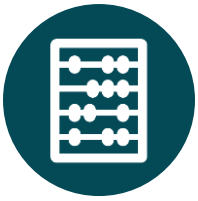
Section 2 Methodology

Activities

The team completed three tasks as part of this weatherization-focused impact evaluation. Collectively, the tasks enabled our team to estimate the primary heating (all fuel types) and secondary heating (electric only) gross savings associated with EWSF weatherization.

Table 3. Summary of Evaluation Activities

	**Billing Analysis** - Used where billing data was available for natural gas and electricity (not used for delivered fuels) - Used to report ex post savings for weatherization when billing analysis results met pre-determined threshold of better than ±20% precision at the 90% confidence level. - Combined customer billing records with weather and measure installation data to get a complete perspective of each customer's energy consumption drivers. - Conducted a structured screening process to ensure that the model uses only those customers with sufficient billing data and without spurious billing records. - Matched each treatment group customer to a control group (future EWSF participants) customer with a similar monthly, preinstallation period energy consumption pattern. - Specified and refined a monthly post-program regression (PPR) model. - Generated results, which were weather-normalized (where applicable) using 30-year historical weather data from three different weather stations across Rhode Island; each participant was mapped to the closest weather station. The numbers in this report reflect using the TMYx (2007-2021) dataset to describe a typical year. - Used survey to identify treatment group participants that use secondary heating. - Specified a second PPR model for electricity consumption that identifies the unique savings contributed by the presence of a secondary electric heat source.



Engineering Algorithms

- Leveraged previous EWSF evaluation program data and results when updated 2021 EWSF program data was not collected or unavailable.
- Adjusted billing analysis results as applicable for delivered fuels and electricity impacts, accounting for differences in heating system efficiencies and home characteristics as relevant.
- Included a brief literature review of relevant US Department of Energy appliance standards, other state TRMs, and similar evaluations in other states to update equipment efficiency assumptions.

Participant Surveys

- Sampled EWSF participants and sent web-based survey via email in batches.
- Surveyed 436 randomly sampled 2021 EWSF participants (15% response rate).
- Provided all participants who completed the survey with a $10 incentive.
- Focused on pre- and post-program secondary heating and cooling usage.
- Survey instrument and results are attached in Appendix A and Appendix B.

Data Sources

RI Energy provided the following datasets, which informed our evaluation activities.

- **EWSF Program Data**. These data include basic customer (account number, address, ZIP code), measure (type, quantity, savings), and timing (assessment and installation dates) information for 2021 (treatment group) and 2022 (control group) participants.
- **Supplemental Tax Parcel**. These data provide additional information regarding the physical structures of participating buildings. This information includes, but is not limited to, building size, building vintage, and rent/own status.
- **Cross-Program Participation Data.** As an assessment program, EWSF can serve as a gateway to other complementary RI Energy residential programs. Since it is critical to account for participation in other programs when estimating savings, the team identified EWSF participants that also participated in another program (i.e., cross-program participants) so that we can control for the energy savings from other programs as part of our billing analysis. Specifically, we controlled for participation in the following non-EWSF residential programs: Natural Gas Heating and Water Heating, ENERGY STAR HVAC, ENERGY STAR Products.[10]
- **Billing Data.** RI Energy provided monthly natural gas and electric consumption data ranging from December 1, 2019 to January 31, 2023 for the relevant 2021 and 2022 EWSF participants. The team did not attempt to gather any information regarding delivered fuels (i.e., heating oil and propane).

[10] Excludes upstream lighting since that program does not collect customer information that would allow for mapping cross-participation.

In addition to the data sources above, the evaluation team acquired weather data from National Oceanic and Atmospheric Administration (NOAA):

- **Weather Data**. Our also team acquired contemporaneous, hourly weather data from NOAA for all weather stations in Rhode Island. We used these data to calculate weather normalized consumption for program participants, which we then used to calibrate building simulations and to determine weatherization energy savings for a Typical Meteorological Year (TMYx 2007-2021). Previous evaluations have relied on the TMY3 data set which is sampled from weather data from 1995-2005. The TMYx data sets sample from more recent years (2007-2021) to better account for changes in climate.[11]

[11] The evaluation team confirmed with RI Energy that TMYx was the appropriate weather data to use for this evaluation.

Section 3 Impact of Weatherization on Primary Heating

In this section, our team summarizes the ex post gross energy savings for weatherized homes that use natural gas, electricity, and delivered fuel (i.e., heating oil or propane) as the fuel for the primary heating system.

Natural Gas

Approach

Consistent with the previous EWSF impact evaluation, our team used billing analysis to evaluate energy savings for weatherized natural gas-heated homes. As noted previously, weatherization refers to one or more of the following measures: air sealing, attic insulation, wall insulation, and floor/basement insulation.

The team started by identifying the qualifying set of weatherized 2021 EWSF participants to include in the billing analysis' treatment group. To qualify, the participant needed to pass the screening criteria listed in Table 4. Some participants in program data do not match billing data either because they are no longer customers, there is some mismatch/typo in the program data, or a data set was incomplete. We also removed natural gas participants without sufficient billing records or whose usage exhibited extreme or counter-intuitive energy consumption.

In total, our billing analysis used a total of 1,955 weatherized natural gas-heated households. This represents 60% of the total weatherized natural gas-heated households from 2021.

Table 4. Billing Analysis Sample Attrition – Natural Gas

Reason for Exclusion	Removed	%	Remaining
All Homes			**3,278**
Could not be mapped to billing data	520	16%	2,758
Insufficient (< 12 months) pre- and/or post-participation billing data	746	23%	2,012
Did not match control with enough data in post period	2	<1%	2,010
Energy consumption outliers (<1st and >99th Percentile)[12]	40	2%	1,970
Extreme consumption behavior (< 500 annual therms or > 10,000 annual therms)	0	0%	1,970
Extreme changes in consumption (±>50% change between pre and post)	15	<1%	1,955
Overall	**1,323**	**40%**	**1,955**

[12] 1% = 237 therms/year, 99% = 2,639 therms/year

Table 4 also references matching participants in the treatment group to a control group. Consistent with the previous EWSF impact evaluation and residential billing analysis evaluation best practices[13], the team used a pool of matched "future" participants (i.e., EWSF participants that weatherized their home in 2022) as the control group. Assuming the program and the mix of participants remain consistent over time, the future participants will resemble the current participants, except for the timing of their involvement in the program.

ARE BILLING ANALYSIS RESULTS GROSS OR NET?

Billing analysis produces a result that lies on a spectrum between net and gross savings. The exact location on that spectrum depends on the customers in the control group and the measure in question. Since we are focusing the billing analysis on weatherization, as well as using future participants as our control group, the results of our billing analysis—per the guidance of the Uniform Methods Project—should be considered **gross**. This interpretation is consistent with the previous EWSF impact evaluation.

Specifically, the team identified 2022 participants with total observed pre-program annual energy consumption usage and monthly usage profile similar to 2021 participants in the treatment group. The control group is anticipated to exhibit similarities with the treatment group concerning general demographics, behaviors, and home characteristics, more so than the overall population.

After identifying the appropriate customer for the treatment and control group, our team used the post-program regression (PRR) model specification, below, to estimate weatherization savings for participants who heat their homes with natural gas:

$$ADC_{ct} = b_1 Treatment_c + b_2 Therm_c + b_3 DHW_c + b_4 ASkit_c + b_5 LagADC_{ct} + \sum_{month\ i} b_{6i} Month_{it} + b_7 CrossProg_c + e_{ct}$$

Where:

- ADC_{ct} = average, daily energy consumption for customer *c* at calendar month *t*
- $Treatment_c$ = 1 if customer *c* is in treatment group, 0 if customer *c* is in control group.
- $Therm_c$ = 1 if customer *c* is received a programmable or Wi-Fi thermostat, 0 if customer *c* did not receive a thermostat.
- DHW_c = *1* if customer *c* installed measures improving their domestic hot water system (DHW), 0 if customer *c* did not receive DHW measures.
- $Askit_c$ = *1* if customer *c* is received an Air Sealing kit[14], 0 if customer *c* did not receive an Air Sealing kit.
- $LagADC_{ct}$ = average daily consumption from customer *c* during calendar month *t* of the pre-program period
- $Month_{it}$ = 1 when index i = calendar month *t*, 0 otherwise. We include this series of 12 terms

[13] Agnew, K.; Goldberg, M. (2017). Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68564. http://www.nrel.gov/docs/fy17osti/68564.pdf

[14] Air sealing kits are a combination of lighting and air infiltration improvement measure. The kits provide better air sealing for recessed lighting cans on thermal boundaries after replacing incandescent or halogen lamps with LEDs (since LED bulbs do not require the same airflow to safely distribute lighting waste heat).

to capture month-specific effects in our analysis.

- $CrossProg_c$ = 1 if customer *c* received an energy-efficiency measure from any non-EWSF program.[15]
- e_{ct} is a cluster-robust error term for customer c during billing cycle t. Cluster-robust errors account for heteroscedasticity and autocorrelation at the customer level.

For this model, the study used billed, pre-program period weather-normalized energy consumption as an explanatory variable which helps to condition expected, billed energy consumption in the post-program period. The model also includes monthly fixed effects and uses the model to interact these monthly fixed effects with the pre-program energy use variable, which allows pre-program usage to have a different effect on post-program usage in each calendar month. In addition, the model excluded any consumption data associated with the month the customer participated. For example, if the customer was weatherized on February 15th, the customer's pre-period stopped at the end of January while their post-period started at the beginning of March.

The team modeled consumption during the pre and post period using the following model:

$$ADC = \mu + \beta_H H_m$$

Where H_m is the average daily heating degree days at the base temperature(τ_H) during month m, based on daily average temperatures on those dates. The team calculated base temperatures τ_H using a variable degree day analysis. The values μ & β_H are fit to the data and describe the base, heating, and cooling behaviors of a participant. The team uses the parameters to calculate a weather normalized Consumption as $\mu + \beta_H \hat{H}_m$ where $\hat{H}_m$ is the average heating degree days based on average temperatures for the corresponding month m from the TMYx (2007-2021) normalized temperature data.

Results

As shown in Table 5, we determined that natural gas-heated EWSF participants who weatherized their homes saved 131 therms/year on average, which reflects 13% of total pre-participation natural gas consumption and 17% of the average annual heating consumption.

These results represent the average savings for all natural gas-heated EWSF weatherization participants. They reflect the range of air sealing, duct sealing, and insulation installed across natural gas-heated participants, which varied for each customer, and are applicable as an average savings value to any natural gas-heated participants that weatherized their home through EWSF. As a reminder, all participants included in the analysis received at least insulation measure. and 96% of those participants also received air sealing, while and 21% received duct sealing.[16]

[15] The total savings from Cross Program analysis was consistent across multiple specification of the model.

[16] According to the program tracking data, none of the natural gas heated participants included in the billing analysis sample received lighting measures. As a result, the team did not conduct a separate analysis to adjust the modeled savings in Table 5 to account for any additional gas consumption required to offset the lost waste heat from the less efficient lighting replaced by the program.

Table 5. Natural Gas Billing Analysis Results (2021 Participants)

Measure	Billing Analysis Sample N	Energy Savings (Therms)	Precision at 90% Confidence (% +/-)	Normalized Annual Total Consumption (Therms)	% of NAC	Normalized Annual Heating Consumption (Therms)	% of Heating NAC
Weatherization	1,955	131	6%	1,048	13%	785	17%

As shown above in the model's specification, the team included terms to control for the savings generated by non-weatherization EWSF measures like thermostats, DHW measures, and air sealing kits. This presence of these terms avoids underspecifying the model. None of the modeled results for the non-weatherization measures in the PPR model were statistically significant.

To validate the PPR-generated estimate, as well as the model specification's ability to control for non-weatherization EWSF measures, the team calculated an alternate estimate using a different model that excluded the 474 participants in the billing analysis that installed measures other than weatherization. In other words, the alternative model was limited to the remaining 1,569 participants that only installed weatherization. This adjustment lowers the sample size by ~ 25% (which may make it less representative of the larger population of EWSF participants), but it effectively isolates weatherization as the source of observed savings. This alternative model yielded an estimated savings of 132 therms/year – nearly identical to the savings determined through the more inclusive model.[17] The outcome of the alternative model supports that the original estimate and confirmed the model specification is properly attributing the savings to weatherization and not to other EWSF natural gas measures.

WHY NOT MODEL INSULATION AND AIR SEALING SEPARATELY?

Since virtually every EWSF weatherization participant had air sealing performed and insulation installed together (96% received both, while 4% received insulation only) on the same day, the measures are collinear, meaning the regression model cannot distinguish between the impact of each measure on observed changes in consumption. Also, EWSF claims and reports savings at the whole house level for weatherization and not for individual measures. As such, the team summarized our findings accordingly.

WHAT ABOUT MODELING EACH TYPE OF INSULATION?

Collinearity also complicates modeling savings for specific types of insulation (e.g., wall or attic insulation) and, in general, adds significant uncertainty to the model. Consequently, this study – like the previous EWSF evaluation – focused on assessing weatherization (air sealing and all types of insulation) as a composite measure. It is possible to use supplementary non-statistical approaches, such as building simulation, to disaggregate billing results and attribute the savings to air sealing and specific types of insulation. This study did not include building simulation; the previous EWSF impact study did.

[17] Both estimates fall within each other's confidence bounds. The average size, age, and number of stories was not significantly different between those that did and did not participate in other measure.

The savings observed through a pooled regression analysis reflect an average value and are never uniform across all customers. To provide the program with more insight, the team segmented the EWSF participants in the natural gas billing analysis into quartiles by home size (i.e., square footage) and vintage (i.e., age of home).

Table 6 and Table 7 provide these summaries, which show some variation in the point estimates across quartiles. However, none of the size- and vintage-specific savings were statistically significantly different from one another – or the program-wide average savings – at the 90% confidence level.

Table 6. Natural Gas Billing Analysis Results by Building Size

Size Quartile	Mean Sqft	Average Savings	Precision at 90%	Mean Age
1st	1,032	132	10%	58
2nd	1,377	140	11%	63
3rd	1,809	115	14%	58
4th	2,763	126	16%	55

Table 7. Natural Gas Billing Analysis Results by Building Vintage

Age Quartile	Mean Age	Average Savings	Precision at 90%	Mean Sqft
1st	23	110	16%	2,058
2nd	41	128	12%	1,471
3rd	65	141	11%	1,470
4th	101	131	14%	1,837

Benchmarking

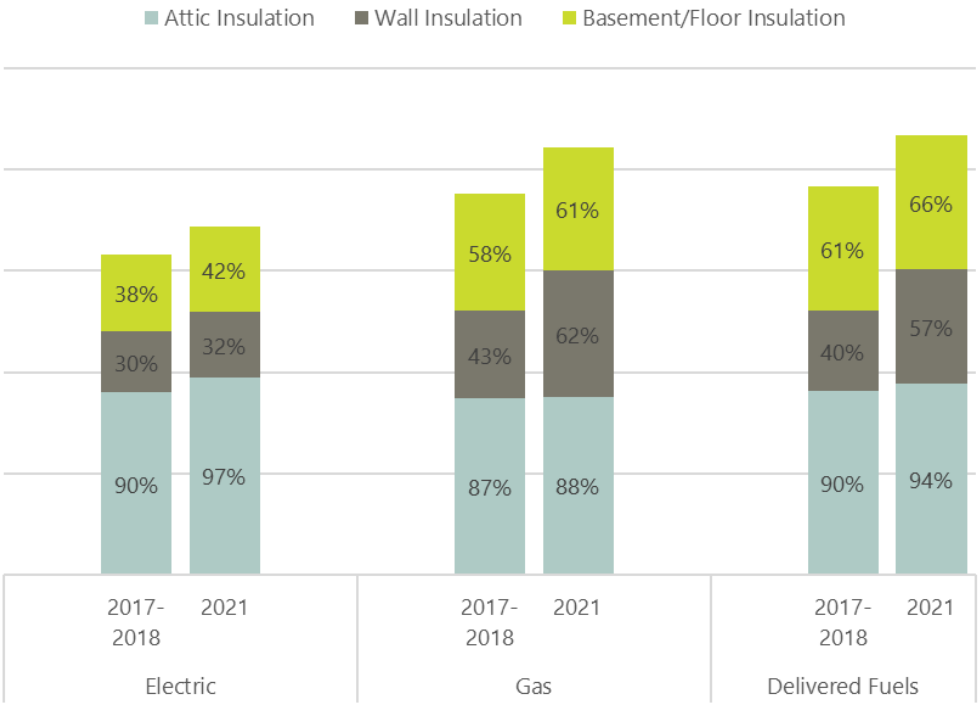
The team's average ex post billing analysis savings for natural gas heated participants weatherized in 2021 are higher than the billing analysis results (96 therms, ±6% precision) estimated as part of the previous EWSF impact evaluation, which informed the program's ex ante assumption. It is worth noting that the two results are statistically significantly different at the 90% confidence level (i.e., the confidence intervals for the two estimates do not overlap).

The team investigated several potential factors impacting the difference between the previous and current evaluation results, including:

- **Difference in types of insulation.** As shown in Figure 4, the team did observe a meaningful difference in rates at which the 2017-2018 and 2021 cohorts installed insulation. On average, 2021 natural gas weatherization participants installed more types of insulation (i.e., attic, wall, and floor each counting as 1.0 insulation type) in their home relative to participants in 2017-2018. For example, the average 2021 participant installed 2.11 types of insulation – up from 1.88 in 2017-2018. Most of the difference comes from a jump in percentage of participants that installed wall insulation, which increased from 43% to 62%. Simply put, 2021 participants more comprehensively insulated their homes compared to 2017-2018 participants so it follows that the savings for 2021 participants would be higher. The figure below shows the trend (more types of

insulation in 2021 compared to 2017-2018) held true for weatherized participants heating with electricity and delivered fuels.[18]

Figure 4. Installed Types of Insulation by Fuel: 2017-2018 and 2021



- **Differences in pre-period heating consumption.** The difference in savings between this and the previous evaluation is not a function of more recent participants having greater pre-program consumption and, consequently, greater opportunity for energy saving. In fact, the opposite is true: the cohort of 2017-2018 participants included in the previous evaluation's natural gas billing analysis had an average pre-program annual heating consumption of 889 therms, which is 13% higher than the average for the 2021 participants included in this evaluation (785 therms).[19] This means the higher savings found as part of this evaluation is driven by other factors (such as greater insulation install rates).
- **Difference in participant characteristics.** The team compared natural gas heated building home characteristics available in the EWSF tracking data across evaluations. We found that, on average, the 2021 participants generally lived in relatively newer and larger homes than the 2017-2018

[18] The frequency of duct sealing insulation was not significantly different between the two evaluated cohorts. In 2017-2018, 20% of weatherization participants had their ducts sealed, while 21% received duct sealing in 2021.

[19] This finding – less residential heating usage in 2021 relative to 2017-2018 – may seem counterintuitive given the behavioral changes (i.e., spending more time at home) that occurred because of the COVID-19 pandemic. However, the finding is consistent with the Residential Building Use and Equipment Characterization study in neighboring Massachusetts. That study found: "The peak day demand for cooling end uses increased, while the demand for heating end uses (boilers, furnaces, and hardwired electric heat) decreased. These shifts can be explained by the increases in homes' internal heat loads. People being home, cooking, working, and using office equipment more during the pandemic likely increased the average heat gain of the home, which added to the cooling load and decreased the resulting heating load." (https://ma-eeac.org/wp-content/uploads/Residential-Building-Use-and-Equipment-Characterization-Study-Comprehensive-Report-2022-03-01.pdf)

cohort.[20] While larger homes tend to use more energy for heating, newer homes tend to be home efficient.

Table 8. Home Characteristics Comparison

Analysis Year	Home Vintage	Home Area (SF)	Number of Stories
2017-2018	1944	1,641	1.6
2021	1959	1,772	1.6

- **Covid interactions.** 2021 and 2022 saw multiple surges of COVID-19 variants, which may have impacted customers' normal behaviors. Although the evaluation team included a control group, which theoretically accounts for these types of non-programmatic changes in energy usage, we definitively cannot rule out any COVID-related impacts amongst 2021 participants that were different than our control group of 2022 participants.

For broader context, Table 9 compares the results of this—and the previous EWSF impact evaluation—to several residential retrofit programs around New England. While the design and delivery of each program differs somewhat,[21] all the programs focus on encouraging participants to weatherize their homes using a home energy assessment and offering incentives to offset the cost of weatherization.

As evident in the Table 9, the average savings for weatherized 2021 natural gas heated EWSF participants is higher than the results of comparable program evaluations in Massachusetts and Connecticut.

Table 9. Benchmarking: Previous RI Studies and Other Regional Weatherization Programs (Natural Gas)

State	Program	Evaluated Program Year(s)	Energy Savings (Therms)	Precision (% +/-)	% of NAC	Billing Analysis Sample N
RI	**EWSF**	**2021**	**131**	**6%**	**13%**	**1,955**
RI	EWSF	2017-2018	96	6%	8%	2,156
RI	EWSF	2014	108	10%	10%	1,252
RI	IES (SF)	2015-2016	124	5%	13%	785
CT	HES	2019	80	11%	7%	1,117
MA	HES	2015-2016	127	2%	14%	3,357

[20] Since this weatherization-focused impact evaluation did not include a concurrent process evaluation, the team cannot speak to any changes in program delivery that may have caused the average home age to change since the previous evaluation. It is also possible the change is unrelated to a delivery change and rather a function of program's saturation into the residential housing stock in Rhode Island and/or a function of the data collection process.

[21] The most notable difference is that the Home Energy Solutions (HES) program in Connecticut conducts air sealing during the initial home energy assessment itself (versus during a subsequent visit to install insulation like EWSF and the Residential Coordinated Delivery program in Massachusetts). For more information about HES visit: https://energizect.com/energy-evaluations/HES

Electricity

This section details the team's analysis of electrically heated weatherization participants.

Approach

To determine the savings associated with the weatherization of homes using electricity as their primary heating fuel, the team took two steps: determining the amount of electricity weatherization participants used before the program and the relevant percent of consumption saved as a result of weatherizing through EWSF. The former was possible using consumption data provided by RI Energy, while the latter required the team make engineering adjustments to - and then apply – the natural gas billing analysis findings.

Primary Heating Fuel	Annual Pre-Consumption	% Saved by Wx
Natural Gas	**Known** (Bill disaggregation of RI Energy provided participant monthly energy consumption data.)	**Known** (Statistically significant billing analysis results)
Electricity	**Known** (Bill disaggregation of RI Energy provided participant monthly energy consumption data.)	**Unknown** (Unable to model statistically significant billing analysis results due to limited participation)

The team adopted this approach after a PPR model – like that used to evaluate savings for natural gas-heated participants – was unable to produce significant estimates for weatherization savings in electrically heated homes (i.e., better than ±20% precision at the 90% confidence level).

Table 10 shows the attrition that produced the final data for analysis. There are an order of magnitude less electrically heated homes than gas heated homes that received weatherization measures as part of the EWSF program, which is the primary reason the team could not model results with the required statistical significant using a comparable regression-based approach.

Table 10: Billing Analysis Sample Attrition – Electricity

Reason for Exclusion	Removed	%	Remaining
All Homes			**223**
Has lighting measures installed	29	13%	194
Could not be mapped to billing data	22	10%	172
Insufficient (< 12 months) pre- and/or post-participation billing data	1	<1%	171
Did not match control with enough data in post period	21	9%	150
Extreme consumption behavior[22] (< 100 avg monthly kWh or > 10,000 monthly kWh)	35	16%	115
Energy consumption outliers (<1st and >99th Percentile)	3	1%	112

[22] The team observed more outlying usage profiles – and therefore greater attrition – as part of the electric billing analysis than the natural gas billing analysis. This is a function of two related factors. First, the team observed greater variation in electric usage than natural gas usage, which resulted in identifying more outliers. Second, there are generally more ways for residential customers to incur outlying usage patterns for electricity (e.g., crypto-mining, or indoor agriculture) than possible for natural gas.

Reason for Exclusion	Removed	%	Remaining
Extreme changes in consumption (±>50% change between pre and post)	12	1%	110
Overall	**113**	**51%**	**110**

Annual Pre-Consumption

Electric pre consumption was modelled the same as gas, but electricity has an explicit temperature sensitive cooling component:

$$ADC = \mu + \beta_H H_m + \beta_C C_m.$$

Where:

- H_m is the average daily heating degree days at the base temperature(τ_H) during month m, based on daily average temperatures on those dates.
- C_m is the average daily cooling degree days at the base temperature(τ_C) during month m.

The team calculated base temperatures τ_H and τ_C using a variable degree day analysis. The team fit values μ, β_H & β_C to the data and describe the base, heating, and cooling behaviors of a participant. The team used these parameters to calculate a weather normalized Consumption as $\mu + \beta_H \hat{H}_m + \beta_C \hat{C}_m$ where $\hat{H}_m$ and $\hat{C}_m$ are the average heating and cooling degree days based on average temperatures for the corresponding month m from the TMYx (2007-2021) normalized temperature data. The team focuses on the heating component of the electricity consumption which is annualized by calculating 365.25 * $\beta_H H_m$

The data provided by Rhode Island Energy indicated the average weatherized participant heating with electricity consumed 14,164 kWh annually. Using billing disaggregation, the team determined that 5,585 kWh (or 40%) of these participants total annual electric consumption was heating related. To confirm this value, which was lower than the team's expectations, the team compared it to the difference in total electric usage (6,311 kWh) between participants identified in the program data as heating with natural gas (7,853 kWh) and electric (again, 14,164 kWh). Holding all other factors constant, the difference in electric consumption between these two participant types is the customer's electric heating consumption. While 6,311 kWh is higher than 5,585 kWh, the relatively proximity of the two values confirmed the validity of the 5,585 kWh heating load for electric heating weatherization participants.

WHAT ABOUT SEASONAL RESIDENTS?

EWSF does not track it, but it is possible that some program participants do not live full-time in their weatherized home (e.g., winter in another place). This could be a factor in the lower-than-expected electric heating load observed through this analysis, although the same phenomenon is equally possible for natural gas heated participants. The team's analysis process also identifies and filters out customers with missing data and large variations in usage.

While possible – if not likely – that some portion of EWSF participants are "snowbirds", the purpose of this impact evaluation was to estimate average savings for the set of customers that participated in the program in 2021 - independent of their occupancy status. If the program is interesting in understanding and assessing savings by occupancy status, the team recommends RI Energy collect such data to inform future evaluations.

Estimating Percent Savings

As noted above, none of the team's model specifications yielded savings results for electric customers that met the team's statistical significance threshold.

Again, the primary reason our team was unable to specify a model with statistically significant savings estimate was the relatively small number of 2021 EWSF weatherization participants that use electricity as their primary heating fuel (n=223). In fact, after applying the quality assurance steps outlined in Table 4, the team was only able to apply the PPR model to 110 customers with electric primary heating. For comparison's sake, the team modeled 1,955 natural gas heated customers.

Since the team was unable to use billing analysis to estimate weatherization savings for electric primary heating, the team used an engineering approach that leveraged the statistically significant billing analysis result for natural gas. The reason our team uses an approach rooted in the natural gas billing analysis (instead of a separate engineering algorithm or building simulation approach) is because of billing analysis' implicit ability to account for the myriad of factors (e.g., pre-conditions, installation quality, behavioral change, and non-programmatic macro trends) that those approaches do not.

However, applying the natural gas billing analysis results to other fuel types requires care. Specifically, the team applied several engineering adjustments to the natural gas billing analysis results to estimate the weatherization savings in electrically heated homes. These included accounting for the following differences between natural gas and electrically heated customers:

- **Installed Insulation.** The data provided by RI Energy for the 2021 cohort did not support disaggregation of the installed insulation (sqft) by insulation type (e.g., attic, wall, and floor). However, our team had access to this information from the previous evaluation. Consequently, we applied 2017-2018 installed insulation amounts to the percent of 2021 participants who installed each type of insulation, which was provided. The result is a weighted average area of installed insulation by fuel type (Table 11). When comparing electrically heated homes to natural gas heated homes, electrically heated homes installed 90% of the insulation per home (59% divided by 65%) compared to gas heated homes, after controlling for differences in homes sizes. As a result, the team developed a 90% adjustment factor to apply to the observed natural gas percent savings from the billing analysis before applying it to electric weatherization participants.

Table 11. Installed Insulation Area: Comparison of Electrically and Natural Gas Heated Participants

Fuel Type	Home Vintage	Home Floor Area (sqft)	Insulation Installed Per Home (sqft)	Insulation As % of total Home Floor Area	Adjustment Factor
Gas	1960	1,756	1,146	65%	1.00
Electricity	1969	1,464	861	59%	0.90

- **Pre-program conditions.** The team also explored the necessity of an additional adjustment to account for potential differences in pre-program insulation levels between natural gas and electrically heated customers. In other words, did natural gas and electrically heated customers enter the program with different existing conditions (e.g., pre-program attic R-values) prior to

being weatherized through EWSF? If so, it would be important for the team to account for that difference when leveraging the natural gas billing analysis results to estimate electric weatherization savings. Since the 2021 program tracking data provided by RI Energy for this evaluation did not include each participant's pre-program R-values, the team again leveraged tracking data from the previous EWSF which did.[23] As shown in Table 12, the team found the average[24] pre-program existing conditions in attic, wall, and floor were similar between electric and natural gas participants, but not identical.

Table 12. Insulation R-Value Comparisons: Electrically and Natural Gas Heated Participants

Insulation Type	Fuel Type	Average Pre-Program R-value[25]	Average Post-Program R-value	ΔU-factor[26]
Wall	Natural Gas	3.6	12.2	0.77
	Electricity	3.8	12.1	0.63
Attic	Natural Gas	3.4	33.2	0.26
	Electricity	4.0	38.1	0.22
Floor	Natural Gas	3.7	19.7	0.22
	Electricity	3.9	21.8	0.21

The team calculated the difference in the U-factors associated with the pre- and post- condition R-values, and weighted those differences by the relative proportion of insulation type to arrive at an overall adjustment factor. The adjustment factor accounts for both the difference in pre- and post- program conditions, as well as the differences in types of installed insulation (wall, attic, and floor), as shown in Table 13.[27]

In general, the electrically heated homes weatherized in 2021 tended to be better insulated prior to the participating in EWSF than natural gas heated homes. As a result, the team needed to make a downward adjustment before applying the savings percentage from the natural gas billing analysis to weatherized electrically heated participants.

[23] The implicit assumption here is that any differences in existing conditions by primary heating fuel type observed in the 2017-2018 data would still be true for 2021 participants.
[24] Please note the team converted the R-values in the tracking data to U-values before averaging them.
[25] The team identified assembly U-factors for pre-conditions with no insulation, converted these U-factors to R-values, and substituted these assembly R-values for instances in the raw program data where pre-condition R-values were lower than the assembly R-values. The team made this adjustment to avoid overestimating relative differences between pre-conditions for natural gas and electrically heated homes, since small differences in insulation pre-conditions can be amplified when calculating U-factors.
[26] The team converted pre- and post- R-values to U-factors for a more accurate comparison of insulation characteristics across fuel types.
[27] Please see the evaluation's supporting workbook for more details about this analysis.

Table 13. Insulation U-factor Comparisons: Electrically and Natural Gas Heated Participants

Insulation Type	Fuel Type	ΔU-factor[26]	ΔU-factor Relative to Natural Gas	2021 Insulation Count	Insulation Count Relative to Natural Gas
Wall	Natural Gas	0.77	100%	0.62	100%
	Electricity	0.63	81%	0.32	52%
Attic	Natural Gas	0.26	100%	0.88	100%
	Electricity	0.22	86%	0.97	110%
Floor	Natural Gas	0.22	100%	0.61	100%
	Electricity	0.21	93%	0.42	69%
Weighted average adjustment factor compared to NG					**87%**

The results from applying these adjustment factors accounting for installed insulation and R-value differences are summarized in Table 14.

Table 14. Estimated Electric Percent Heating Savings

Metric	Value	Notes
Natural Gas Percent of Heating Savings	**17%**	Based on billing analysis bill disaggregation; weather normalized using TMYx (2007-2021)
Adjustment Factor #1: Installed Insulation	90%	Electricity participants installed less insulation per square foot of home floor area
Adjustment Factor #2: R-value Differences	87%	Electricity participants had more existing insulation pre-program, and generally had less frequent insulation installations than natural gas participants
Electricity Percent Heating Savings	**13%**	

Results

Using this approach, we determined that EWSF participants saved 13% of pre-participation household electricity heating consumption. Applying this value to the electric heating consumption determined through the bill disaggregation resulted in an average savings of 732 kWh/year. This savings is lower than the previous evaluation's estimate of 803 kWh. Comparing these two values, which represent the program's ex ante and ex post savings, yields a gross realization rate of 91%.

Please note these savings reflect the savings in primary electric heating usage as well as secondary electric heater usage (when relevant) since the evaluation team used total electric heating load, which includes both, to estimate savings. Electric savings associated with weatherization effect on cooling usage and decreased use of electric furnace fans/pumps or blowers are reported separately—for all primary heating fuel types—in Section 5.[28]

[28] Section 4 includes estimates for secondary electric heater usage for homes heated primarily with natural gas and delivered fuels.

Table 15. Electric Weatherization Results (2021 Participants)

Measure	Total Participants	Energy Savings (kWh/year)	Normalized Annual Consumption (kWh)	% of NAC	Normalized Annual Heating Consumption (kWh)	% of Heating NAC
Weatherization	110	732	14,164	5%	5,585	13%

Benchmarking

Like the natural gas results, our team compared the 2021 electric heating savings to the previous EWSF evaluation, as well as residential retrofit programs in neighboring Massachusetts and Connecticut. Again, we found average savings for weatherized 2021 electrically heated EWSF participants is similar to these regional benchmarks.

Table 16. Benchmarking: Other Regional Weatherization Programs (Electric)

State	Program	Evaluated Program Year(s)	Energy Savings (kWh/year)	% of NAC
RI	**EWSF**	**2021**	**732**	**5%**
RI	EWSF	2017-2018	803	11%
RI	IES (SF)	2015-2016	1,616	23%
CT	HES	2019	586	9%
MA	HES	2015-2016	1,298	N/A

Delivered Fuels

Approach

Unlike the monthly natural gas and electric consumption data provided by RI Energy, the team did not attempt to obtain detailed usage data for weatherized EWSF participants that heat their homes with heating oil or propane. This meant that the team could not use direct information about delivered fuel usage to determine annual pre-program consumption or to undertake a billing analysis to model savings.

Primary Heating Fuel	Annual Pre-Consumption	% Saved by Wx
Natural Gas	**Known** (Bill disaggregation of RI Energy provided participant monthly energy consumption data.)	**Known** (Statistically significant billing analysis results)
Delivered Fuels	**Unknown** (No access to participant consumption records)	**Unknown** (Unable to complete billing analysis without consumption records)

Consequently, the team again leveraged the natural gas billing analysis – first to estimate the annual pre-program heating consumption for delivered fuel participants and, second to estimate the percent of that consumption they saved after weatherizing their home through EWSF.

Estimating Annual Pre-Consumption

The team estimated the delivered fuel pre-period heating consumption by adjusting the observed natural gas pre-period heating consumption (784 therms or 78.4 MMBTUs) using two factors: differences in home size and equipment efficiencies between natural gas and delivered fuels participants.

- **Home size.** The square footage of a home impacts the volume of space that the heating system must heat (i.e., the size of the heating load). Since average home sizes can differ by heating fuel type,[29] the team compared the average home size for natural gas and delivered fuel heated participants in 2021. As shown in Table 17, delivered fuel homes were slightly smaller on average (1,728 compared to 1,772 square feet). As a result, the team made a modest downward adjustment to the observed natural gas pre-program heating consumption when converting it to reflect likely delivered fuel consumption.

Table 17. Delivered Fuels Average Annual Pre-Period Heating Consumption

Fuel Type	Home Floor Area (SF)	Home Floor Area relative to Natural Gas
Natural Gas	1,772	100%
Delivered Fuels	1,728	98%

[29] Fuel types are often associated with specific building types and/or vintages, which are, in turn, correlated with home size.

- **Heating equipment efficiency.** For delivered fuel heating equipment, the team reviewed the latest Department of Energy (DOE) Technical Support Documents (TSD) to identify the relevant equipment efficiency assumptions and compare them across fuels. The team also compared the DOE assumptions to those used in the previous EWSF evaluation, as well as other regional TRM assumptions (Table 18) The MA and RI TRMs used similar efficiencies across fuel types, but the more recent DOE standards showed greater differences across fuel types. Considering DOE's furnace lifetime estimate of 21 years, the team assumed the efficiency of installed equipment would include a blend of the older and newer DOE standards. The team calculated a weighted average by dividing the equipment lifetime by the years elapsed since 2015 (6 years, or 1/3 of the total equipment lifetime), and weighting the newer standard efficiency levels by this amount and the older standards by 2/3 of the equipment lifetime. The team compared the average efficiency assumption for oil and gas furnaces (79% and 78%, respectively) and applied a modest downward adjustment (78% divided by 79%, or 99%) to the annual heating consumption to account for the higher assumed efficiencies for oil compared to gas furnaces.

Table 18. Equipment Efficiency Comparisons and Assumptions

Source	Oil[30] Furnace Efficiency	Gas Furnace Efficiency
EWSF 2021	**79%**	**78%**
DOE, Prior to 2015	78%	78%
DOE, 2015-current	83%	80%
MA TRM	77-80%	80%
RI TRM	81%	81%

The team did not have access to equipment saturation data in the 2021 dataset, thus we were unable to identify the split between installed furnaces and boilers across fuel types. The differences between oil and non-condensing gas furnace efficiencies are similar to the differences between oil and gas boiler efficiencies, therefore the team made a simplifying assumption to only apply the differences between gas and oil furnace efficiencies as the basis for adjusting the natural gas savings to delivered fuels. Future evaluations could improve on this analysis by analyzing the equipment saturations by fuel type as well as

[30]As part of EWSF, delivered fuels refers to both heating oil and propane. However, for this system efficiency analysis, the team focused on heating oil efficiencies since propane equipment efficiencies are similar to gas and represented a very small portion of the program.

the installed baseline equipment efficiencies, since it is likely that condensing gas furnaces with much higher efficiencies compared to oil furnaces are being more frequently installed in recent years.

Based on these two adjustments to the observed natural gas consumption, the team estimated 2021 delivered fuel-heated weatherization participants used an average of 76.2 MMTBUs/year to heat their homes before they participated in EWSF (Table 19).

Table 19. Estimating Delivered Fuel Heating Consumption

Metric	Value	Notes
Natural Gas Heating Consumption (therms/year)	**784**	Based on billing analysis bill disaggregation; weather normalized using TMYx (2007-2021)
Adjustment Factor #1: Home Size	98%	Delivered fuels participants installed less insulation per square foot of home floor area
Adjustment Factor #2: Equipment Efficiency	99%	Adjustment accounting for marginally more efficient delivered fuel equipment compared to natural gas
Fuel Conversion (therms-to-MMBtu)	0.1	
Delivered Fuel Heating Consumption (MMBtu/year)	**76.2**	

Estimating Percent Savings

Not having access to delivered fuel consumption records to determine average annual consumption also meant that the team could not conduct a delivered fuel-specific billing analysis. To overcome this and estimate how much energy weatherized delivered fuel participants saved, the team had to make an important assumption: holding other factors constant, the weatherized natural gas and delivered fuel participants save the same percentage of their pre-program heating consumption.

However, rather than apply this assumption unchecked, the team investigated the validity that these "other factors" are indeed the same for natural gas and delivered fuel participants like the approach used for electrically heating homes. Specifically, the team reviewed and made adjustments to the observed percent savings found through the natural gas billing analysis before applying it for delivered fuel participants for the following two factors: the amount and types of insulation installed and the pre-program conditions.

- **Installed insulation.** To estimate the delivered fuels heating energy savings, the team completed the same approach for delivered fuels as described in the electricity section above accounting for differences in area of installed insulation (Table 20). When comparing delivered fuel heated homes to natural gas heated homes, delivered fuel heated homes installed 3% less insulation per home (63% divided by 65%), thus the team applied a 97% adjustment factor to the natural gas savings.

**Table 20. Installed Insulation Area:
Delivered Fuels Homes Compared to Natural Gas**

Fuel Type	Home Floor Area (sqft)	Insulation Installed Per Home (sqft)	Insulation As % of to Home Floor Area	Adjustment Factor
Gas	1,756	1,146	65%	1.00
Delivered Fuels	1,728	1,095	63%	0.97

- **Pre-Program Conditions**. Again, the team checked for potential differences in pre-existing conditions for delivered fuel customers (relative to natural gas participants) and found marginal differences (Table 21).

Table 21. Insulation R-Value Comparison: Delivered Fuels Homes Compared to Natural Gas

Insulation Type	Fuel Type	Average pre R-value[31]	Average post R-value	ΔU-factor
Wall	Natural Gas	3.6	12.2	0.8
	Delivered Fuels	3.5	12.1	0.7
Attic	Natural Gas	3.4	33.2	0.3
	Delivered Fuels	3.4	32.3	0.3
Floor	Natural Gas	3.7	19.7	0.2
	Delivered Fuels	3.7	19.7	0.2

Consequently, the team made a marginal adjustment to the percent of savings determined through the billing analysis before applying it to delivered fuel participants (Table 22).

**Table 22. Insulation U-factor Comparison:
Delivered Fuels Homes Compared to Natural Gas**

Insulation Type	Fuel Type	ΔU-factor	ΔU-factor Relative to Natural Gas	2021 Insulation Count	Insulation Count Relative to Natural Gas
Wall	Natural Gas	0.8	100%	0.62	100%
	Delivered Fuels	0.7	96%	0.57	92%
Attic	Natural Gas	0.3	100%	0.88	100%
	Delivered Fuels	0.3	101%	0.9	102%
Floor	Natural Gas	0.2	100%	0.61	100%
	Delivered Fuels	0.2	99%	0.66	108%
Weighted average adjustment factor compared to NG					**99%**

[31] Ibid.

The results from applying these adjustment factors accounting for the differences in installed insulation and pre-program conditions are summarized in Table 23.

Table 23. Estimated Delivered Fuels Percent Heating Savings

Metric	Value	Notes
Natural Gas % of Heating Savings	**17%**	Based on billing analysis bill disaggregation; weather normalized using TMYx (2007-2021)
Adjustment Factor #1: Installed Insulation	97%	Delivered fuels participants installed less insulation per square foot of home floor area
Adjustment Factor #2: Pre-Program Conditions	99%	Delivered Fuels participants had marginally more existing insulation pre-program, thus slightly lower overall savings due to weatherization
Delivered Fuels Percent Heating Savings	**16%**	

Results

Using this approach, we determined that EWSF participants that use delivered fuels as their primary heating fuel saved 16% of pre-participation household delivered fuel heating consumption, or 12.2 MMBtu/year on average. This savings is higher than the previous evaluation's estimate of 9.8 MMBtu. Comparing these two values, which represent the program's ex ante and ex post savings, yields a gross realization rate of 125%.

Table 24. Delivered Fuel Weatherization Results (2021 Participants)

Measure	Total Participants	Energy Savings (MMBtu/year)	% of Heating NAC
Weatherization	**2,839**	**12.2**	**16%**

Benchmarking

Like the natural gas results, our team compared the 2021 delivered fuels heating savings to the previous EWSF evaluation, as well as residential retrofit programs in neighboring Massachusetts and Connecticut. The study found average savings for weatherized 2021 delivered fuel heated EWSF participants is similar to these regional benchmarks.

Table 25. Benchmarking: Other Regional Weatherization Programs (Delivered Fuels)

State	Program	Evaluated Program Year(s)	Energy Savings (MMBtu/year)
RI	**EWSF**	**2021**	**12.2**
RI	EWSF	2017-2018	10.0
RI	IES (SF)	2015-2016	12.6
CT	HES	2019	12.5
MA	HES	2015-2016	13.1

Section 4 Impact of Weatherization on Secondary Heating

In this section, our team summarizes the approach and results of our analysis of the impact of EWSF weatherization on secondary electric and other fuels (other than electric and natural gas) heating usage.

RI Energy hypothesized that homes weatherized through EWSF may change not only how they use their primary heating system but also—when present in the home—their secondary heating sources. For example, it is possible that, after weatherizing their home, a participant may stop or reduce using the plug-in heater since their weatherized home is less drafty. It is also possible that a weatherized participant could use their secondary heating system more because – post weatherization – it can sufficiently heat a portion of their home without turning on the primary heating system.

Approach

Determining the impact of weatherization on secondary electric heat usage involved two of the study's evaluation activities: the participant survey and billing analysis.

Participant Survey

The team used a survey of 436 participants that received weatherization measures in 2021 to answer two important questions (see Appendix B for participant survey results):

1. **What is the prevalence of secondary heating among participants?** More specifically, what percent of total weatherization participants used secondary heaters as a supplemental source of heating before and/or after participating in EWSF? The answer to this question was critical for correctly applying the weatherization savings associated with secondary heating to the full population of EWSF participants since many of which do not have secondary heaters.
2. **Which specific weatherized EWSF participants used secondary heaters before and/or after participating?** Identifying a subset of participants with known secondary heating was critical for the viability of the billing analysis.[32] This is because focusing the billing analysis on participants with known secondary heating reduces the total usage variance in our analysis sample (compared to a mix of participants that do and do not use secondary electric heat). Minimizing variance increased our team's ability to detect statistically significant changes in winter electric consumption associated with secondary heating sources before and after weatherization.

Table 26 shows the result of pre-program secondary heating equipment types the participant survey respondents reported who primarily heat their homes with natural gas. In total, the survey collected data on 393 participants that received weatherization measures and used natural gas as a primary heating fuel in 2021. [33]

[32] Because an explicit objective of the participant survey was to identify participants to include the secondary heating billing analysis, the team limited survey outreach to weatherization participants in 2021 that use natural gas or electricity as their primary heating fuel. This is because the team had consumption data for these participants and therefore could conduct a billing analysis; the same was not true for customers heating with a delivered fuel.

[33] Most of the electrically heated survey respondents indicated they used an electric source of secondary heat when applicable. The savings associated with any secondary electric heaters is already embedded in the estimate of primary electric heating savings.

Of these 393 participants, 147 indicated they used some kind of secondary heating source. Most (68%) self-reported using an **electric secondary heater** – most commonly a portable, plug-in type heater. The team estimated the savings associated with electric secondary heaters following EWSF weatherization using the secondary electric heating billing analysis described later in this section. The secondary heaters include sources with varying degree of efficiency, although most were less efficient options – most notably portable, plug-in models.

Another 13% indicated they used **wood or propane-**powered secondary heating source, specifically a wood or pellet-fired stove (9%) or a wood or propane fireplace (4%). The team estimated savings for these secondary heating participants using an engineering approach that leveraged the secondary electric heating billing analysis.

The remaining 16% of respondents cited using a **gas fireplace** for secondary heat. However, since all these participants also used natural gas as their primary heating fuel, any change in their gas fireplace usage is already embedded in the natural gas primary heating analysis shown in Section 3. Consequently, no additional analysis is required.

Table 26. Secondary heating equipment types (Natural Gas Primary)

Secondary heating equipment types	Equipment used for secondary heat	
	Count	%
Electric heaters	**116**	**68%**
Portable, plug-in heater	69	41%
Ductless mini-split system	17	10%
Electric baseboard	14	8%
Fireplace (electric)	13	8%
Wall mounted heater (electric)	3	2%
Gas heaters	**27**	**16%**
Fireplace (gas)	27	16%
Other fuels heating	**22**	**13%**
Wood or pellet stove	15	9%
Fireplace (propane, wood)	7	4%

Electric

Approach

In total, the team's survey collected data on 393 participants that received weatherization measures and used natural gas as a primary heating fuel in 2021.[34] Of these 393 respondents, 131 self-reported using

[34] The small number of remaining respondents (n=43) used electricity as their primary heating fuel, which the team used as part of the attempted electric billing analysis. As described earlier in this memo, the team was unable to specify a statistically significant electric weatherization model. Consequently, the analysis in this section focuses on weatherization participants that use natural gas as their primary heating fuel.

electric secondary heating sources before and/or after being weatherized through EWSF. This equates to a 33% saturation of secondary electric heating customers amongst weatherized EWSF participants.[35]

Billing Analysis

The impacts of secondary heating can be evaluated only when isolated from the primary heating fuel. The analysis only has access to billing data for electricity and gas utilities (no data on delivered fuel quantities). There were not enough participants with electric primary heating and gas secondary heating to generate reliable estimates. This billing analysis was limited to the participants with natural gas primary heating that use electricity to power a secondary source.

The team applied a similar method for determining the impact of weatherization on secondary electric heating as used for the natural gas primary heating analysis (described in section 0). However, for this analysis, the model focused on the two subpopulations – participants reporting use of secondary electric heaters and those that reported they did not –identified through the survey. Like the natural gas analysis, the team used a PPR regression to estimate secondary heating electricity savings due to weatherization.

Electric pre and post consumption was modelled the same as gas, but electricity has an explicit temperature sensitive cooling component:

$$ADC = \mu + \beta_H H_m + \beta_C C_m.$$

Where:

- H_m is the average daily heating degree days at the base temperature(τ_H) during month m, based on daily average temperatures on those dates.
- C_m is the average daily cooling degree days at the base temperature(τ_C) during month m.

The team calculated base temperatures τ_H and τ_C using a variable degree day analysis. The team fit values μ, β_H & β_C to the data and describe the base, heating, and cooling behaviors of a participant. The team used these parameters to calculate a weather normalized Consumption as $\mu + \beta_H \hat{H}_m + \beta_C \hat{C}_m$ where $\hat{H}_m$ and $\hat{C}_m$ are the average heating and cooling degree days based on average temperatures for the corresponding month m from the TMYx (2007-2021) normalized temperature data.

To qualify for inclusion in the analysis, the participant needed to be part of the natural gas primary heating system billing analysis and pass the screening criteria listed in Table 27, which removed participants without sufficient electric billing records or who were unable to identify a similar control that had data matching the appropriate post-period. We limited the analysis to the participants included in the natural gas primary heating billing analysis because we know that the customers have a complete, non-outlying usage of natural gas as their primary heating fuel therefore would not introduce uncertainty into this secondary heating-focused analysis.

In total, our billing analysis used a total of 132 weatherized natural gas-heated participants that completed the survey: 33 that self-reported they used secondary electric heating sources (before and/or after participation) and 99 that reported they did not.

[35] As noted above, the team intentionally only surveyed participants that use natural gas or electricity as their primary heating fuel. This average implicitly assumes the prevalence of secondary electric heating usage among participants heating with these regulated fuels is the same as those heating with delivered fuels.

Table 27. Billing Analysis Sample Attrition – Secondary Electric Heating

Reason for Exclusion	Remaining with Secondary Electric Heating	Remaining w/o Secondary Electric Heating
All homes with survey responses	**136**	**257**
Included in the gas analysis study	62	158
Could not be mapped to billing data	43	124
Insufficient pre- and/or post-participation billing data	35	108
Did not match control with data in post period	33	99
Overall	**33**	**99**

For the secondary electric heating model, the team used a pool of matched "future" participants (i.e., EWSF participants that weatherized their home in 2022) as the control group. The future participants used in the control group are not survey participants and their usage of secondary heat is unknown. Estimated savings are relative to the typical customer, not relative to the behavior of the study participants.

For this analysis, the team used the following regression specification to evaluate electric savings. Consumption refers to electric consumption in kWh. Here the Wx variable captures average weatherization savings, but the treatment component identifies the savings attributed to secondary heating use:

$$ADCct = b_1 Treatment_c + b_2 Wx_c + b_3 Therm_c + b_4 DHW_c + b_5 ASkit_c + b_6 LagADC_{ct} + \sum_{month\ i} b_{7i} Month_{it} + b_8 CrossProg_c + e_{ct}$$

Where:

- ADC_{ct} = average, daily consumption for customer *c* at calendar month *t*
- $Treatment_c$ = 1 if customer *c* uses a heating source to supplement home heating, 0 if customer *c* does not use a secondary heating source.
- $Therm_c$ = 1 if customer *c* is received a programmable or Wi-Fi thermostat, 0 if customer *c* did not receive a thermostat.
- DHW_c = *1* if customer *c* installed measures improving their domestic hot water system (DHW), 0 if customer *c* did not receive DHW measures.
- $Askit_c$ = *1* if customer *c* is received an Air Sealing kit, 0 if customer *c* did not receive an Air Sealing kit.
- $LagADC_{ct}$ = average daily consumption from customer *c* during calendar month t of the pre-program period
- $Month_{it}$ = 1 when index i = calendar month t, 0 otherwise. We include this series of 12 terms to capture month-specific effects in our analysis.
- $CrossProg_c$ = 1 if customer *c* received an energy-efficiency measure from any non-EWSF program.[36]
- e_{ct} is a cluster-robust error term for customer k during billing cycle t. Cluster-robust errors account for heteroscedasticity and autocorrelation at the customer level.

[36] The total savings from Cross Program analysis was consistent across multiple specification of the model.

Results

As shown in Table 28, we determined that natural gas heated EWSF participants who weatherized their homes and used secondary heating saved an additional 209 kWh/year. This represents only 2.2% of the annual electric consumption of participants with secondary heating but nearly half (46%) of these customer's estimated electric annual heating consumption. In other words, the model found that secondary heating usage is relatively small (in terms of total energy consumption) but that weatherization had a material impact on secondary heating consumption (i.e., weatherized customers used their secondary electric heating much less after EWSF).[37]

Table 28. Electric Secondary Heating Billing Analysis Results (2021 Participants)

Measure	Billing Analysis Sample N	Energy Savings (kWh)	Precision at 90% Confidence (% +/-)	Normalized Annual Consumption (kWh)[38]	% of NAC	Normalized Annual Heating Consumption (kWh)[39]	% of Heating NAC
Weatherization	132	209	19%	9,184	2.2%	456	46%

Table 29 converts the results above to reflect the weatherization savings associated with reduced secondary electric heating usage for the *average* EWSF weatherization participant. The average EWSF weatherization participant reflects a mix of the 25% of participants that use secondary heating (209 kWh of additional savings) and the remaining 75% of participants that do not (no additional savings). As shown below, the weighted average of these participant types comes out to 52 kWh/year.

This average secondary electric heating savings is applicable for weatherized participants heating with natural gas and delivered fuels. It is not applicable for participants that use electricity as their primary heating fuel as the electric savings reported in Table 29 are based on participant's total observed electric heating load, which includes both primary (e.g., a central electric furnace) and, when present, any secondary electric heating (e.g., a zonal plug-in space heater).

Table 29. Per-Participant Electric Secondary Heating Savings

Participant Type	Percent of Weatherization Participants	Energy Savings (kWh)
With secondary electric heating	25%	209
Without secondary electric heating	75%	0
Average Across All Participants	**100%**	**52**

[37] The team also verified that the gas consumption did not significantly differ between those using secondary heaters and those without secondary heating.

[38] The participants in this table use natural gas as their primary heating fuel. This differs from Table 15, which shows savings and consumption for participants use electricity as their primary heating fuel. There participants have lower overall consumption of electricity and that is primarily taken from the heating load.

[39] Ibid.

Benchmarking

Our team conducted an industry search for other secondary heating savings associated with weatherization but found very little. After looking at multiple TRMs and evaluation reports we only found approaches for estimating primary heating savings only. There were no mentions of savings – let alone methodologies for calculating savings – for secondary heating sources.

In the absence of relevant benchmarks, our team took an alternative path to corroborate the PPR model results. Specifically, the team compared the simple pre- and post-weatherization electric usage for EWSF participants that identified themselves as secondary heat users (before or after) to their self-reported change (via the survey) in secondary heater usage after being weatherized (i.e., used more or used less).

When interpreting the survey responses, the team considered respondents to have "No or Low" secondary heating usage (before or after EWSF weatherization) if they reported not having a secondary electric heater or using their secondary electric heater, on average, less than 1 hour a day (or 7 hours per week). Conversely, we designated self-reported usage as "High" if they used secondary heaters more than 7 hours per week.

The top of Table 30 (where In Survey = "No") shows the average change in annual electric consumption for those that did not participate in the survey is 406 kWh. Since the team does not know whether these participants use secondary electric heating, this group serves as a point of comparison when we look at the customers that did respond to the survey (for which we know if they have secondary heaters or not).

The middle of the table summarizes usage for the survey participants that self-identified as having low electric usage before participation. Their measured NAC before participation was lower than the survey respondents that self-reported as high users, which validates each group's self-reported consumption.

Lastly, at the bottom of the table, we summarize usage for the 29 survey respondents that reported high usage of their secondary heaters before participating. As expected, the largest difference in usage between pre- and post-weatherization (1,980 kWh, or a 19% reduction) comes from the small number of participants (n=11) that were high users before EWSF and low users after. The set of pre-program high users that didn't change their behavior after weatherization showed a change in consumption of 555 kWh, which, logically, is similar to the general population of EWSF participants with natural gas as a primary heat source.

Overall, this table – as well as the detailed participant survey tables shared in the appendix – suggests the directional results observed in the billing analysis (i.e., EWSF participants use their secondary electric heaters less after being weatherized) are accurate. Consistency between the differences in consumption for the aforementioned participant cohorts, the model, and self-reported survey results tell a consistent story: weatherization impacts secondary fuel usage too.

Table 30. Electric Usage (Pre & Post Wx) by Self-Reported Secondary Electric Heating Usage

In Survey	Reported Secondary Heating Use Pre		Reported Secondary Heating Use Post		
			N/A	No or Low	High
No	N/A	Measured NAC pre (kWh)	7,730		
		Measured NAC Post (kWh)	7,324		
		Change in Usage	**406 (-5%)**		
		Distinct customers	1706		
Yes	No or Low	Measured NAC pre (kWh)		7,714	6,826
		Measured NAC Post (kWh)		7,368	N/A
		Change in Usage		**346 (-4%)**	**N/A**
		Distinct customers		150	8
	High	Measured NAC pre (kWh)		10,482	9,641
		Measured NAC Post (kWh)		8,502	9,086
		Change in Usage		**1,980 (-19%)**	**555 (-6%)**
		Distinct customers		11	18

Wood & Propane

Since the team does not have access to actual pre- and post- usage consumption data for fireplaces and stoves, the team started with the simplified assumption that the secondary heating needs of those using wood/pellet and propane are the same as those that use electric secondary heating, which is known from the secondary electric heating billing analysis.

However, results of the survey suggest that participants using wood/propane for secondary heating use those fuels differently than participants heating secondarily with electricity (Table 31). Given this significant difference in usage patterns, we determined that leveraging the results from the electric heating to estimate the savings for the wood/propane is not justifiable.

Table 31. Frequency of pre-program secondary heat use

	Occasionally (<7 hrs/wk)		Sometimes (7-35 hrs/wk)		Often (35+ hrs/wk)	
	Count	Row%	Count	Row%	Count	Row%
Electric heaters	44	38%	55	47%	17	15%
Wood and propane heating	4	18%	11	50%	7	32%

Section 5 Impact of Weatherization on Furnace Fan, Boiler Pump and Cooling Savings

The primary goals of this study were to identify the primary and secondary heating savings across fuel types, which the team completed through billing analysis and engineering adjustments as discussed in Section 3 and Section 4. However, these are not the only savings generated when EWSF weatherizes a participant's home. By improving the building envelope, weatherization also has an impact on participants' cooling usage. Also, lessened heating and cooling loads can generate electric savings from reduced HVAC fan and pump usage.

This study did not directly analyze these additional elements of weatherization savings. However, we did revisit and update the building simulation-based findings from the previous EWSF evaluation related to cooling and furnace fan savings,[40] which are shown in Table 32.

Table 32. 2017-2018 Cooling and Furnace Fan Savings

Savings Metric	Electric	Gas	Delivered Fuels
Weatherization Heating Savings	803 kWh	96 therms	9.8 MMBtu
Furnace Fan/Pump Savings (kWh)	10	32	32
Cooling Savings (kWh)	27	16	16

Our team leveraged the building simulation results from the previous EWSF evaluation by estimating the proportion of total weatherization savings that furnace fans and cooling represent. For example, for natural gas heated homes, in the prior study, furnace fan savings represented 1.1% of weatherization savings, and cooling savings represented 0.6%. The team applied these percentages to the updated weatherization savings for each fuel type to arrive at updated cooling and furnace fan/Pump savings (Table 33).

Table 33. 2021 Cooling and Furnace Fan/Pump Savings

Savings Metric	Gas	Electric	Delivered Fuels
Weatherization Heating Savings	131 therms	732 kWh	12.2 MMBtu
Furnace Fan/Pump Savings, % of Heating Savings	1.1%	1.2%	1.1%
Cooling Savings, % of Heating Savings	0.6%	3.3%	0.5%
2021 Furnace Fan/Pump Savings (kWh)	47	9	43
2021 Cooling Savings (kWh)	23	24	21
Total (MMBTU)	**13.3**	**2.6**	**12.4**

[40] Our team acknowledges that there are fan savings associated with cooling as well as heating savings. However, the previous building simulation results did not fully capture all elements of HVAC fan savings and focused primarily on furnace fan savings. Thus, our analysis in this evaluation is subject to the same limitation.

The cooling and furnace fan estimates maintain the same building simulation assumptions used in the previous analysis, namely, the cooling equipment type saturations identified in Table 34, which may have changed since the 2017-2018 program year.

Table 34. Cooling and Furnace Fan Equipment Saturation Assumptions

Cooling Type	Electric		Gas/Delivered Fuels	
	Radiant Baseboard	Heat Pump	Boiler, Forced Draft	Forced Air Furnace
No AC	63%	0%	39%	30%
Central AC	100%	100%	24%	56%
Room AC	0%	0%	38%	14%

The team acknowledges the simplicity of this approach and associated assumptions. However, more sophisticated updates would require building simulation efforts that were not part of this scope. The team recommends future EWSF evaluations include building simulation so they can produce more comprehensively updated – and more prospectively accurate – HVAC fan and cooling savings estimates.

Appendix A Participant Survey Instrument

A.1 Introduction

You participated in Rhode Island Energy's (formerly National Grid Rhode Island) EnergyWise Single Family Program to receive weatherization services in [pipe-in: MONTH-YEAR] for your house at [pipe-in: ADDRESS].

We have a small number of questions about your heating and cooling equipment and how you operate it that will help Rhode Island Energy better understand the impact of their program.

These questions will take less than 5 minutes to answer. As a thank you for your time, you'll receive a $10 e-gift card immediately after you complete the survey and submit your response.

If you have any questions or concerns about this outreach, please contact Brett Feldman (bsfeldman@rienergy.com).

A.2 Primary Heating

[**ASK ALL**]

S1. According to the program database, your house uses [pipe-in: FUEL_PRIMARY] as the main source of heat. Is this correct?

[**SINGLE RESPONSE**]

1. Yes [SKIP TO Q1]
2. No
-97. I don't know [THANK AND TERMINATE: To qualify to take this survey, you need to know your home's heating and cooling equipment. Thank you for your time!]

[**ASK IF S1=2**]

S2. Please tell us the main heating equipment and fuel type for your home.

[**MATRIX RESPONSE**]

a. Primary Heating Equipment	**[ASK IF S2a=1, 6, 7, 8, OR 9] b. Fuel for the primary heating equipment**
1. Furnace (forced air)	1. Electric
2. Heat pump (ducted)	2. Natural gas
3. Mini-split heat pump (ductless)	3. Oil
4. Packaged terminal heat pump	4. Pellets
5. Baseboard, wall heater, other electric resistance heat	5. Propane
6. Boiler	6. Wood
7. Wood or pellet stove	-96. I don't know
8. Fireplace insert	
9. Radiant	
-96. I don't know	

[IF S2a=-96 OR S2b=-96, THANK AND TERMINATE: To qualify to take this survey, you need to know your home's heating and cooling equipment. Thank you for your time!]

[IF S2b=3-6, THANK AND TERMINATE: Your primary heating fuel type doesn't qualify you to take this survey. Thank you for your time!]

[IF S2a <> -96 AND S2b <> -96, UPDATE THE "FUEL_PRIMARY" AND "HEATING_PRIMARY"]

A.3 Secondary Heating

[**ASK IF PASSED SCREENING**]

Q1. **Before participating in the program** in [pipe-in: MONTH-YEAR], did you use any supplemental heating sources – such as a space heater, electric or gas fireplace, mini-split, or something similar – to heat any part of your house? This would be in addition to – or instead of – the primary [pipe-in: FUEL_PRIMARY] [pipe-in: HEATING_PRIMARY] system you previously mentioned.

[**SINGLE RESPONSE**]

1. Yes
2. No

-98. I don't know

[**ASK IF Q1=1**]

Q2. Which supplemental heating equipment type(s) did you use?

[**MULTIPLE RESPONSE**]

1. Portable, plug-in heater (radiant, infrared, ceramic heater, etc.)
2. Electric baseboard
3. Wall mounted heater
4. Fireplace (gas)
5. Fireplace (electric)
6. Fireplace (propane, wood)
7. Wood or pellet stove
8. Ductless mini-split system
9. Other, please specify: [**OPEN-ENDED RESPONSE**]

-96. I don't know [EXCLUSIVE]

[**ASK IF ANY 0_1-9 SELECTED**]

Q3. Which of the following best describes how you used each of the supplemental heating equipment you said you used before participating during the heating season?

[**MATRIX RESPONSE**]

[DISPLAY ITEM IF SELECTED IN 0]	**Occasionally (less than 1 hour a day or 7 hours a week)**	**Sometimes (1-5 hours a day or 7-35 hours a week)**	**Often (5+ hours a day or 35+ hours a week)**
Portable, plug-in heater (radiant, infrared, ceramic, etc.)			
Electric baseboard			
Wall mounted heater			

Fireplace (gas)			
Fireplace (electric)			
Wood or pellet stove			
Ductless mini-split system			
0_9 [PIPE-IN]			

[**ASK ALL**]

Q4. How about **after participating in the program** in [pipe-in: MONTH-YEAR]? Do you use supplemental heating – such as a space heater, fireplace, mini-split, or something similar – to heat any part of your house in addition to – or instead of – the primary [pipe-in: FUEL_PRIMARY] [pipe-in: HEATING_PRIMARY] system you previously mentioned.

[**SINGLE RESPONSE**]

1. Yes
2. No

-96. I don't know

[**ASK IF 0=1**]

Q5. Which supplemental heating equipment type(s) do you use?

[**MULTIPLE RESPONSE**]

1. Portable, plug-in heater (radiant, infrared, ceramic heater, etc.)
2. Electric baseboard
3. Wall mounted heater
4. Fireplace (gas)
5. Fireplace (electric)
6. Fireplace (propane, wood)
7. Wood or pellet stove
8. Ductless mini-split system
9. Other, please specify: [**OPEN-ENDED RESPONSE**]

-96. I don't know [EXCLUSIVE]

[**ASK IF ANY 0_1-9 SELECTED**]

Q6. Which of the following best describes how you use each of the supplemental heating equipment you said you use after participating during the heating season?

[**MATRIX RESPONSE**]

[DISPLAY ITEM IF SELECTED IN 0]	**Occasionally (less than 1 hour a day or 7 hours a week)**	**Sometimes (1-5 hours a day or 7-35 hours a week)**	**Often (5+ hours a day or 35+ hours a week)**
Portable, plug-in heater (radiant, infrared, ceramic, etc.)			
Electric baseboard			
Wall mounted heater			
Fireplace (gas)			
Fireplace (electric)			
Wood or pellet stove			
Ductless mini-split system			
0_9 [PIPE-IN]			

[**ASK IF Q1=1 OR 0=1**]

Q7. Please briefly describe in your words *how and why* your supplemental heating usage changed before and after participating in the program.

1. [**OPEN-ENDED RESPONSE**]
-98. Don't know

A.4 Cooling [ASK ALL]

Now, we'd like to ask you about how you cool your home.

[**ASK ALL**]
Q8. **Before participating in the program** in [pipe-in: MONTH-YEAR], how often did you **cool** any part of your house during the summer?

[**SINGLE RESPONSE**]

1. I never cool my house (no cooling equipment in the house)
2. Sparingly (only during a few hottest days of the summer in part or most of the home)
3. Occasionally (only during the moderately hot days of the summer in part or most of the home)
4. A moderate amount (most summer days in part of the home)
5. Almost always on (most summer days in most of the home)
-96. I don't know

[**ASK IF 0=2-5**]
Q9. Please select all the cooling equipment type(s) you used **before participating in the program**.

[**MULTIPLE RESPONSE**]

1. Central cooling
2. Heat pump
3. Ductless mini-split
4. Room air conditioner (including portable/plug-in and window unit): How many? _____
5. Fan: How many? _____
-96. Other, please specify: [**OPEN-ENDED RESPONSE**]
-97. I don't know [EXCLUSIVE]

[**ASK ALL**]
Q10. How about **after participating in the program** in [pipe-in: MONTH-YEAR]? How often do you **cool** any part of your house during the summer?

[**SINGLE RESPONSE**]

1. I never cool my house (no cooling equipment in the house)
2. Sparingly (only during a few hottest days of the summer in part or most of the home)
3. Occasionally (only during the moderately hot days of the summer in part or most of the home)
4. A moderate amount (most summer days in part of the home)
5. Almost always on (most summer days in most of the home)
-96. I don't know

[**ASK IF 0=2-5**]

Q11. Please select all the cooling equipment type(s) you use **after participating in the program**.

[**MULTIPLE RESPONSE**]

1. Central cooling
2. Heat pump
3. Ductless mini-split
4. Room air conditioner (including portable/plug-in and window unit): How many? _____
5. Fan: How many? _____
-96. Other, please specify: [**OPEN-ENDED RESPONSE**]
-97. I don't know [EXCLUSIVE]

[**ASK IF 0=2-5 OR 0=2-5**]

Q12. Please briefly describe in your words *how and why* your cooling usage changed before and after participating in the program.

1. [**OPEN-ENDED RESPONSE**]
-98. Don't know

A.5 Demographics and Housing Characteristics [ASK ALL]

A.5.1 Type of home

[**ASK ALL**]

Q13. What type of home do you live in?

[**SINGLE RESPONSE**]

1. Single-family detached house
2. Single-family attached home (such as townhouse)
3. Duplex, triplex, or four-plex
4. Apartment or condominium with 5 units or more
5. Manufactured or mobile home
-96. Other, please specify: [**OPEN-ENDED RESPONSE**]
-97. Not applicable
-98. I don't know
-99. Refused

A.5.2 Householder

[**ASK ALL**]

Q14. Including yourself, how many people currently live in your home year-round?

1. [NUMERIC RESPONSE]
98. I don't know
99. Refused

A.5.3 Home square footage

[**ASK ALL**]

Q15. How many square feet of living space are there in your residence, including bathrooms, foyers and hallways (exclude garages, basements and unheated porches)?

1. Less than 500
2. 500 to under 1,000
3. 1,000 to under 1,500
4. 1,500 to under 2,000
5. 2,000 to under 2,500
6. 2,500 to under 3,000
7. Greater than 3,000
98. I don't know
99. Refused

A.5.4 Home Vintage

[**ASK ALL**]
Q16. About when was your home first built?

1. 2010 or later
2. 2000 to 2009
3. 1990 to 1999
4. 1980 to 1989
5. 1970 to 1979
6. 1960 to 1969
7. 1950 to 1959
8. 1940 to 1949
9. 1939 or earlier
98. I don't know
99. Refused

A.5.5 Incentive Distribution

[**ASK ALL**]
Q17. Those are all the questions we have. Your responses are very important to Rhode Island Energy. We thank you for your time.

Please provide the following information including where you would like us to email your $10 e-gift card, then click on the "Submit" button to complete.

1. Your name: [**OPEN-ENDED RESPONSE**]
2. Your email (to send the e-gift card): [**OPEN-ENDED RESPONSE**]
3. Your phone number (in case there's any problem sending you the e-gift card: [**OPEN-ENDED RESPONSE**]

Appendix B Participant Survey Results

The evaluation team received completed survey responses from 436 EWSF participants participated during the Program Year 2021.

B.1 Secondary Heating Use Before and After Program Participation by Primary Heating Fuel and Equipment

Primary Heating Fuel	Primary Heating Equipment	S1-S2		Q1		Q4	
		Primary heating fuel and equipment		Used secondary heating **before** program		Use secondary heating **after** program	
		Count	Column %	Count	%	Count	%
Electric	Baseboard, wall heater, other resistance heat	17	40%	6	35%	6	35%
	Mini-split heat pump (ductless)	16	37%	14	88%	10	63%
	Furnace (forced air)	5	12%	0	0%	2	40%
	Heat pump (ducted)	4	9%	4	100%	2	50%
	Packaged terminal heat pump	1	2%	0	0%	1	100%
	Total	**43**	**100%**	**24**	**56%**	**21**	**49%**
Gas	Furnace (forced air)	214	54%	77	36%	73	34%
	Boiler	169	43%	53	31%	67	40%
	Fireplace	6	2%	4	67%	3	50%
	Radiant	3	1%	1	33%	1	33%
	Stove	1	0%	1	100%	1	100%
	Total	**393**	**100%**	**136**	**35%**	**145**	**37%**

- Table B.1 shows prevalence of primary heating fuel and equipment (S1-S2) as well as secondary heating usage before (Q1) and after (Q4) program participation per primary heating fuel and equipment.
- Among the participants that primarily heat their home with electric, there was a slight reduction of prevalence of secondary heat usage after program participation (56% to 49%). These reductions are mostly attributable to those who use mini-split or ducted heat pump systems as primary.
- Among the participants that primarily heat their home with natural gas, there was almost no overall change in the prevalence of secondary heat usage before and after program participation (35% to 37%).

B.2 Secondary Heat Equipment Use and Frequency of Use Before Program Participation

Secondary heating equipment types	Q2		Q3					
	Equipment used for secondary heat (n=160)		Frequency of secondary heat use					
			Occasionally (<7 hrs/wk)		Sometimes (7-35 hrs/wk)		Often (35+ hrs/wk)	
	Count	%	Count	Row %	Count	Row %	Count	Row %
Portable, plug-in heater (ele)	80	50%	35	44%	39	49%	6	8%
Fireplace (gas)	27	17%	12	44%	10	37%	5	19%
Electric baseboard (ele)	24	15%	6	25%	5	21%	13	54%
Wood or pellet stove (wood, pellet)	21	13%	2	10%	10	48%	9	43%
Ductless mini-split system (ele)	18	11%	3	17%	10	56%	5	28%
Fireplace (ele)	14	9%	5	36%	9	64%	0	0%
Fireplace (propane, wood)	7	4%	3	43%	4	57%	0	0%
Wall mounted heater (ele)	5	3%	2	40%	3	60%	0	0%
Other	6	4%	1	17%	4	67%	1	17%

- Table B.2 summarizes, among those reporting secondary heat usage before program participation, prevalence of equipment used for secondary heating as well as self-reported frequency of use of secondary heat equipment used.
- Portable, plug-in heater (electric) is by far the most common secondary heat equipment used, however, frequency of use appears to be less than other equipment used for secondary heating. Equipment used for secondary heat that are most frequently used are wood/pellet stove (91% 'sometimes' or 'often'), mini-split (84% 'sometimes' or 'often'), and electric baseboard (75% 'sometimes' or 'often').

B.3 Secondary Heat Equipment Use and Frequency of Use After Program Participation

Secondary heating equipment types	Q5		Q6					
	Equipment use for secondary heat (n=166)		Frequency of secondary heat use					
			Occasionally (<7 hrs/wk)		Sometimes (7-35 hrs/wk)		Often (35+ hrs/wk)	
	Count	%	Count	Row %	Count	Row %	Count	Row %
Portable, plug-in heater (ele)	66	40%	32	48%	27	41%	7	11%
Fireplace (gas)	21	13%	11	52%	7	33%	3	14%
Electric baseboard (ele)	17	10%	8	47%	4	24%	5	29%
Wood or pellet stove (wood, pellet)	16	10%	4	25%	7	44%	5	31%
Ductless mini-split system (ele)	33	20%	8	24%	19	58%	6	18%
Fireplace (ele)	12	7%	5	42%	7	58%	0	0%
Fireplace (propane, wood)	14	8%	8	57%	5	36%	1	7%
Wall mounted heater (ele)	3	2%	1	33%	2	67%	0	0%
Other	7	4%	1	14%	5	71%	1	14%

- Table B.3 summarizes, among those reporting secondary heat usage after program participation, prevalence of equipment used for secondary heating as well as self-reported frequency of use of secondary heat equipment used.
- Portable, plug-in heater (electric) is still by far the most common secondary heat equipment used after program participation, but the prevalence is lower compared to before program (50%). Use of mini-split is more commonly reported after program participation.

B.4 Computed Change of Secondary Heat Equipment Use

Secondary heating equipment types	Q2, Q3, Q5, Q6					
	Computed change of secondary heat use					
	Decreased		Same		Increased	
	Count	Row %	Count	Row %	Count	Row %
Portable, plug-in heater (ele)	40	40%	39	39%	20	20%
Fireplace (gas)	12	39%	15	48%	4	13%
Electric baseboard (ele)	15	52%	8	28%	6	21%
Wood or pellet stove (wood, pellet)	10	43%	11	48%	2	9%
Ductless mini-split system (ele)	4	11%	14	40%	17	49%
Fireplace (ele)	7	41%	7	41%	3	18%
Fireplace (propane, wood)	1	7%	6	43%	7	50%
Wall mounted heater (ele)	3	50%	2	33%	1	17%
Other	2	22%	4	44%	3	33%

- Table B.4 summarizes the computed change of secondary heat equipment use. The followings detail the computation:
  - pre-program use only -> decreased
  - post-program use only -> increased
  - pre- and post-program use AND increased frequency of use -> increased
  - pre- and post-program use AND decreased frequency of use -> decreased
  - pre- and post-program use AND no change in frequency of use -> same
- Secondary heat equipment that notably decreased use according to self-report include electric baseboard, wood/pellet stove, portable/plug-in heater, and fireplace (gas and electric).
- Secondary heat equipment that notably increased use according to self-report include mini-split and propane/wood fireplace.

B.5 Change of Secondary Heat Equipment Use by Primary Heat Equipment

		Secondary heating type (After-**Before** program) (Q5-Q2)								
		Portable plug-in (ele)	Fireplace (gas)	Baseboard (ele)	Stove (other)	DHP (ele)	Fireplace (ele)	Fireplace (other)	Wall mounted (ele)	Other
		Count	Count	Count	Count	Count	Count	Count	Count	Count
PRIMARY	Ele resistance	-1	0	0	-1	2	0	0	0	0
	Ele boiler	0	0	0	0	0	0	0	0	0
	Ele furnace	1	0	1	0	0	0	0	0	0
	Ele ducted HP	0	0	-1	0	0	-1	0	0	0
	Ele mini-split	-5	0	-6	0	1	0	0	-1	-1
	Ele PTHP	0	0	0	1	0	0	0	0	0
	Gas resistance	0	0	0	0	0	0	0	0	0
	Gas boiler	0	-1	0	-4	9	1	6	-1	0
	Gas furnace	-8	-5	-1	-1	3	-2	1	0	2
	Gas ducted HP	0	0	0	0	0	0	0	0	0
	Gas radiant	0	0	0	0	0	0	0	0	0
	Gas fireplace/stove	-1	0	0	0	0	0	0	0	0
	Total	**-14**	**-6**	**-7**	**-5**	**15**	**-2**	**7**	-2	1

- Table B.5 summarizes the change of secondary heat equipment use (count of after minus count of before program) by primary heat fuel/equipment. The shade of green indicates the degree of reduction, and the red indicates the degree of increase after program.
- The participants that use gas furnace or electric mini-split for primary heat reported the most notable reduction in secondary heat equipment after program, whereas the participants that use gas boiler for primary heat reported notable increase in secondary heat equipment after program.

B.6 Computed Change of Cooling Equipment Use

		Prevalence of cooling equipment use (n=436)		Computed **change** in cooling use by cooling equipment type **after** program (Q8, Q9, Q10, Q11)					
				Decreased		Same		Increased	
		Count	%	Count	Row%	Count	Row%	Count	Row%
Cooling equipment	Room AC	197	45%	20	10%	158	80%	19	10%
	Central cooling	171	39%	15	9%	141	82%	15	9%
	Fan	171	39%	13	8%	143	84%	15	9%
	Mini-split	67	15%	8	12%	38	57%	21	31%
	Heat pump	11	3%	2	18%	7	64%	2	18%
	Other	16	4%	2	13%	11	69%	3	19%

- Table B.6 summarizes the prevalence of cooling equipment use as well as computed change of cooling behavior per equipment before and after program.
- More than a third of the participant respondents reported cooling equipment use as room AC (45%), central cooling (39%), and fan (39%).
- The only notable self-reported change in cooling equipment use after program was increased use of mini-split.