January 23, 2025

# Income Eligible Single Family Impact Evaluation

(RI-24-RX-IncEligible)

Rhode Island Energy

**For**

Rhode Island Energy

**By**

Cadeo Group
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**Note:**
In June 2024, Cadeo was acquired by Resource Innovations, Inc. More information about the acquisition available here.

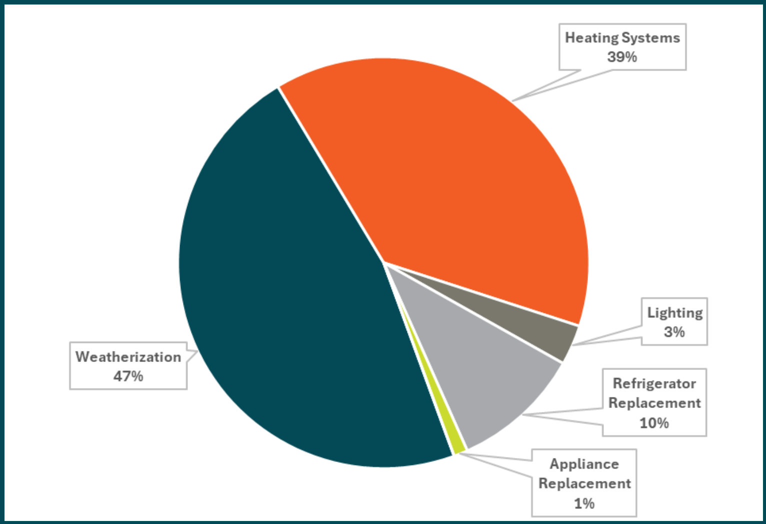
# Executive Summary

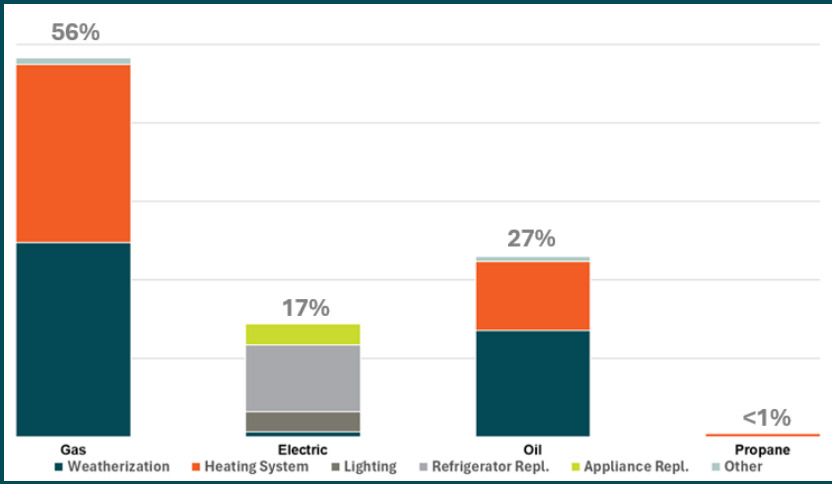
This report details the findings of Cadeo's impact evaluation of Rhode Island (RI) Energy's Income Eligible Single Family (IESF) Program (RI-24-RX-IncEligible). The primary goal of the evaluation was to update the gross per-unit energy savings for every IESF measure using program and energy consumption data for recent participants (2021–2023). This evaluation updates Cadeo's previous impact evaluation of the program, which was completed in 2018 and focused on 2015 and 2016 IESF participants.

## Program Summary

**In 2021, 2022, and 2023…**

- Weatherization (i.e., air sealing and/or insulation) accounted for 47% of total lifetime IESF gross ex ante energy savings across all fuel types.
- Collectively, weatherization and heating system retrofits represented more than three-quarters (86%) of IESF savings.
- Lighting, which RI Energy discontinued in 2023, constituted 15% of annual savings during this 3-year period but only 3% of lifetime savings.




- Natural gas measures accounted for more than half (56%) of IESF lifetime gross ex ante savings, followed by heating oil (27%) and electricity (17%).
- More than half the electric savings between 2021 and 2023 came from lighting. Because IESF assessors are no longer directly installing LEDs, electric savings will likely decline meaningfully in future program years.
- Propane measures make up less than 1% of total savings.

# Approach

Cadeo evaluated savings for each IESF measure and fuel type using a combination of three approaches: **billing analysis, calibrated building simulation**, and technical reference manual-based (TRM) **engineering algorithms**.

For electric and natural gas measures, our team relied on billing analysis whenever possible (i.e., when results are sufficiently precise). This preference is because billing analysis reflects the observed change in participants' recorded energy consumption and inherently accounts for the myriad of factors (e.g., pre-program conditions, installation quality, and behavioral change) that can impact measure savings. When billing analysis results were not reliable for electric and natural gas measures, our team used one of the two engineering approaches—either calibrated building simulation or engineering algorithms—to estimate savings. For many measures, our team combined elements of the billing analysis and one of these engineering approaches to estimate savings.

We also conducted a **participant survey,** which yielded key IESF-specific inputs for the engineering algorithms. In addition to informing the engineering analysis, the participant survey also enabled our team to identify weatherization participants who used secondary fuels to heat their homes and analyze if being weatherized through IESF impacted their use of secondary heating sources. Specifically, our team looked at a variety of secondary heating sources, including electric options such as portable/plug-in space heaters, wall-mounted units, electric resistance baseboards, and ductless heat pumps as well as non-electric alternatives like fireplaces and woodstoves. Alongside primary heating, accounting for changes in secondary heating usage as well as cooling and electrical usage (e.g., fans and pumps) ensures the evaluation provides a complete assessment of weatherization impact on participants' consumption.

## What about delivered fuels?

For weatherized homes heating with heating oil or propane, our team used an engineering-based approach that leveraged the statistically significant results of the natural gas weatherization billing analysis. This multi-method approach was necessary because the team did not have access to delivered fuel usage data, which is common for evaluations of programs like IESF.

To ensure the leveraged natural gas results were appropriate for delivered fuel homes, the team completed a series of engineering adjustments. Our adjustments accounted for the following potential differences between natural gas and delivered fuel customers:

- Home Size
- Pre- and Post-Program Building Envelope Conditions (i.e., insulation levels and amount installed)
- HVAC Efficiency

For key IESF measures, most notably weatherization and heating systems, the body of this report includes a detailed explanation of how the team calculated ex post savings. This report includes fewer details for less impactful measures. For these additional details, we refer readers to the evaluation's supporting documentation workbook.

# Key Findings

Notable results of this study include:

**Lower Weatherization Savings.** Relative to the previous evaluation, this evaluation found lower average natural gas weatherization savings for the more recent cohort of IESF participants included in the team's billing analysis (93 vs. 124 therms/year). To explore this difference, the team compared available information (e.g., pre-program energy usage) for the treatment group from this study (2021 and 2022 participants) with those from the previous evaluation (2015 and 2016 participants). Key data limitations associated with one (lack of insulation location for the previous study) or both studies (lack of pre-program R-values) unfortunately make comparisons imperfect. However, a comparison of available data indicates that IESF natural gas weatherization participants included in the current evaluation received less comprehensive weatherization than the cohort included in previous evaluation. Specifically, fewer 2021 and 2022 participants received both air sealing and insulation (68%) than 2015 and 2016 participants (81%). This represents a 16% decrease across cohorts.

The decline in air sealed and insulated participants across cohorts could be a function of the average IESF participant in 2021 and 2022 "needing" both measures less often (i.e., the assessor determines the house is sufficiently sealed or already insulated). It is also possible the program encountered a greater number of participants in 2021 and 2022 with a pre-weatherization barrier that prevented IESF from either air sealing or insulating. Regardless of the reason, the scenarios would contribute to lower average savings at least partially responsible for the decrease in average weatherization savings between the studies. It's also important to highlight that both scenarios—encountering increasingly efficient homes and a greater percentage of homes with pre-weatherization barriers—are consistent with the theory of program maturation.

Table ES-1 offers a broader comparison between the two studies, including total and heating usage between the two cohorts. As detailed in the report, this difference is due, at least in part, to two improvements in weather normalization and usage disaggregation methodologies made as part of the current study: using variable base degree day approach for participant consumption disaggregation (allows participants to have different, empirically derived heating and cooling set points) and switching from TMY3 to TMYx historical weather data (to reflect observed temperatures in more recent years).

**Table ES-1. Comparing Participants and Results Across Evaluations**

| Characteristic | Previous Evaluation | Current Evaluation | Directional Effect on Savings | Notes |
|---|---|---|---|---|
| **Evaluated Savings (therms/year)** | **124** | **93** | ↓ | **25% decline in evaluated savings** |
| Average Pre-Program NAC (therms/year) | 1,047 | 1,041 | ↔ | No change in total consumption |
| Savings as % of Pre-Program NAC | 12% | 9% | ↓ | Decrease in the savings as % of total consumption |
| Average Pre-Program HNAC (therms/year) | 938 | 741 | ↓ | 21% decline in heating pre-usage, which directly effects size of savings opportunity |
| Savings as % of Pre-Program HNAC | 13% | 13% | ↔ | Similar across studies |
| % of Wx Participants who Received Air Sealing | 95% | 79% | ↓ | Decrease in the percentage receiving Air Sealing |
| % of Wx Participants who Received Insulation (Any Type) | 87% | 88% | ↔ | Similar across studies |
| % of Wx Participants who Received Air Sealing and Insulation (Any Type) | 81% | 68% | ↓ | 16% decrease in the percentage receiving both |

**Weatherization has Secondary Heating Benefits.** Consistent with the EnergyWise Single Family (EWSF) evaluation[1] completed last year, this IESF study found weatherization causes small but observable decreases in participants' use of secondary electric heating sources (e.g., plug-in electric space heaters). The team's billing analysis found that the subset of IESF participants (42%) that self-reported using secondary electric heating prior to and/or after IESF reduced their consumption by, on average, 213 kWh/year after being weatherized. This means that average IESF weatherization participant that received air sealing and/or insulation through the program saved 90 kWh in secondary electric heating reduction (i.e., 42% save 213 kWh while 58% save 0 kWh since they do not use secondary electric heating). The evaluation also estimated the electric impact of weatherization—across all heating fuels—on cooling and furnace fan and pumps usage.

[1] Rhode Island Energy EnergyWise Single Family Program Weatherization Impact Evaluation, October 2023, https://eec.ri.gov/wp-content/uploads/2024/03/ri-23-rx-ewisepy21_final-report_10oct2023.pdf

# Measure-Specific Savings

**Error! Reference source not found.** offers a complete list of this evaluation's measure-specific savings for each IESF measure and fuel type.

As shown below, some measures—in particular weatherization measures—generate both **primary fuel savings** (i.e., lessened natural gas usage in a home that primarily heats with gas) and **secondary fuel savings** (e.g., reduced electric usage due to less heating system run time or abated usage of a secondary heater). The savings shown in the table reflect the evaluation team's best estimate of each measure's primary and secondary savings using the data available to our team. The ultimate decision regarding which savings to prospectively claim as part of future IESF cycles resides with RI Energy.

A few notes about select results in this table as well as the format of the table itself:

**Weatherization**

- As defined earlier in the report, weatherization describes participants who received air sealing and/or insulation through IESF. To reflect the different savings associated with various weatherization scenarios (e.g., air sealing only, air sealing and insulation), the table includes multiple perspectives on weatherization savings and associated secondary savings. The "Air Sealing and/or Insulation" scenario reflects the savings associated with the average IESF weatherization participant between 2021 and 2023, which is a mix of customers who received air sealing only, insulation only, or both.
- Weatherization of natural gas, heating oil, and propane heated homes also generates electric savings (kWh). The electric savings denoted with an "α" subscript means those savings are relevant for all three fossil fuel heating types. (These electric savings are not relevant for electrically heated homes as they are already factored into the reported electric weatherization savings.)
- Weatherization measure savings are per home savings; all other measure savings are per unit savings.

**Heating System Retrofits**

- The furnace and boiler savings are driven by baseline and program efficiency assumptions. The lower savings shown for oil furnaces (relative to both oil boilers and natural gas furnaces) is the result of two factors: 1) a higher baseline efficiency (81% for oil furnaces compared to 77% for oil boilers), and 2) lower program efficiency (86% for oil furnaces compared to 87% for oil boilers). Furnace fan and boiler pump savings are not applicable for heating system retrofits.

**Table ES-2: ESF Per Unit PY 2021–2023 Annual Gross Savings by Measure and Fuel**

| Measure | Electric (kWh) | Natural Gas (MMBtu) | Oil (MMBtu) | Propane (MMBtu) |
|---|---|---|---|---|
| Weatherization | | | | |
| **Air Sealing*** | | | | |
| With Electric Resistance Heating | 208 | | | |
| With a Heat Pump | 51 | | | |
| With Fossil Fuel Heating | | 5.1 | 5.4 | 3.8 |
| Secondary Electric Heating$^{\alpha}$ | 49 | | | |
| **Insulation** | | | | |
| With Electric Resistance Heating | 556 | | | |

| Measure | Electric (kWh) | Natural Gas (MMBtu) | Oil (MMBtu) | Propane (MMBtu) |
|---|---|---|---|---|
| With a Heat Pump | 138 | | | |
| With Fossil Fuel Heating | | 6.0 | 7.5 | 5.1 |
| Secondary Electric Heating[α] | 58 | | | |
| Furnace Fan Savings[α]**Error! Bookmark not defined.** | 33 | | | |
| Pump Savings[α]**Error! Bookmark not defined.** | 2 | | | |
| Cooling Savings[α]**Error! Bookmark not defined.** | 62 | | | |
| **Air Sealing <u>and</u> Insulation** | | | | |
| With Electric Resistance Heating | 764 | | | |
| With a Heat Pump | 189 | | | |
| With Fossil Fuel Heating | | 11.1 | 12.9 | 8.9 |
| Secondary Electric Heating[α] | 107 | | | |
| Furnace Fan Savings[α] | 33 | | | |
| Pump Savings[α] | 2 | | | |
| Cooling Savings[α] | 60 | | | |
| **Air Sealing and/or Insulation**** | | | | |
| With Electric Resistance Heating | 596 | | | |
| With a Heat Pump | 145 | | | |
| With Fossil Fuel Heating | | 9.3 | 8.5 | 5.8 |
| Secondary Electric Heating[α] | 90 | | | |
| Furnace Fan Savings[α] | 29 | | | |
| Pump Savings[α] | 2 | | | |
| Cooling Savings[α] | 53 | | | |
| **Heating Systems** | | | | |
| **Boilers** | | 12.1 | 8.9 | 8.9 |
| **Furnaces** | | 10.6 | 4.1 | 7.8 |
| **Wi-Fi Thermostats** | | | | |
| Heating savings | 154 | 3.0 | 3.1 | 3.0 |
| Cooling savings, kWh | 16 | | | |
| **Mini-Split Heat Pump (Electric Resistance Baseline Only)** | 2,865 | | | |
| **Appliances** | | | | |
| **Smart Strips** | | | | |
| - Tier 1 Smart Strips | 105 | | | |
| - Tier 2 Smart Strips | 207 | | | |
| **Refrigerator Rebates** | 285 | | | |
| **Freezers** | 238 | | | |
| **Room Air Conditioner Replacement** | 84 | | | |
| **Dehumidifiers** | 109 | | | |
| **Early Retirement Clothes Washer and Dryer** | | | | |
| - Electric DHW & electric dryer | 398 | | | |
| - Electric DHW & gas dryer | 139 | 0.9 | | |

| Measure | Electric (kWh) | Natural Gas (MMBtu) | Oil (MMBtu) | Propane (MMBtu) |
|---|---|---|---|---|
| - Gas DHW & electric dryer | 264 | 0.4 | | |
| - Gas DHW & gas dryer | 59 | 1.1 | | |
| - Oil DHW & electric dryer | 264 | | 0.4 | |
| - Propane DHW & electric dryer | 264 | | | 0.4 |
| **Domestic Hot Water** | | | | |
| Showerheads | 221 | 1.2 | 1.2 | 1.2 |
| Faucet Aerators | 32 | 0.2 | 0.2 | 0.2 |
| **Education Materials** | | | | |
| Basic Education Measures | 21 | | | |

*The evaluation team found that air sealing alone (i.e., not alongside insulation) did not produce meaningful (i.e., non-zero) electric savings associated with reduced furnace fan or cooling usage.

**Based on the actual mix of air sealing, insulation, or both that evaluated IESF participants received.

| KEY | |
|---|---|
| (dark teal) | Billing Analysis |
| (light blue) | Building Simulation |
| (green) | Engineering Adjusted Billing Analysis |
| (lime) | TRM-based Engineering Algorithm |

# Recommendations

The team offers the following recommendation based on our experience conducting this IESF impact evaluation.

1. **Establish Reliable Baseline HVAC Efficiency Values.** The evaluation team observed that baseline HVAC (i.e., boilers and furnaces) equipment efficiency values contained in the provided audit data were much lower than observed as part of similar studies in other states. Discussions with RI Energy staff determined that the lower-than-usual value—an annual fuel utilization efficiency (AFUE) of 63% for heating oil systems—was a default value (i.e., not a field-tested value). Our team recognizes the difficulty, and sometimes impracticability, of field-testing the operating efficiency of all existing HVAC systems in the program (whether part of heating system retrofit or a weatherization project). Our team recommends that IESF conduct field-testing when possible (e.g., on a random sample of participating HVAC systems) and use the fuel-specific values from that effort as new defaults when field-testing cannot be completed. If developing IESF-specific field-tested values is not possible, our team recommends replacing the current default baseline efficiency assumptions with a different, empirically based secondary source, such as the recent residential baseline study in neighboring Massachusetts.[2]
2. **Collect Characteristics of Replaced Appliances.** The tracking data provided by RI Energy did not include information about the age, size, or configuration of replaced refrigerators or freezers. These key appliance characteristics are essential for understanding the profile of the appliances replaced through the program as

[2] Guidehouse 2022. Massachusetts Residential Building Use and Equipment Characterization Study. Available at: https://ma-eeac.org/wp-content/uploads/Residential-Building-Use-and-Equipment-Characterization-Study-Comprehensive-Report-2022-03-01.pdf

well as estimating savings using engineering approaches. We recommend that RI Energy collect these three data elements (typically available on appliance nameplates) for every replaced appliance to inform future evaluation efforts.

3. **Track Pre- and Post-Weatherization Building Envelope Characteristics.** Although the audit data provided by RI Energy contained brief descriptions of the installed insulation (e.g., "R-30 Fiberglass Batt Faced Unfaced – ATTIC"), it did not explicitly state the R-values of insulation surfaces (wall, attic, and floor) before and after receiving insulation through IESF. In addition, RI Energy was unable to provide information on air infiltration rates before or after being air sealed through IESF. Collectively, these data are essential for characterizing the savings associated with weatherization. We recommend that RI Energy record pre- and post-measure R-values for insulation surfaces and conduct blower door tests to find the pre- and post-air sealing air infiltration rates (e.g., ACH50) to inform future program planning and evaluation. Without these details, it is difficult to accurately characterize and track changes in participating homes over time that can influence evaluated savings.
4. **More Granular Categorization of Weatherization Measures.** Currently, RI Energy tracks 327 unique measure descriptions under the three fuel-specific impact groups (*WEATHER, Wx-Elec*, and *Wx-DelFuel*) associated with weatherization. These 327 unique measures encompass a wide range of disparate sub-weatherization elements including air sealing, insulation, minor infiltration measures, and health and safety measures. However, RI Energy does not currently group these unique measures into these broader sub-weatherization categories. This means the evaluation team must review and classify them in preparation for studies like this. While this situation is not uncommon, the manual classification process is inherently subjective, which can produce inconsistencies between how the evaluation team and RI Energy classify a given measure. To avoid this in the future, we recommend RI Energy establish explicit and standardized sub-weatherization measure categories at a specificity between the current measure description and impact groups. This approach will not only reduce reliance on subjective judgment and evaluation costs, but also establish a robust and shared language for tracking changes in program delivery and evaluation results over time. With this information, RI Energy and future evaluators can more readily identify trends, uncover root causes of any performance issues, and inform data-driven decision-making for future program cycles.

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# Section 1 Introduction

The primary goal of the Income Eligible Single Family (IESF) Program Impact Evaluation (RI-24-RX-IncEligible) was to update the gross per-unit energy savings for every IESF measure using program and energy consumption data for recent participants (2021–2023). This evaluation updates Cadeo's previous impact evaluation of the program, which was completed in 2018 and focused on 2015 and 2016 IESF participants.[3]

As detailed in this report and the evaluation's supporting documentation, Cadeo evaluated savings for each IESF measure and fuel type using a combination of three approaches: billing analysis, calibrated building simulation, and technical reference manual-based (TRM) engineering algorithms. We also conducted a participant survey, which yielded key IESF-specific inputs for the engineering algorithms.

The survey also enabled our team to identify and analyze how weatherization impacted participant's use of secondary heating (e.g., 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 IESF may also change how they use their secondary heating sources. Given the central role of weatherization in driving IESF savings—the measure was responsible for nearly half (43%) of total program first-year ex ante gross savings across all fuel types in 2021–2023—it was critical the evaluation considered the full impact of IESF weatherization, including primary and secondary heating sources, cooling sources, and associated electric usage (i.e., fans and pumps).

## About IESF

Rhode Island Energy offers IESF to help income-eligible individuals and families reduce their electric and gas bills by insulating their homes, replacing inefficient appliances and products, and providing energy efficiency education at no cost to the customer. The program process starts with a home energy assessment. During the assessment, IESF assessors identify opportunities for building shell and heating and water heating system upgrades, directly install energy-saving measures like smart power strips and LEDs, and provide energy education.[4] Again, all measures—whether installed during the assessment or in a separate visit after the assessment—are provided to the customer free of charge.

To be eligible for IESF, customers must live in a one- to four-unit building and be enrolled in Rhode Island Energy's fuel discount rate plans (A-60 Electric Low-Income rate and/or 1301 Low-Income Heat rate). Customers who qualify for the Low-Income Home Energy Assistance Program (LIHEAP), also known as "fuel assistance," are also eligible to participate in IESF.

IESF is delivered by Rhode Island's territory-based Community Action Agency Program agencies and local contractors. The program closely collaborates with the State of Rhode Island Department of Human Services Weatherization Assistance Program (WAP) and Low Income Home Energy Assistance Program (LIHEAP), overseen by the federal Department of Energy and Department of Human Services, respectively.

[3] Cadeo, *Impact Evaluation: National Grid Rhode Island Income Eligible Services*, August 2018. https://rieermc.ri.gov/wp-content/uploads/2019/04/ng-ri-ies-impact-evaluation-report_final_30aug2018.pdf

[4] Some of the participants included in this evaluation received LEDs during their assessment. However, RI Energy is no longer installing LEDs as part of IESF.

# Study Objectives

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

- What are the natural gas, electric, or delivered fuel energy savings associated with every IESF measure when accounting for all factors (i.e., primary and secondary heating as well as cooling)?
- How do the evaluated savings from this study compare to the previous evaluation as well as recent evaluations of comparable programs in neighboring states?
- Do these savings and realization rates (i.e., ex ante/ex post savings) vary by building type, age, size, or any other key customer or building factors?
- How can Rhode Island Energy and their vendors use the results of this study to target customers and meet energy savings, greenhouse gas reduction, and equity goals?

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

# Key Terminology

The evaluation team uses the language defined in Table 1 throughout the report to explain key impact evaluation concepts.

**Table 1. Summary of Key Evaluation Terminology**

| Term | Definition |
|---|---|
| **Participant** | An individual or household (also identified by a unique account number) who receives at least one IESF measure (such as basic educational measures, LED lighting, a refrigerator replacement, a heating system replacement, and/or weatherization). |
| **Ex Ante Savings** | Savings assumed by Rhode Island Energy prior to an evaluation, usually based on the prior IESF impact evaluation and/or the Rhode Island TRM. |
| **Ex Post Savings** | Savings determined through this evaluation. |
| **Treatment Group** | The IESF participants for whom the team estimated ex post savings: customers who received IESF measures in program year 2021 or 2022.[5] |
| **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 IESF participants (i.e., IESF participants in 2023) as the control group. |
| **Weatherization** | A general term used to describe air sealing and/or insulation (one or more of attic, wall, or floor insulation). References to air sealing or insulation in the report are specific to that measure, whereas weatherization refers to one or both measures. |

[5] For the billing analysis, the team began each participant's post-installation period with the second full billing cycle after the participant's final measure installation date, which allows for at least one full month of "transition time" between pre- and post-period.

# Program Summary

To provide context for the evaluation results provided in this report, this section offers readers insight into the key measures and fuel types that drove overall program savings in 2021–2023. Our team used this information (i.e., what matters most in IESF) to focus and prioritize our evaluation efforts.

*In 2021, 2022, and 2023, IESF completed over 11,000 home energy assessments, installed over 150,000 individual measures, and generated approximately 58,000 MMBTUs in annual gross ex ante energy savings.*

To summarize program activity, the team also aggregated all IESF measures into the following six measure groups:

1. **Weatherization.** Air sealing and insulation
2. **Lighting[6] and Smart Strips**. LED bulbs (all types) and smart strips
3. **Heating System Retrofits.**
4. **Refrigerator Replacement / Freezer Replacement.**
5. **Appliance Replacement/Removal (Other than refrigerators).** Room air conditioners, dehumidifiers, and washing machine/clothes dryer replacement
6. **Other.[7]** Wi-Fi thermostats, domestic hot water direct install measures, basic educational measures

Using installation counts and per-unit ex ante savings for each measure, we compared the total annual ex ante savings generated by each measure category in 2021–2023. To enable comparison savings across fuels, the team converted all fuel-specific savings into MMBtus.

As shown in Figure 1, weatherization measures (across all heating fuel types) are responsible for the most first-year annual gross energy savings (43%) and heating system retrofits (27%). Collectively, these groups reflect 70% of total annual gross ex ante IESF savings during the 2021–2023 period. The team also assessed lifetime savings, which accounts for each measure's expected useful life. From this perspective, the savings associated with measures with a longer expected useful life—like heating systems (17-23 years)—become more impactful. Conversely, a measure like lighting (expected useful life of 1 year) is less impactful. As seen in Figure 2, the transition to lifetime savings increases the contributions of weatherization and heating system retrofits to 86% of total IESF savings.

[6] Some of the participants included in this evaluation, which received their assessments in 2021 and 2022, received LEDs during their assessment. However, RI Energy is no longer installing LEDs as part of IESF. The team has included lighting in these historical summaries of program activity, but—because evaluated savings are not relevant prospectively—this limited our reporting of lighting savings to a brief summary in the report's appendix.

[7] IESF did not install water heaters during the evaluation period, but recently added heat pump water heaters to the offering.

**Figure 1. Total Annual Savings by Measure Category (% in 2021–2023)**

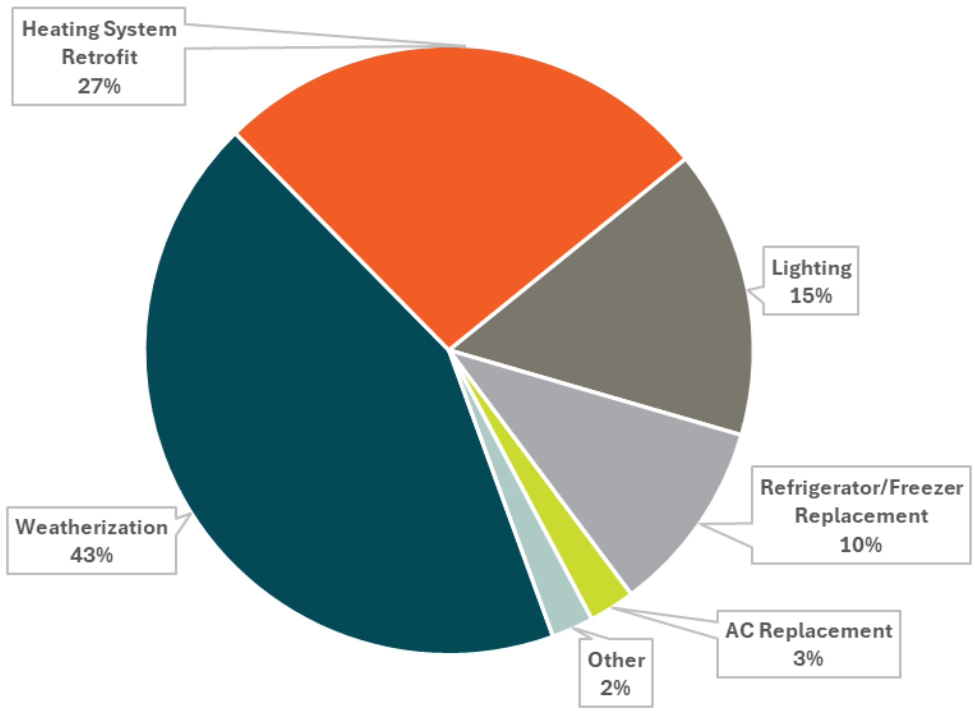
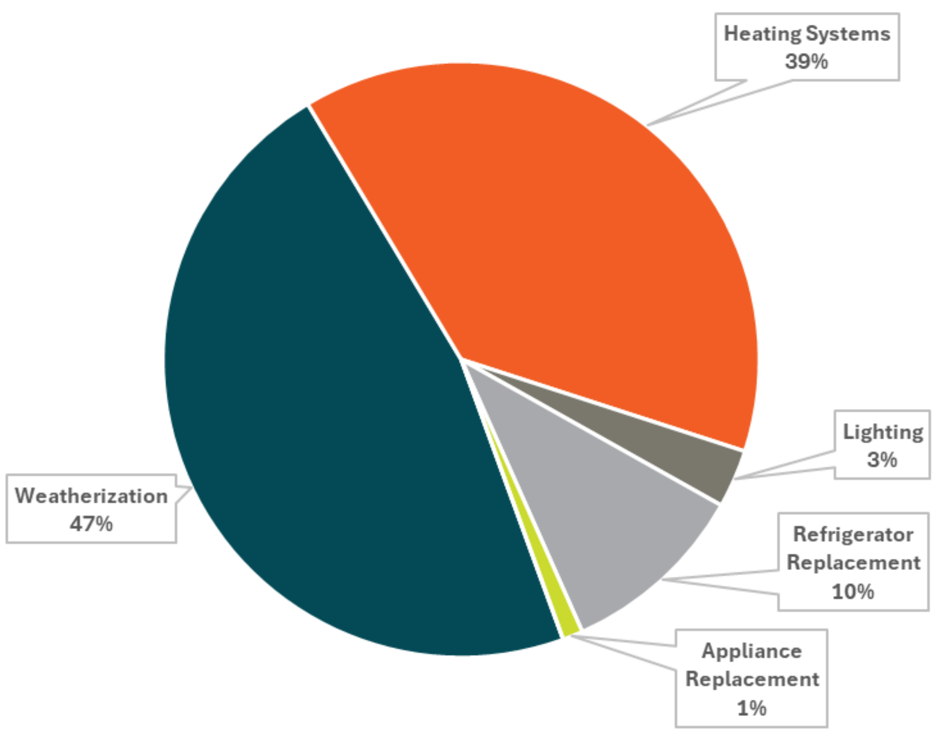



**Figure 2. Total Lifetime Savings by Measure Category (% in 2021–2023)**



The team also investigated how each fuel type—electricity, natural gas, oil, and propane—contributed to the program's overall savings. As evident in Figure 3, natural gas is the leading source of the program's overall annual gross ex ante savings (46%), with electric and oil savings contributing relatively equally (29% and 24%, respectively). Propane makes up a small percentage of total IESF savings. Here, too, the shift to lifetime savings provides a different perspective (Figure 4): the portion of savings associated with electricity, which is driven by lighting, drops from 29% to 17%.

**Figure 3. Total Annual Savings by Fuel (% in 2021–2023)**

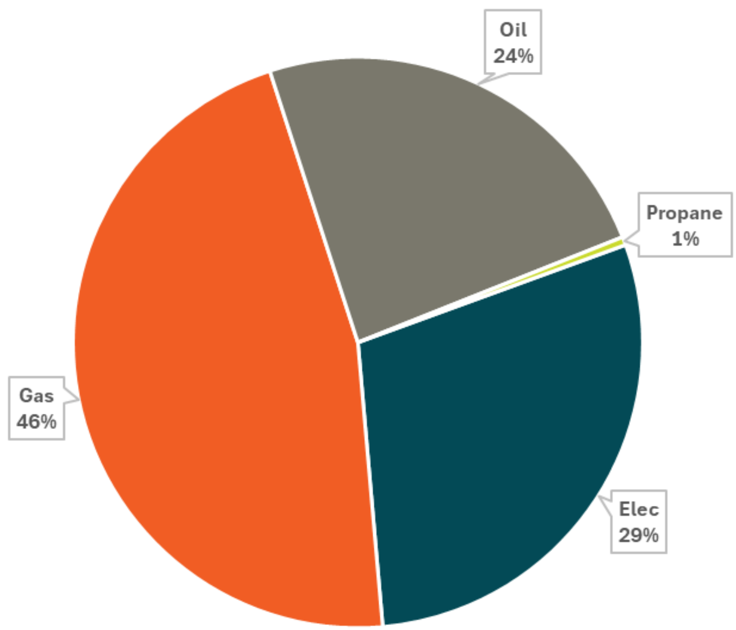
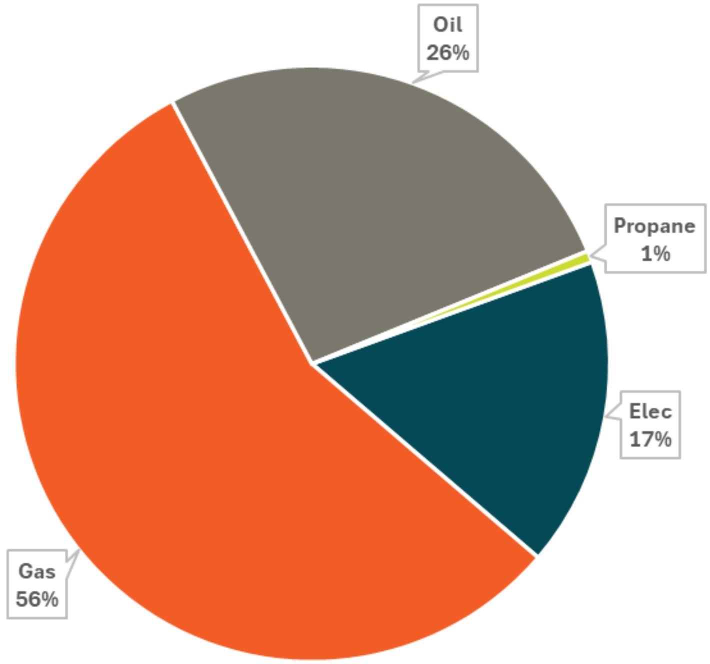


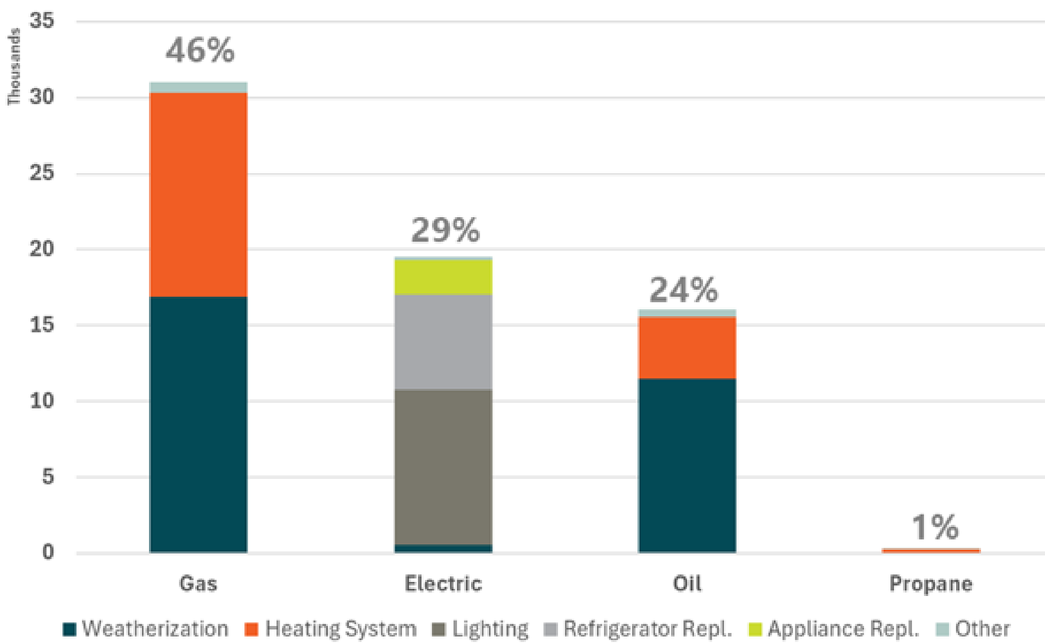
**Figure 4. Total Lifetime Savings by Fuel (% in 2021–2023)**




To further understand the drivers of program savings for each fuel type, the team analyzed annual and lifetime savings by measure group and fuel type.

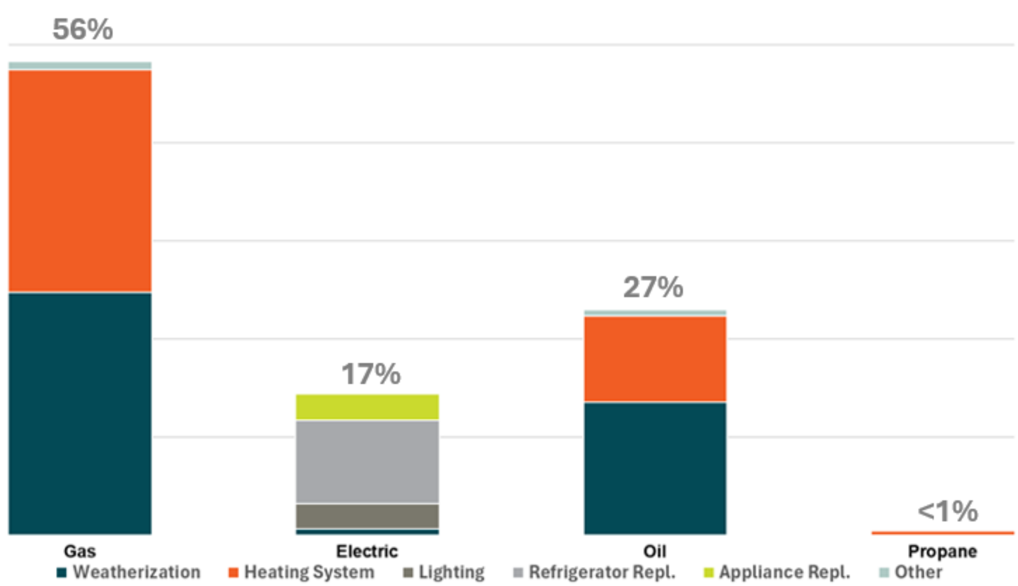
Figure 5, which summarizes annual savings, shows natural gas and heating oil savings collectively represent 70% of total savings. These savings were primarily driven by weatherization (54% and 71%, respectively) and heating system retrofits (43% and 25%, respectively). Given the low number of electrically heated weatherization participants, electric savings primarily comprised lighting (53%) and refrigerator replacement (32%) savings. Propane savings, which only account for 1% of total program savings, are largely attributable to heating system retrofits (83%).

**Figure 5. Total Annual Savings by Measure and Fuel Type (% in 2021–2023)**




Shifting the perspective to lifetime savings (Figure 6) results in higher proportional savings associated with natural gas and heating oil (up to 86%) and lower contribution from lighting (down to 17%). Propane's contribution remains negligible.

**Figure 6. Total Lifetime Savings by Measure and Fuel Type**




Figures 3 and 4 reflect IESF participation across 3 years. The team also looked for changes in the measure mix and/or fuel savings over the course of the 3-year period to identify any potential trends that might extend into future program cycles. We found that savings by measure group, as well as by fuel type, were relatively stable between 2021, 2022, and 2023. The only notable trends over time were a modest dip in total program savings coming from electricity (32% of total savings in 2021 down to 26% in 2023), which corresponded with less savings from lighting and a slight rise in heating oil savings (20% in 2021 up to 25% in 2023).

# How to Use the Results of this Evaluation

We present the results of this evaluation in three parts: The **main body of this report**, a **Supporting Documentation workbook,** and an **Appendix**.

The **main body of this report** summarizes the results of the evaluation and briefly outlines the evaluation methodologies used. For key IESF measures, most notably weatherization and heating systems, the body of this report includes a more detailed explanation of how the team calculated ex post savings. This report does not, however, include details such as the engineering algorithms and the specific primary and secondary data used to develop ex post savings for other measures.

For these types of details, users of this evaluation should rely on the second evaluation output: **Supporting Documentation workbook**. This Excel workbook includes additional details about all aspects of this evaluation. Specifically, the workbook includes the detailed regression results (parameters, coefficients, and standard errors) for both the natural gas and electric billing analyses. It also includes a tab for each IESF measure that was evaluated using an engineering approach (algorithms or building simulation). For measures assessed using an algorithmic approach, the workbook details the Rhode Island TRM engineering algorithm used to evaluate that measure and the values (and sources) for all inputs used in that algorithm. Each measure-specific worksheet also includes a direct comparison of ex ante and ex post savings. Each tabs links to common participant, housing stock, and engineering assumptions to ensure consistency across measures and transparency. Readers interested in accessing the Supporting Documentation Workbook should request access from Rhode Island Energy evaluation staff.

The third and final part of this report's **Appendices** contain:

- Appendix A: The original scope of work for this study
- Appendix B: Additional methodological details for each of the team's three impact approaches (billing analysis, engineering algorithms, and building simulation)
- Appendix C: Insulating Delivered Fuel Homes Planning to Electrify
- Appendix D: Lighting results
- Appendix E: The participant survey
- Appendix F: Additional results from the participant survey

# Section 2 Methodology

## Activities

The team completed four complementary tasks as part of this impact evaluation: billing analysis, engineering algorithms, building simulation, and a participant survey. Table 2 briefly summarizes each methodology.

**Table 2. Summary of Evaluation Methodologies**

| Methodology | Details |
|---|---|
| **Billing Analysis** | • Used where billing data was available for natural gas and electricity (not used for delivered fuels)<br>• Used to report ex post savings when measure-specific billing analysis results met pre-determined threshold of better than ±25% precision at the 90% confidence level[8]<br>• Combined customer billing records with weather and measure installation data to get a complete perspective of each customer's energy consumption drivers<br>• Conducted a structured screening process to ensure that the model uses only those customers with sufficient billing data and without spurious billing records<br>• Performed variable based degree day (VBDD) analysis to model weather dependent consumption for each account. Modeled pre and post installation periods independently for each account<br>• Matched each treatment group customer to a control group (future IESF participants) customer with a similar monthly, pre-installation period energy consumption pattern.<br>• Specified and refined a monthly post-program regression (PPR) model.<br>• Generated results, which were weather-normalized (where applicable) using TMYx (2007-2021) historical weather data from three different weather stations across Rhode Island; each participant was mapped to the closest weather station.<br>• Used survey to identify treatment group participants that use secondary heating.<br>• 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** | • Referenced the 2024 Rhode Island TRM to compare results from this evaluation to existing deemed savings values and sources, and algorithmic approaches when available. The 2024 TRM typically included deemed savings values referencing the 2018 Impact Evaluation approach and results, thus the team also referenced the 2018 Rhode Island Impact Evaluation for the detailed approach behind existing deemed savings values and algorithms.<br>• Relied on recent studies from other jurisdictions (notably Massachusetts and New York) where the Rhode Island TRM did not specify a savings algorithm or specific input value.<br>• Leveraged detailed IESF program data to calculate baseline and efficient cases for each measure.<br>• Relied on regionally appropriate secondary data sources and other relevant studies when IESF program data was not collected or unavailable (sources included the most recent low-income impact evaluation |

[8] Our estimate for Freezer rebates came from a ±50% precision. The estimate for secondary heating savings has a ±46% precision. In both cases, the estimate is compared to other metrics in this data or similar studies that supports the estimated values. The team presents the additional support for the estimates when presenting the results below. All other measure savings reported using billing analysis exceed this ±25% threshold and are included later in the report.

| Methodology | Details |
|---|---|
| | in Massachusetts, Residential Energy Consumption Survey, ENERGY STAR® standards, Building America Benchmark Program Database, etc.).<br>• Included a literature review of recent studies, relevant US Department of Energy appliance standards, other state TRMs, and similar evaluations in other states. |
| **Building Simulation** | • Used the Residential Energy Efficiency and Demand Response (REEDR) tool, energy modeling software to model representative IESF homes.[9]<br>• Constructed baseline home geometry and building characteristics based on audit data; inputs such as square footage and the R values of installed insulation were informed by audit data.<br>• Calibrated each model using disaggregated (heating, cooling, and baseload) monthly energy consumption data for IESF participants<br>• Simulated four different scenarios reflecting heating fuels and whether buildings had cooling systems.<br>• Weighted results by the cooling types and saturations found in the audit data to generate unique savings for natural gas and electrically heated homes.<br>• Primarily used the results of the building simulations to disaggregate the billing analysis results for weatherization into the savings by weatherization type (i.e., air sealing, attic insulation, etc.). |
| **Participant Surveys** | • Sampled 1,094 IESF participants that had their home weatherized (regardless of heating fuel type) between 2021-2023.<br>• Programmed survey in Qualtrics, sent initial e-mail, and up to three reminder emails to nonrespondents.<br>• Completed surveys with 235 participants (22% response rate).<br>• Provided all participants who completed the survey with a $25 e-gift card incentive.<br>• The survey itself, which can be found in Appendix C, focused on pre- and post-program secondary heating and cooling usage, household characteristics, and appliance information. |

**What about delivered fuels?**

For weatherized homes heating with heating oil or propane, our team used an engineering-based approach that leveraged the statistically significant results of the natural gas weatherization billing analysis. This multi-method approach was necessary because the team did not have access to delivered fuel usage data, which is common for evaluations of programs like IESF.

To ensure the leveraged natural gas results were appropriate for delivered fuel homes, the team completed a series of engineering adjustments. Our adjustments accounted for the following potential differences between natural gas and delivered fuel customers:

- Home Size
- Pre- and Post- Program Building Envelope Conditions (i.e. insulation levels and amount installed)
- HVAC Efficiency

[9] REEDR is a front-end energy modeling software used to run energy models for residential buildings in EnergyPlus. It is well-suited for this analysis due to its ability to define a myriad of inputs for a large sample size of residential buildings and process batches of parametric runs, which is vital during the calibration of energy models.

# Data Sources

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

- **IESF Program Data**. This data included basic customer information (account number, address, ZIP code), measure (type, quantity, savings), and timing (assessment and installation dates) for 2021-2023 participants.
- **Supplemental Measure Details**. This data provided additional information regarding the specific measures installed. The data included individual tables for the following IESF measure: smart strips, AC, clothes washers, dehumidifiers, refrigerators/freezers, and heating system replacements.
- **Program Audit Data.** Rhode Island Energy also provided a subset of data about participating homes gathered through IESF home energy assessments. Data included heating and cooling equipment efficiency, domestic hot water tank temperature settings and take size, and installed insulation characteristics (location installed, quantity in square feet, and added insulation descriptions). These data represented homes that received weatherization (and potentially other measures). The audit data provided by Rhode Island Energy also included details for customers who had measures fully, partially, or not funded by Rhode Island Energy. These measures and/or improvements were funded by one of the following sources: Department of Energy Weatherization Assistance Program (DOE WAP) or Health & Human Service Weatherization Assistance Program (HHS WAP). The evaluation team used the full dataset, including participants who did not receive funding from Rhode Island Energy. This decision was made to create a larger dataset for analysis purposes and includes the embedded assumption that customers who received funding exclusively from a non-Rhode Island Energy source are not materially different from those who did. The team considered limiting the analysis to Rhode Island Energy-only funded participants but found it meaningfully reduced the sample of participants available to assess impacts.
- **Billing Data.** Rhode Island Energy provided monthly natural gas and electric consumption data ranging from July 12, 2019 to June 30, 2024 for 2021, 2022, and 2023 participants. The team did not attempt to gather any information regarding delivered fuels (i.e., heating oil and propane).[10]

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

- **Weather Data**. Our team also acquired contemporaneous, hourly weather data from NOAA for three weather stations in Rhode Island (Block Island, Newport, & T.F. Green Airport). 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.

[10] It is common for evaluations of programs like this to not have access to delivered fuel records. The team does not suggest RI Energy attempt to collect such records as part of future evaluations because the process can be costly (metering) or inaccurate (using delivery records given the irregularity of tank refills).

# Section 3 Results Summary

Table 3 presents the per unit savings results for each evaluated IESF measure. The table also indicates which methodology the evaluation team used to estimate ex post savings.

A few notes about select results in this table as well as the format of the table itself:

**Weatherization**

- As defined earlier in the report, weatherization describes participants who received air sealing and/or insulation through IESF. To reflect the different savings associated with various weatherization scenarios (e.g., air sealing only, air sealing and insulation), the table includes multiple perspectives on weatherization savings and associated secondary savings. The "Air Sealing and/or Insulation" scenario reflects the savings associated with the average IESF weatherization participant between 2021 and 2023, which is a mix of customers who received air sealing only, insulation only, or both.
- Weatherization of natural gas, heating oil, and propane heated homes also generates electric savings (kWh). The electric savings denoted with an "α" subscript means those savings are relevant for all three fossil fuel heating types. (These electric savings are not relevant for electrically heated homes because they are already factored into the report's electric weatherization savings.)
- Weatherization measure savings are per home savings; all other measure savings are per unit savings.
- There is a notable difference in electric weatherization savings between homes with electric resistance heating systems and homes with a heat pump. This difference is primarily driven by heat pumps' greater coefficient of performance (COP). However, there are other reasons as well. For instance, heat pumps can operate their heating and cooling coils at multiple speeds, whereas the heating and cooling coils in the home with the electric resistance HVAC system are only single speed. This difference is not something directly included in the COP calculation and can allow the home heated with the heat pump to condition zones in a more precise and energy efficient manner.

**Heating System Retrofits**

- The furnace and boiler savings are driven by baseline and program efficiency assumptions. The lower savings shown for oil furnaces (relative to both oil boilers and natural gas furnaces) is the result of two factors: 1) a higher baseline efficiency (81% for oil furnaces compared to 77% for oil boilers), and 2) lower program efficiency (86% for oil furnaces compared to 87% for oil boilers). Furnace fan and boiler pump savings are not applicable for heating system retrofits.

**Table 3. IESF Per Unit Annual Gross Savings by Measure and Fuel**

| Measure | Electric (kWh) | Natural Gas (MMBtu) | Oil (MMBtu) | Propane (MMBtu) |
|---|---|---|---|---|
| Weatherization | | | | |
| **Air Sealing*** | | | | |
| With Electric Resistance Heating | 208 | | | |
| With a Heat Pump | 51 | | | |
| With Fossil Fuel Heating | | 5.1 | 5.4 | 3.8 |
| Secondary Electric Heating[α] | 49 | | | |
| **Insulation** | | | | |
| With Electric Resistance Heating | 556 | | | |
| With a Heat Pump | 138 | | | |
| With Fossil Fuel Heating | | 6.0 | 7.5 | 5.1 |
| Secondary Electric Heating[α] | 58 | | | |
| Furnace Fan Savings[α]**Error! Bookmark not defined.** | 33 | | | |
| Pump Savings[α]**Error! Bookmark not defined.** | 2 | | | |
| Cooling Savings[α]**Error! Bookmark not defined.** | 62 | | | |
| **Air Sealing and Insulation** | | | | |
| With Electric Resistance Heating | 764 | | | |
| With a Heat Pump | 189 | | | |
| With Fossil Fuel Heating | | 11.1 | 12.9 | 8.9 |
| Secondary Electric Heating[α] | 107 | | | |
| Furnace Fan Savings[α] | 33 | | | |
| Pump Savings[α] | 2 | | | |
| Cooling Savings[α] | 60 | | | |
| **Air Sealing and/or Insulation**** | | | | |
| With Electric Resistance Heating | 596 | | | |
| With a Heat Pump | 145 | | | |
| With Fossil Fuel Heating | | 9.3 | 8.5 | 5.8 |
| Secondary Electric Heating[α] | 90 | | | |
| Furnace Fan Savings[α] | 29 | | | |
| Pump Savings[α] | 2 | | | |
| Cooling Savings[α] | 53 | | | |
| **Heating Systems Retrofits** | | | | |
| **Boilers** | | 12.1 | 8.9 | 8.9 |
| **Furnaces** | | 10.6 | 4.1 | 7.8 |
| **Wi-Fi Thermostats** | | | | |
| Heating savings | 154 | 3.0 | 3.1 | 3.0 |
| Cooling savings, kWh | 16 | | | |
| **Mini-Split Heat Pump (Electric Resistance Baseline Only)** | 2,865 | | | |
| **Appliances** | | | | |
| **Smart Strips** | | | | |

| Measure | Electric (kWh) | Natural Gas (MMBtu) | Oil (MMBtu) | Propane (MMBtu) |
|---|---|---|---|---|
| - Tier 1 Smart Strips | 105 | | | |
| - Tier 2 Smart Strips | 207 | | | |
| **Refrigerator Rebates** | 285 | | | |
| **Freezers** | 238 | | | |
| **Room Air Conditioner Replacement** | 84 | | | |
| **Dehumidifiers** | 109 | | | |
| **Early Retirement Clothes Washer and Dryer** | | | | |
| - Electric DHW & electric dryer | 398 | | | |
| - Electric DHW & gas dryer | 139 | 0.9 | | |
| - Gas DHW & electric dryer | 264 | 0.4 | | |
| - Gas DHW & gas dryer | 59 | 1.1 | | |
| - Oil DHW & electric dryer | 264 | | 0.4 | |
| - Propane DHW & electric dryer | 264 | | | 0.4 |
| **Domestic Hot Water** | | | | |
| Showerheads | 221 | 1.2 | 1.2 | 1.2 |
| Faucet Aerators | 32 | 0.2 | 0.2 | 0.2 |
| **Education Materials** | | | | |
| Basic Education Measures | 21 | | | |

*The evaluation team found that air sealing alone (i.e., not alongside insulation) did not produce meaningful (i.e., non-zero) electric savings associated with reduced furnace fan or cooling usage.

**Based on the actual mix of air sealing, insulation, or both that evaluated IESF participants received.

| KEY | |
|---|---|
| (dark teal) | Billing Analysis |
| (light blue) | Building Simulation |
| (dark green) | Engineering Adjusted Billing Analysis |
| (lime green) | TRM-based Engineering Algorithm |

Table 4 Table 5 compare the non-weatherization measures' ex post savings presented in the previous table with the program's ex ante savings, which were largely determined through the previous impact evaluation (weatherization savings are discussed in more detail in later report sections). Table 4 focuses on electric measures, while Table 5 compares natural gas, oil, and propane measures. Each table indicates if the evaluation team used the same methodology as the previous evaluation, or an updated approach based on more recent or relevant references.

Both tables include a brief explanation of why ex ante and ex post savings may differ. Also, both tables focus on the primary savings associated with each measure. Information about changes in the savings associated with measure's other energy impacts (e.g., electric furnace fan savings resulting from insulation) is provided in the Supporting Documentation workbook.

**Table 4. Comparison of Ex Ante and Ex Post Savings – Electric Measures (kWh/year)**

| Measure | Ex Ante | Ex Post | % Change | Approach | Details |
|---|---|---|---|---|---|
| **Wi-Fi Thermostat, Heating Savings** | N/A | 154 | N/A | Different | The existing value listed in the TRM did not previously include heating savings for electrically heated homes. The evaluation team's estimated heating savings using the average percent savings results (5.5% for heating, 5.2% for cooling) from the 2021 Guidehouse Wi-fi Thermostats study and applied the savings to the disaggregated billing analysis from this evaluation. |
| **Wi-Fi Thermostat, Cooling Savings** | 64 | 16 | -75% | Different | The existing value listed in the TRM references an older Guidehouse Wi-Fi Thermostat Impact Evaluation[11] which was a secondary research report that did not have sufficient data to provide a savings value more specific to Rhode Island. The updated approach that the team used in this evaluation leverages an updated Guidehouse Wi-Fi Thermostats study,[12] which leverages pre-program consumption. The team applied the estimated percent savings from the report (5.5% for heating, 5.2% for cooling), along with program data for the average number of thermostats per home (1.4 units), to calculate savings per unit. |
| **Mini-Split Heat Pump (Electric Resistance Baseline Only)** | 6,549 | 2,865 | -56% | Different | The previous Mini-split Heat Pumps measure used a 2020 calculator that leveraged data from Energy Federation, Inc (EFI). The TRM did not provide any additional information related to how the previous savings were calculated, though it did list baseline efficiency for heating as residential electric resistance heating, and cooling as residential window AC unit with EER 8.9. In this evaluation, the team calculated full displacement savings in this evaluation using building simulation. Using information from the audit data (such as the mean square footage of electrically heated homes), the team modeled a home with electric resistance heating and a room AC unit with EER 10.7 and calibrated the energy consumption to the disaggregated billing data for electrically heated homes with cooling. The team then replaced the electric resistance heating system with a mini-split heat pump and calculated the difference in annual energy consumption to find the savings for this measure. |

[11] https://ma-eeac.org/wp-content/uploads/Wi-Fi-Thermostat-Impact-Evaluation-Secondary-Literature-Study_FINAL.pdf
[12] https://ma-eeac.org/wp-content/uploads/MARES24-Final-Report-2021-09-29.pdf

| Measure | Ex Ante | Ex Post | % Change | Approach | Details |
|---|---|---|---|---|---|
| **Dehumidifier** | 489 | 109 | -78% | Same | The significant reduction in savings per unit is due to the smaller unit capacities contained in this measure compared to the existing TRM savings (and the previous evaluation), and thus lower minimum efficiency requirements. The existing TRM value assumes a larger capacity unit is installed which has less stringent minimum efficiency requirements under Federal code, and thus less efficient baseline units installed and greater overall savings from replacing the baseline with an efficient unit. |
| **Window AC replacement** | 71 | 84 | 18% | Same | The existing savings uses program data for baseline and measure efficiency and capacity assumptions. The resulting savings per unit are similar to the previous evaluation's deemed savings. |
| **Refrigerator Replacement** | 467 | 285 | -41% | Same | Both the previous evaluation and this evaluation used billing analysis to estimate the savings per unit for refrigerator replacement. The evaluation team believes the savings reduction is most likely due to more efficient baseline units replaced compared to the previous evaluation. |
| **Freezer Replacement** | 333 | 238 | -29% | Same | The team used billing analysis to estimate the deemed savings per unit, which are consistent with the refrigerator replacement savings. While the freezer confidence interval (33%) was outside of the bounds of what the billing analysis typically requires (25%), the savings align with the refrigerator savings (with 16% confidence interval) which suggests the savings are accurate. While there are differences in refrigerator and freezer characteristics and consumption, the previous evaluation as well as similar evaluations in the region found similar savings between refrigerators and freezers which also indicates that the billing analysis results are accurate. |
| **Smart Strips** | 105 | 105 | 0% | Same | The current TRM and BCR savings were determined from the 2019 Advanced Power Strip Metering Study. The team reviewed this study and recommends maintaining the existing deemed savings value. |
| **Faucet Aerators** | 50 | 32 | -36% | Same | The team updated income eligible occupancy information and the number of installed units using updated audit and program data. Other measure input points did not change. Note that the current TRM does not include electric savings per unit for IESF showerhead or faucet |
| **Showerheads** | 187 | 221 | 18% | Same | |

| Measure | Ex Ante | Ex Post | % Change | Approach | Details |
|---|---|---|---|---|---|
| | | | | | aerator savings. The ex ante values listed in this table are from the previous evaluation. |
| **Early Retirement CW Elec DHW & Elec Dryer** | 588 | 398 | -32% | Same | The team updated the baseline assumptions to reflect more recent federal efficiency requirements. Previous evaluation assumed baseline units complied with 2007 standards; the team updated the baseline assumptions to reflect 2015 standards. |
| **Early Retirement CW Elec DHW & Gas Dryer** | 307 | 139 | -55% | Same | |
| **Early Retirement CW Gas DHW & Elec Dryer** | 327 | 264 | -19% | Same | |
| **Early Retirement CW Gas DHW & Gas Dryer** | 46 | 59 | 28% | Same | |
| **Early Retirement CW Oil DHW & Elec Dryer** | 327 | 264 | -19% | Same | |
| **Early Retirement CW Propane DHW & Elec Dryer** | 327 | 264 | -19% | Same | |
| **Basic Educational Measures** | 69 | 69 | 0% | Same | The evaluation team did not find evidence to suggest a change to existing claimed savings. |

**Table 5. Comparison of Ex Ante and Ex Post Savings (MMBtu/year) – Natural Gas, Oil, and Propane Measures**

| Measure | Savings | % Change | Approach | Details |
|---|---|---|---|---|
| **Boilers** | **Natural Gas**<br>Ex Ante: 16, Ex Post: 12.1<br>**Heating Oil**<br>Ex Ante: 7.8, Ex Post: 8.9<br>**Propane**<br>Ex Ante: 7.9, Ex Post: 8.9 | **Natural Gas**<br>-24%<br>**Heating Oil**<br>14%<br>**Propane**<br>13% | Different | The team calculated evaluated savings using existing HVAC equipment saturation in the provided audit data and leveraged billing analysis heating consumption data from this evaluation where relevant. The previous evaluation was able to use billing analysis to evaluate this measure, so the previous efficiency assumptions are unknown. The savings per unit are higher for gas units compared to heating oil/propane units due to differences in pre/post program equipment efficiency and differences in home sizes between gas-heated homes and homes heated with heating oil or propane. Because existing and replacement HVAC efficiency data was not available, the team used the same HVAC efficiency requirements identified in the recent Massachusetts Heat Pump Metering Study[13], which provided derated equipment efficiencies for HVAC equipment including boilers and furnaces based on analysis of the Massachusetts Residential Baseline Study. |
| **Furnaces** | **Natural Gas**<br>Ex Ante: 16, Ex Post: 10.6<br>**Heating Oil**<br>Ex Ante: 10, Ex Post: 4.1<br>**Propane**<br>Ex Ante: 16, Ex Post: 7.8 | **Natural Gas**<br>-34%<br>**Heating Oil**<br>-59%<br>**Propane**<br>-51% | Different | The team calculated evaluated savings using existing HVAC equipment saturation in the provided audit data and leveraged billing analysis heating consumption data from this evaluation where relevant. The previous evaluation was able to use billing analysis to evaluate this measure, so the previous efficiency assumptions are unknown. Oil boilers have a lower savings per unit compared to gas or propane units because both the existing unit efficiency (81%) is slightly higher than gas or propane units (80%), and the replacement unit efficiency is lower (86%) than the gas/propane units (95%). Because existing and replacement HVAC efficiency data was not available, the team used the same HVAC efficiency requirements identified in the recent Massachusetts Heat Pump Metering Study, which provided derated equipment efficiencies for HVAC equipment including boilers and furnaces based on analysis of the Massachusetts Residential Baseline Study. |

[13] Guidehouse 2024. Massachusetts and Connecticut Heat Pump Metering Study (MA22R51-B-HPMS) / (CT R2246). Available at: https://ma-eeac.org/wp-content/uploads/MA-HPMS-CT-R2246-Heat-Pump-Metering-Study-Final-Report_August_2024.pdf.

| | | | | |
|---|---|---|---|---|
| **Wi-Fi Thermostat, Heating Savings** | **Natural Gas**<br>Ex Ante: 2.0[14], Ex Post: 3<br>**Heating Oil**<br>Ex Ante: 2.79, Ex Post: 3.1<br>**Propane**<br>Ex Ante: 2.79, Ex Post: 3 | **Natural Gas**<br>50%<br>**Heating Oil**<br>12%<br>**Propane**<br>0% | Different | The evaluation team's estimated heating savings using the average percent savings results from the 2021 Guidehouse Wi-fi Thermostats study and applied the savings to the disaggregated billing analysis from this evaluation. The savings are calculated per thermostat, assuming 1.4 thermostats per home. |
| **Showerheads** | **Natural Gas**<br>Ex Ante: N/A, Ex Post: 1.2<br>**Heating Oil**<br>Ex Ante: 0.9, Ex Post: 1.2<br>**Propane**<br>Ex Ante: N/A, Ex Post: 1.2 | **Natural Gas**<br>N/A<br>**Heating Oil**<br>N/A<br>**Propane**<br>N/A | Same | The team updated income eligible occupancy information and the number of installed units using updated audit and program data. Other measure input points did not change. Note that the current Rhode Island TRM does not include showerheads as a gas or propane savings measure. |
| **Faucet Aerators** | **Natural Gas**<br>Ex Ante: N/A, Ex Post: 0.2<br>**Heating Oil**<br>Ex Ante: 0.9, Ex Post: 0.2<br>**Propane**<br>Ex Ante: N/A, Ex Post: 0.2 | **Natural Gas**<br>N/A<br>**Heating Oil**<br>N/A<br>**Propane**<br>N/A | Same | The team updated income eligible occupancy information and the number of installed units using updated audit and program data. Other measure input points did not change. Note that the current Rhode Island TRM does not include aerators as a gas or propane savings measure. |
| **Early Retirement CW** | **Elec DHW & Gas Dryer**<br>Ex Ante: 1, Ex Post: 0.9<br>**Gas DHW & Elec Dryer**<br>Ex Ante: 1.3, Ex Post: 0.4<br>**Gas DHW & Gas Dryer**<br>Ex Ante: 2.2, Ex Post: 1.1<br>**Oil DHW & Elec Dryer**<br>Ex Ante: 1.28, Ex Post: 0.4 | **Elec DHW & Gas Dryer**<br>-8%<br>**Gas DHW & Elec Dryer**<br>-70%<br>**Gas DHW & Gas Dryer** | Same | The team updated the baseline assumptions to reflect more recent federal efficiency requirements. Previous evaluation assumed baseline units complied with 2007 standards; the team updated the baseline assumptions to reflect 2015 standards. |

[14] Note that the 2024 TRM lists gas savings at 20 MMBtu, but that value is likely a typo and the evaluation team assumed 2.0 MMBtu savings.

| | | |
|---|---|---|
| **Propane DHW & Elec Dryer**<br>Ex Ante: 1.28, Ex Post: 0.4 | -51% | |
| | **Oil DHW & Elec Dryer**<br>-70% | |
| | **Propane DHW & Elec Dryer**<br>-70% | |

# Section 4 Weatherization

Because nearly half of IESF total savings come from weatherization (i.e., air sealing and/or insulation), the team has focused the first results section on the weatherization savings by heating fuel type (natural gas, electricity, heating oil and propane.)

## Natural Gas

Consistent with the previous IESF 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.

### Approach

The team started by identifying the qualifying set of weatherized 2021-2022 IESF participants to include in the billing analysis treatment group. To qualify, a participant needed to pass the screening criteria listed in Table 6. These screening criteria removed participants without sufficient months of pre- and/or post-installation billing records, as well as whose usage exhibited extreme or energy consumption.

Of the 385 total weatherized natural gas-heated households from 2021 & 2022 considered for the treatment group, 299 (78%) qualified for inclusion in the billing analysis.

**Table 6. Billing Analysis Sample Attrition – Natural Gas**

| Reason for Exclusion | Removed | % | Remaining |
|---|---|---|---|
| **All natural gas heated homes receiving weatherization in 2021 & 2022** | | | **385** |
| Insufficient (< 12 months) pre- and/or post-participation billing data | 77 | 20% | 308 |
| Energy consumption outliers (<1st and >99th Percentile)[15] | 5 | 1% | 303 |
| Extreme consumption behavior<br>(< 500 annual therms or > 10,000 annual therms) | 2 | 1% | 301 |
| Extreme changes in consumption (±>50% change between pre and post) | 2 | 1% | 299 |
| **Overall** | **86** | **22%** | **299** |

Consistent with the previous IESF impact evaluation and residential billing analysis evaluation best practices[16], the team next identified a pool of matched "future" participants (i.e., IESF participants that weatherized their home in late 2022-2023) as the control group. Including a control group is essential for billing analysis as its inclusion helps control for the non-programmatic factors on energy consumption (people moving in or out, changes in utility rates, macroeconomic factors, etc.) that can be conflated with programmatic factors unless properly accounted for.

[15] 1% = 237 therms/year, 99% = 2,639 therms/year

[16] 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

Assuming the program and the mix of participants remain consistent over time, the future participants (the control group) are most likely to resemble—and therefore serve as an effective counterfactual—for previous participants (the treatment group). To ensure this is true, the team identified 2022-2023 IESF natural gas weatherization participants with total pre-program annual energy consumption usage and monthly usage profiles similar to 2021-2022 participants in the treatment group.

**WHAT ABOUT COVID-19?**

Any changes in consumption associated with COVID-19 or "post-COVID" behavior (e.g., more people working from home) are accounted for by the control group which was experiencing similar societal trends.

After identifying the appropriate participants 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:

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

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.
- $Duct_c$ = 1 if customer *c* received duct sealing, 0 if customer *c* did not receive duct sealing.
- $Heat_c$ = *1* if customer *c* installed measures indicating a Boiler or Furnace replacement, 0 if customer *c* did not receive heating system replacement measures.
- $Askit_c$ = *1* if customer *c* is received an Air Sealing kit[17], 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.
- $e_{ct}$ 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.

[17] 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).

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($\tau_H$) during month m, based on daily average temperatures on those dates. The team calculated base temperatures $\tau_H$ using a variable degree day analysis. The values $\mu$ & $\beta_H$ 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 7, we determined that natural gas-heated IESF participants who weatherized their homes saved 93 therms/year[18] on average, or 9% of pre-participation household natural gas consumption.

Our team also attempted to estimate savings for heating systems and duct sealing installed as part of IESF. However, precision associated with the savings estimate for heating systems (±38% at the 90% confidence level) and duct sealing (±65% at the 90% confidence level) was well outside our team's requirement (±25%) for reporting billing analysis-based results.

**ARE THESE 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. Because 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**.

**Table 7. 2021–22 Natural Gas Billing Analysis Results**

| Measure | Sample | Energy Savings (Therms/year) | Precision (at 90% CI) | NAC (Therms/year) | % NAC | Heating NAC (therms/year) | % HNAC |
|---|---|---|---|---|---|---|---|
| Wx | 299 | 93 | ±25% | 1,041 | 9% | 741 | 13% |

## Benchmarking

The team's ex post billing analysis savings for natural gas weatherization are lower than the billing analysis results (124 therms) estimated as part of the previous IESF impact evaluation, which informed the program's ex ante assumption.

To explore this difference, the team compared available information (e.g., pre-program energy usage) for the treatment group from this study (2021 and 2022 participants) with those from the previous evaluation (2015 and 2016 participants). Table 8 details the customer, building, and program characteristics that the

[18] We applied an adjustment to the weather normalize the billing analysis model result. The average annual, post-period weather for participants, 4,312 HDD with 60-degree base, was warmer than the average TMYx weather of 4,796 HDD with 60-degree base.

team could—and could not—compare across the two evaluations. As evident below, the data provided as part of the previous evaluation was generally less robust and granular. This prevented our team from comparing all the characteristics that could have shed light on the difference in the savings between studies. There are two particularly impactful data shortcomings:

1. **Insulation Type-Specific Information.** The program tracking data provided as part of the previous evaluation did not include details about location (or surface, i.e., wall, attic, or floor) of installed insulation or the specific amount of insulation added. Understanding differences in these values across cohorts is fundamental to understanding observed differences in evaluated savings.
2. **Pre-Program R-Values**. Both this and the previous evaluation lacked pre-program R-values for weatherization participants. Since pre-program conditions are a direct driver of savings potential, the team was unable to consider changes in these values when comparing studies.

**Table 8. Availability of Information Across Evaluations**

| Characteristic | Previous Evaluation | Current Evaluation |
|---|---|---|
| Average Total Pre-Program Normalized Annual Consumption (NAC) (therms/year) | Yes | Yes |
| Average Pre-Program Heating Normalized Annual Consumption (HNAC) (therms/year) | Yes | Yes |
| Average Home Size (square feet) | **No** | Yes |
| % of Wx Participants who Received Air Sealing | Yes | Yes |
| % of Wx Participants who Received Insulation (Any Type) | Yes | Yes |
| % of Wx Participants who Received Air Sealing and Insulation (Any Type) | Yes | Yes |
| # of Types of Insulation Installed | **No** | Yes |
| % of Wx Participants who installed Attic/Ceiling Insulation | **No** | Yes |
| Pre-Program R-Value for Attic/Ceiling Insulation[19] | **No** | **No** |
| % of Wx Participants who installed Wall Insulation | **No** | Yes |
| Pre-Program R-Value for Wall Insulation | **No** | **No** |
| % of Wx Participants who installed Basement/Floor Insulation | **No** | Yes |
| Pre-Program R-Value for Basement/Floor Insulation | **No** | **No** |

Table 9 compares the characteristics supported by data from both evaluations. As shown in the table, the IESF natural gas weatherization participants included in the current evaluation received less comprehensive weatherization than the cohort included in previous evaluation. Specifically, fewer 2021

[19] Although the audit data did not explicitly contain this information, it provided brief measure descriptions that allowed for deductions of pre-program R-values for walls and floors. More information on the process of these variable assignments can be found in in the Additional Building Simulation Details section within Appendix B.

and 2022 participants received both air sealing and insulation (68%) than 2015 and 2016 participants (81%). This represents a 16% decrease across cohorts.

The decline in air sealed and insulated participants across cohorts could be a function of the average IESF participant in 2021 and 2022 "needing" both measures less often (i.e., the assessor determines the house is sufficiently sealed or already insulated). It is also possible the program encountered a greater number of participants in 2021 and 2022 with a pre-weatherization barrier that prevented IESF from either air sealing or insulating. Regardless of the reason, the scenarios would contribute to lower average savings at least partially responsible for the decrease in average weatherization savings between the studies.

It's also important to highlight that both scenarios—encountering increasingly efficient homes and a greater percentage of homes with pre-weatherization barriers—are consistent with the theory of program maturation. Table 9 includes another notable difference: Pre-Program Heating Normalized Annual Consumption or HNAC. Though the two participating cohorts had nearly identical Total Pre-Program Normalized Annual Consumption (NAC), the estimated portion of total natural gas consumption associated with space heating—and subject to change after IESF weatherization—is different between the two studies. It is important to note that this difference is due, at least in part, to two improvements in weather normalization and usage disaggregation methodologies between the two studies.[20]

1. **Using Variable Base Degree Day.** This study, unlike the previous one, used a variable degree day analysis to disaggregate IESF participant's consumption. This more robust approach (relative to the fixed set point approach used in the prior evaluation) better accounts for individual customers' behaviors by allowing dwellings to have different thermostat set points (determined based on the relationship between their consumption and outdoor temperature).
2. **Using TMYx.** The previous study used the TMY3 data set that uses actual temperatures from the years 1991–2005 to describe a typical meteorological year. This study normalized consumption using the TMYx which relies on the more recent 2007–2021 timeframe to describe a typical meteorological year to better reflect higher observed temperatures in recent years.

[20] As a basic check on the accuracy of the enhanced normalization and disaggregation analyses, the team assessed average monthly natural gas usage for weatherization participants in June, July, and August (i.e., during the summer when these customers are unlikely to use natural gas for heating). The team found an average of 29 therms/month, which could be interpreted as participant's non-heating natural gas load (i.e., natural gas used for water heating, cooking, or clothes drying). A simple annualization of this monthly average results in an estimated annual usage of 348 therms on non-space heating end uses, which aligns very closely with the team's more robust disaggregation analysis. This suggests the HNAC from this evaluation is reasonable.

**Table 9. Comparing Participants and Results Across Evaluations**

| Characteristic | Previous Evaluation | Current Evaluation | Directional Effect on Savings | Notes |
|---|---|---|---|---|
| **Evaluated Savings (therms/year)** | **124** | **93** | ↓ | **25% decline in evaluated savings** |
| Average Pre-Program NAC (therms/year) | 1,047 | 1,041 | ↔ | No change in total consumption |
| Savings as % of Pre-Program NAC | 12% | 9% | | Decrease in the savings as % of total consumption |
| Average Pre-Program HNAC (therms/year) | 938 | 741 | ↓ | 21% decline in heating pre-usage, which directly effects size of savings opportunity |
| Savings as % of Pre-Program HNAC | 13% | 13% | ↔ | Similar across studies |
| % of Wx Participants who Received Air Sealing | 95% | 79% | ↓ | Decrease in the percentage receiving Air Sealing |
| % of Wx Participants who Received Insulation (Any Type) | 87% | 88% | ↔ | Similar across studies |
| % of Wx Participants who Received Air Sealing and Insulation (Any Type) | 81% | 68% | ↓ | 16% decrease in the percentage receiving both |

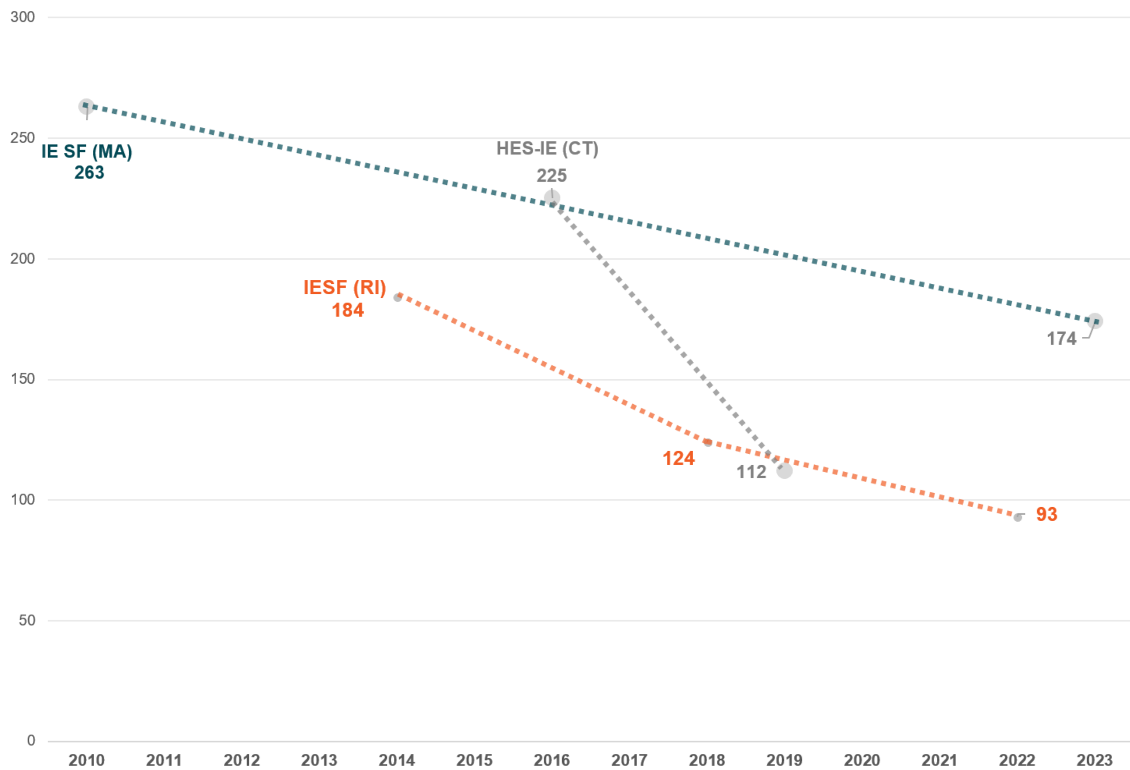
Our team also compared the natural gas weatherization savings from the current and previous IESF impact evaluations to the evaluation of similar programs in nearby states. While this comparison offers general insight into savings values and trends, it is difficult to directly compare the specifics of each result given differences in program design[21], average pre-program building conditions[22], and evaluation methodologies.[23] Zooming out however, the lower natural gas weatherization savings observed as part of this study is clearly consistent with long-term term savings trends in the region. As shown in Figure 7, all subsequent residential single-family income eligible evaluations in the same state have resulted in lower savings than the previous study. The reasons for this meta trend are multiple, but the primary causes are likely the increasing efficiency of heating systems and participants with less savings potential as programs like IESF mature and reach deeper into the qualifying building stock.

[21] For example, Home Energy Solution-Income Eligible program completes air sealing at all participating homes during the initial assessment.

[22] Without pre-program building envelope characteristics for IESF, it's not possible to compare the pre-program conditions – which directly inform the savings opportunity – across these programs.

[23] All the benchmarked evaluation used billing analysis (consistent with this study) to evaluate weatherization savings except for the most recent IE SF impact evaluation in Massachusetts, which relied on building simulation due to data access issues. The studies also used a variety of weather normalization approaches.

**Figure 7. Evaluated IE Weatherization Savings Over Time in New England (therms/years)**




## Weatherization Type-Specific Savings

Our team also explored using billing analysis to go beyond "weatherization" savings and estimate the savings associated with air sealing specifically, as well as the different types of insulation (i.e., attic, wall, floor/basement, and duct) installed through IESF. However, none of these more granular model specifications yielded statistically significant, weatherization type-specific results. This results, which is common for similar income eligible programs, is due to several factors:

1. **Multicollinearity.** Nearly all air sealing participants also installed at least one kind of insulation, which makes it difficult for the billing analysis regression model to attribute savings accurately between the two elements of weatherization.
2. **Smaller savings.** The savings associated with a specific type of weatherization (e.g., attic insulation) is less than the total savings from weatherization overall (e.g., attic insulation and air sealing). This decreased "signal" (weatherization type savings) to "noise" (total household consumption) ratio contributes to modeling difficulty.
3. **Smaller sample sizes.** Only 299 natural gas weatherization participants qualified for the billing analysis, which is not a large sample in billing analysis terms. The pool of participants for the billing analysis shrinks further when focusing on the participants that received a specific type of weatherization measure like, for example wall insulation (140), which adversely impacts modeled precision.

Since billing analysis was unable to reliably estimate specific savings for air sealing or for each type of insulation, our team used the calibrated building simulation models to disaggregate the billing analysis' weatherization results into its sub-elements. In other words, our team utilized the relative savings for each type of weatherization (determined through the building simulation process) and the profile of the average weatherization participant (from program records) to divide the observed weatherization savings from the billing analysis its constituent parts. The results of this process, detailed in **Error! Reference source not found.**, could also be described as billing analysis-calibrated building simulation estimates.

As shown below, the average natural gas-heated IESF participant (that weatherized their home) received 2.29 types of weatherization. Most participants (79%) had their home air sealed, while the most common insulation type was attic insulation (55%). As evident in Table 10, basement/floor (46%) and wall insulation (41%) were slightly less common. According to our analysis, wall insulation was the largest weatherization saver (104 therms/year), followed by air sealing (40 therms/year).[24]

**Table 10. Natural Gas Weatherization Savings by Weatherization Type (therms/year)**

| | Air Sealing | Attic Insulation | Wall Insulation | Basement/Floor Insulation | Overall |
|---|---|---|---|---|---|
| Building Simulation Savings* | 44 | 33 | 113 | 4 | |
| %. of weatherized participants who received each weatherization type** | 0.79 | 0.55 | 0.41 | 0.46 | 2.21 |
| Billing Analysis-Calibrated Savings | 40# | 31# | 104# | 4# | 93^ |

*Reflects the savings, based on IESF-specific calibrated building simulation modeling, associated with installing each weatherization element independently (i.e., our team modeled each weatherization element separately).
**Based on the same set of 2021 & 2022 IESF natural gas-heated weatherization participants included in the billing analysis
#Reflects the savings associated with installing each weatherization element independently. This row calibrates building simulation results to billing analysis results (and accounts for the mix of installed weatherization types present in the billing analysis).
^Overall savings from billing analysis, which reflects the average of the billing analysis-calibrated weatherization type savings. weighted by the percent of natural gas participants who received each type of weatherization.

# Delivered Fuels (Heating Oil and Propane)

Savings from heating oil made up nearly a quarter (24%) of total IESF ex ante gross savings in 2021, 2022, and 2023—and most of those oil savings (74%) resulted from weatherization. Propane constituted a small fraction of total savings, but the approach our team used to evaluate heating oil and propane weatherization are so similar that we have combined them under the broader banner of delivered fuel weatherization.

## Approach

Unlike for natural gas weatherization participants, the team did not have access to usage data for weatherized IESF participants that heat their homes with a delivered fuel (i.e., heating oil or propane.) This

[24] Savings by type (or location) of insulation varies across evaluations (based on the characteristics of participating homes) but it is common for wall insulation to have the higher savings than attics or floors.

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 and estimate savings.

Consequently, the team employed an engineering-based approach that leveraged the natural gas billing analysis results. The team's approach, detailed in the next section, determined savings by first estimating the annual pre-program heating consumption for delivered fuel participants and, second, estimating the percent of that consumption they saved after weatherizing their home through IESF.

### Calculating Annual Pre-Program Consumption

The team estimated the delivered fuel pre-period space heating consumption by adjusting the billing analysis disaggregated natural gas pre-period HNAC (741 therms or 74.1 MMBtus) by two factors: differences in **home size** and **heating 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,[25] the team compared the average home size for natural gas and delivered fuel heated participants. As shown in Table 11, heating oil fueled homes were meaningfully larger on average (1,814 square feet) while propane heated homes were notably smaller (1,238 square feet), compared to 1,681 square feet for natural gas. As a result, the team proportionally adjusted the observed natural gas pre-program heating consumption from the billing analysis as shown below to reflect likely delivered fuel consumption for heating oil and propane.

**Table 11. Average 2021–2023 Weatherized Home Floor Area by Fuel Type**

| Fuel Type | Home Floor Area (SF)[26] | Home Floor Area Relative to Natural Gas |
|---|---|---|
| Natural Gas | **1,681** | **100%** |
| Heating Oil | 1,814 | 108% |
| Propane/Other | 1,238 | 74% |

- **Heating equipment efficiency.** The program data included estimates of the operating efficiency for delivered fuel heating systems that the team initially planned to use for this analysis. However, a closer review of the existing efficiency data revealed that the program was defaulting to a predetermined value in most instances. This told our team that the values in the program data were not field-tested values and, therefore, should not be considered an empirical data source for the analysis. We also found, particularly for existing heating oil ratings, that the frequently referenced default value (63% AFUE) was appreciably lower than the average existing efficiency rating used in nearby states, which was resulting in much higher than anticipated savings

[25] Fuel types are often associated with specific building types and/or vintages, which are, in turn, correlated with home size.
[26] Floor area extracted from 2021 Tax Parcel data.

estimates.[27] To avoid this issue as part of future evaluations, the team included a recommendation that RI Energy develop IESF-specific field-tested values.

In the interim, the team opted to rely on the efficiency assumptions used in the most recent Massachusetts Income Eligible Single Family Impact Evaluation[28] (Table 12), which were based on the 2022 Massachusetts Residential Baseline Study.[29] The values represent a combination of rated and derated equipment efficiencies based on the saturation of new and used equipment assessed as part of the baseline study. While the values are not specific to RI Energy customers, the values are based on actual data from a neighboring state (versus a default assumption).

**Table 12. Equipment Efficiency Comparisons and Saturation, 2021–2023[30]**

| Equipment Type | Existing Efficiency | Saturation |
|---|---|---|
| Natural Gas/Propane Furnace | 80% | 22% |
| Natural Gas/Propane Boiler | 75% | 78% |
| Heating Oil Furnace | 81% | 20% |
| Heating Oil Boiler | 77% | 80% |

Based on these two adjustments to the observed natural gas consumption, the team estimated delivered fuel-heated weatherization participants used an average of 78 MMBtus/year heating oil and 55 MMBtus/year propane to heat their homes before they participated in IESF (Table 13 and Table 14).

[27] Average efficiencies, including the 63% instances, were 70% and 67% for oil furnaces and boilers, respectively. Average efficiencies for natural gas units were 75% and 74% for gas furnaces and boilers, respectively. The evaluation team verified with program administrators that the 63% was likely a default efficiency value entered during building audits for systems that were unable to be tested at the time of the audit (i.e., a non-operational unit) or, if there was too much soot in the flue pipe for oil heating systems, the efficiency could not be tested because it would damage the equipment used for testing.

[28] Guidehouse 2024. Income Eligible Single Family Impact Evaluation (MA23R56-B-IESF). Available at: https://ma-eeac.org/wp-content/uploads/MA23R56-B-IESF-Income-Eligible-Single-Family-Impact-Report_FINAL_15AUG2024.pdf

[29] Guidehouse 2022. Massachusetts Residential Building Use and Equipment Characterization Study. Available at: https://ma-eeac.org/wp-content/uploads/Residential-Building-Use-and-Equipment-Characterization-Study-Comprehensive-Report-2022-03-01.pdf

[30] Existing efficiency assumptions represent Massachusetts values, while saturation data represents Rhode Island program data.

**Table 13. Estimating Heating Oil Heating Consumption**

| Metric | Value | Notes |
|---|---|---|
| Natural Gas Heating Consumption (therms/year) | **741** | Based on building simulation analysis; weather normalized using TMYx (2007-2021) |
| Adjustment Factor #1: Home Size | 108% | Heating oil heated homes are larger than gas heated homes |
| Adjustment Factor #2: Equipment Efficiency | 98%[31] | Adjustment accounting for marginally more efficient heating oil equipment compared to natural gas |
| Fuel Conversion (therms-to-MMBtu) | 0.1 | - |
| **Heating oil Heating Consumption** (MMBtu/year) | **78** | **-** |

**Table 14. Estimating Propane Heating Consumption[32]**

| Metric | Value | Notes |
|---|---|---|
| Natural Gas Heating Consumption (therms/year) | **741** | Based on building simulation analysis; weather normalized using TMYx (2007-2021) |
| Adjustment Factor #1: Home Size | 74% | Propane heated homes are smaller than gas heated homes |
| Adjustment Factor #2: Equipment Efficiency | 100% | No adjustment needed; natural gas and propane systems have a similar ability to covert fuel into heat |
| Fuel Conversion (therms-to-MMBtu) | 0.1 | - |
| **Propane Heating Consumption** (MMBtu/year) | **55** | **-** |

### Estimating Percent Savings

Not having access to delivered fuel consumption records also meant that the team could not conduct a delivered fuel-specific billing analysis to estimate the percentage of pre-program consumption that participants saved due to IESF weatherization.

Consequently, the team had to make an important assumption to estimate delivered fuel weatherization savings: Holding other factors constant, the weatherized natural gas and delivered fuel participants save the same percentage of their pre-program heating consumption. In other words, the heating fuel does not affect—in percentage terms—how much energy weatherization saves.

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[31] This factor is the ratio of the weighted average gas heating equipment efficiency (76%) compared to the weighted average heating oil equipment efficiency (76%).

[32] The team assumed propane equipment efficiency was the same as natural gas equipment, thus an adjustment for Equipment Efficiency (Adjustment Factor #2) was unnecessary.

Rather than apply this assumption unchecked, the team investigated the validity that "other factors" are indeed the same for natural gas and delivered fuel participants. Specifically, the team reviewed and, when necessary, adjusted the observed percentage savings found through the natural gas billing analysis before applying it to delivered fuel participant data. Unlike our team's calculation of pre-program heating consumption, we combined heating oil and propane participants (under the banner of delivered fuels) when determining the appropriate percent savings for weatherization. This decision was largely based on sample size as the team had relatively few propane customers to include in the analysis.

The team reviewed and adjusted for the following two factors for delivered fuels: pre-program conditions, and the amount and types of insulation installed.

- **Pre-program conditions.** To estimate the delivered fuels heating energy savings, the team checked for potential differences in pre-existing conditions for delivered fuel customers (relative to natural gas participants) and found some differences**Error! Reference source not found.**.

**Table 15. Insulation R-Value Comparison: Delivered Fuels Homes Compared to Natural Gas**[33]

| Insulation Type | Fuel Type | Average pre R-value | Average post R-value | ΔU-factor |
|---|---|---|---|---|
| Wall | Natural Gas | 3.4 | 11.3 | 0.206 |
| | Delivered Fuels | 3.4 | 11.5 | 0.207 |
| Attic | Natural Gas | 7 | 28.0 | 0.107 |
| | Delivered Fuels | 8.3 | 28.6 | 0.086 |
| Floor | Natural Gas | 3.5 | 14.5 | 0.217 |
| | Delivered Fuels | 3.5 | 14.8 | 0.218 |

Consequently, the team adjusted the percentage of natural gas savings determined through the billing analysis before applying it to delivered fuel participants who received insulation (Table 16).

[33] This analysis, summarized in the table, relied exclusively on 2022 and 2023 IESF weatherization participants as the data for 2021 participants did not include the required information.

**Table 16. Insulation U-factor Comparison:
Delivered Fuels Homes Compared to Natural Gas**

| Insulation Type | Fuel Type | ΔU-factor | ΔU-factor Relative to Natural Gas | 2021-2022 Insulation Participants | Insulation Count Relative to Natural Gas | Combined Average (%) |
|---|---|---|---|---|---|---|
| Wall | Natural Gas | 0.206 | 100% | 0.47 | 100% | 100% |
| | Delivered Fuels | 0.207 | 100% | 0.42 | 89% | 89% |
| Attic | Natural Gas | 0.107 | 100% | 0.62 | 100% | 100% |
| | Delivered Fuels | 0.086 | 80% | 0.63 | 102% | 81% |
| Floor | Natural Gas | 0.217 | 100% | 0.53 | 100% | 100% |
| | Delivered Fuels | 0.218 | 100% | 0.61 | 115% | 115% |
| **Weighted Average Adjustment Factor (Relative to Natural Gas)** | | | | | | **95%** |

- **Installed insulation.** The team compared the total quantity of insulation installed per home to the total square footage of each home for both natural gas and delivered fuels. Taking this whole building approach (versus an insulation location-specific approach similar to that shown in **Error! Reference source not found.**) was necessary because the team did not have information regarding the surface area for each respective insulation location (wall, attic, floor). Compared to natural gas-heated homes, delivered fuel heated homes had a lesser portion (i.e., reported insulation square feet relative to total home square footage) of their home insulated (56% relative to 61%). As a result, the team applied a 91% adjustment factor to the natural gas savings for delivered fuels.

**Table 17. Installed Insulation Area:
Delivered Fuels Homes Compared to Natural Gas**

| Fuel Type | Home Floor Area (sqft) | Insulation Installed Per Home (sqft) | Insulation as Percentage of Home Floor Area | Adjustment Factor |
|---|---|---|---|---|
| Natural Gas | 1,681 | 1,030 | 61% | 1.00 |
| Delivered Fuels | 1,814 | 1,016 | 56% | 0.91 |

Applying these adjustment factors to account for the differences in pre-program conditions and installed insulation resulted in the team making a downward adjustment to the percentage of heating savings observed in the natural gas weatherization billing analysis before applying it to weatherized IESF participants heating with a delivered fuel.

**Table 18. Estimated Delivered Fuel Percent Heating Savings**

| Metric | Value | Notes |
|---|---|---|
| Natural Gas Percentage of Heating Savings | **13%** | Based on billing analysis bill disaggregation; weather normalized using TMYx (2007-2021). |
| Adjustment Factor #1: Pre-program Conditions | 93% | Delivered fuel participants had a greater amount of pre-program attic insulation relative to natural gas participants. |
| Adjustment Factor #2: Installed Insulation | 91% | Delivered fuel participants installed less insulation per square foot of home floor area relative to natural gas participants. |
| Delivered Fuel Percent Heating Savings | **11%** | |

## Results

Using this approach to leverage the natural gas billing analysis results for delivered fuels, the team determined that weatherized IESF participants that use heating oil and propane as their primary heating fuel save 9.2 and 5.8 MMBtu per year on average.

**Table 19. Delivered Fuel Weatherization Results**

| Measure | Fuel Type | Energy Savings (MMBtu/year) | Percentage of Heating NAC |
|---|---|---|---|
| Weatherization | Heating Oil | 8.5 | 11% |
| | Propane | 5.8 | 11% |

# Electricity

This section summarizes the evaluation team's approach and findings for electrically heated homes receiving weatherization (n=35), which have historically represented a small portion of IESF participants (most heat with natural gas or heating oil).

## Approach

The team attempted a billing analysis, but there were too few weatherization participants that heated their homes primarily with electric heat to reliably attribute weatherization savings. The following subsections offer details regarding the team's building simulation approach to generate weatherization savings for electrically heated homes.

### Developing Baseline Models

Because far fewer weatherized IESF participants heat their homes with electricity, the sample of such participants in the audit data was very small (n=35) compared to natural gas (n=385). For this reason, the team had to make a simplifying assumption: that the baseline conditions in electrically heated homes are the same as the baseline conditions in *all* IESF weatherized homes (i.e., regardless of the heating fuel).[34] Making this assumption allowed the team to combine available baseline data for weatherized electric (n=35) and natural gas (n=385) participants, which increased the total available sample to 420.

Table 20 summarizes the percent participants that received each measure and, when received, the average baseline for that measure (i.e., the existing condition prior to IESF intervention).

**Table 20. Electric Building Simulation Baseline (Pre-IESF) Values**

| | Percentage of Weatherized Participants | Baseline Value |
|---|---|---|
| Attic Insulation (R) | 55% | 7.2 |
| Basement/Floor Insulation (R) | 46% | 3.5 |
| Wall Insulation (R) | 41% | 3.5 |
| Air Sealing (ACH50) | 79% | 17.4 |
| **Total** | **100%** | - |

### Calibration

To ensure that the baseline models accurately represented electrically heated homes, the baselines were calibrated against annual consumption data for electrically heated homes. The team leveraged the results of the billing analysis's VBDD analysis, which yielded weather-normalized information specific to electrically heated homes about the average IESF participant's heating, cooling, and baseload for electricity.

The team ran dozens of model iterations to refine the baseline model inputs so that they produced annual load shapes that were sufficiently like those generated from the billing analysis's VBDD analysis for electrically heated homes. From these calibrated baseline models, the team then developed efficient models that were used to calculate measure-level savings.

### Develop Efficient Models

The team again turned to the audit data to assess the changes to electrically heated homes after weatherization through IESF. Table 21 summarizes this information, which serves as the counterpart to the pre-IESF conditions summarized in Table 20.

[34] This simplifying assumption does not account for the fact that building energy codes took effect for electrically heated homes before other fuels. Thus, older electrically heated homes may be better insulated—prior to participating in IESF—than comparably aged homes that heat with another fuel. However, the evaluation team did not have access to sufficiently detailed population-level electronic participation tracking data to develop a model specifically for electrically heated homes and therefore needed to apply this simplifying assumption. It is also important to note that because so few IESF participants heat with electricity (compared with natural gas and heating oil), this assumption does not have a material impact on the initiative's overall energy savings.

**Table 21. Electric Simulation Efficient (Post-IESF) Values**

| | Percentage of Weatherized Participants | Efficient Value |
|---|---|---|
| Attic Insulation (R) | 55% | 28.4 |
| Basement/Floor Insulation (R) | 46% | 14.8 |
| Wall Insulation (R) | 41% | 11.3 |
| Air Sealing (ACH50) | 79% | 14.7 |
| **Total** | **100%** | - |

### Weighting

To translate the savings generated from running the calibrated models into final values, the team weighted the results between a variety of electric heating and cooling systems. The team divided the electric heating systems present in participants' homes into two categories: ducted heating and non-ducted heating. Of the 35 weatherization participants with electric heat, all but one were non-ducted - electric radiant heating specifically. The remaining participant had an electric furnace. The team also differentiated the ducted and non-ducted heating systems room AC, a CAC, or no AC.

The full list of HVAC systems and assigned weights are shown in Table 22.

**Table 22. Electric Simulation Segment Weights**

| Heating Type | Cooling Type | Weight |
|---|---|---|
| Non-ducted heating | CAC | 0.03 |
| | No AC | 0.80 |
| | Room AC | 0.14 |
| Ducted heating | CAC | 0.00 |
| | No AC | 0.03 |
| | Room AC | 0.00 |

## Results

Table 23 summarizes the results of the team's calibrated building simulation modeling of weatherized IESF participants that heat their homes with electricity.

As shown below, the average weatherization participant—i.e., an IESF customer that received air sealing and one or more types of insulation—saved 596 kWh/year. This result is based on the pre- and post-IESF building envelope and measure details gleaned from all weatherization participants provided to the evaluation team in the audit data. As a reminder, the electric weatherization sample in the audit data was too small (n=35) to find building characteristics specific to electrically heated homes, so the team made the simplifying assumption that the pre- and post-IESF conditions in weatherized electric heating homes is like that of the average weatherization participant regardless of their heating fuel. However, as noted above, the team did calibrate the baseline models to billing data specific to electrically heated homes.

Table 23 also breaks down overall weatherization savings into its contributing components. As shown in the table, most of the modeled weatherization savings come from insulation (490 kWh or 82%) with air sealing contributing 208 kWh (35%). Per the audit data, the average weatherization participant (across all heating fuel types) received roughly 1.5 types of insulation: 55% received attic, 46% baseline/floor, and 41% wall. The evaluation team's modeling found wall insulation saved the most, followed by attic insulation and then basement/floor insulation. Combining the percentages of participants that received each type of insulation with the modeled insulation-specific savings yields the total weatherization savings of 596 kWh. This total represents 13% savings compared to the pre-program heating annual consumption of 4,725 kWh.

Since the heating, cooling, and fan savings associated with the weatherization of an electric home are all electric, the modeled results in Table 23 reflect the full range of electric savings associated with weatherization: heating savings, cooling savings, and reduced furnace fan usage.[35]

**Table 23. Evaluated Weatherization Savings – Electricity**

| Measure | Evaluated Savings (kWh/year) | Percent of Electricity Weatherization Participants That Received the Measure |
|---|---|---|
| **Weatherization (Air Sealing & Insulation)** | **596** | **100%** |
| • Air Sealing | 208 | 79% |
| • Insulation | 490 | 88% |
| o Attic Insulation | 324 | 55% |
| o Basement/Floor Insulation | 5 | 46% |
| o Wall Insulation | 766 | 41% |

### Heating Systems

As noted in the previous section, the team attempted to evaluate savings associated with natural gas heating system retrofits via billing analysis. While the billing results confirmed that there were identifiable savings, the precision on any estimate generated was too high (±38%) to provide a reliable estimate. As a result, the team used an engineering approach to estimate savings for replaced natural gas heating systems, as well as for heating oil and propane systems.

[35] As **Error! Reference source not found.** shows, the team also developed electric cooling and furnace fan savings for natural gas and delivered fuel weatherization participants. However, because those customers heat with non-electric fuel, those electric savings associated with weatherization are shown separately from their heat fuel-specific heating related savings.

## Approach

The team's savings approach—for all three fuel types—centered on the difference between the efficiency of the existing heating system and the high-efficiency system installed through IESF. The team ran into two issues when looking to use IESF-specific data to inform these key evaluation inputs:

- **Uncharacteristically Low Existing Efficiency Ratings.** As mentioned in the Delivered Fuels weatherization section, the team initially planned to use the existing efficiencies provided in the program audit data for this analysis. However, a closer review of the existing efficiency data revealed that the program was defaulting to a predetermined value in most instances. This told our team that the values in the program data were not field-tested values and, therefore, should not be considered an empirical data source for the analysis. We also found, particularly for existing heating oil ratings, that the frequently referenced default value (63% AFUE) was appreciably lower than the average existing efficiency rating used in nearby states, which was resulting in much higher than anticipated savings estimates.
- **No Installed Efficiency Data.** The available program data provided by Rhode Island Energy for this evaluation did not include rated efficiency of the new heating system installed through IESF.

For these reasons, the team opted to rely on the existing and installed equipment efficiency assumptions used in the most recent Massachusetts Income Eligible Single Family Impact Evaluation (Table 24). As mentioned in the earlier Delivered Fuels section, these values were based on analysis of the 2022 Massachusetts Residential Baseline Study[36] and were consistent with values used in the 2024 Massachusetts Heat Pump Metering Study.[37]

**Table 24. Heating System Equipment Assumptions**

| Equipment Type | Existing Efficiency | Installed Efficiency |
|---|---|---|
| Natural Gas/Propane Furnace | 80% | 95% |
| Natural Gas/Propane Boiler | 75% | 89% |
| Heating Oil Furnace | 81% | 86% |
| Heating Oil Boiler | 77% | 87% |

The team calculated the pre-program heat load for natural gas heating equipment first using a combination of disaggregated heating consumption billing analysis,[38] equipment saturation information provided in the program data, and the above Massachusetts-based equipment efficiency values. Next, the team converted the pre-program annual heating load determined for natural gas for heating oil and propane through engineering adjustments that accounted for the relative difference in each fuel's ability

[36] Guidehouse 2022. Massachusetts Residential Building Use and Equipment Characterization Study. Available at: https://ma-eeac.org/wp-content/uploads/Residential-Building-Use-and-Equipment-Characterization-Study-Comprehensive-Report-2022-03-01.pdf

[37] Guidehouse 2024. Massachusetts and Connecticut Heat Pump Metering Study (MA22R51-B-HPMS) / (CT R2246). Available at: https://ma-eeac.org/wp-content/uploads/MA-HPMS-CT-R2246-Heat-Pump-Metering-Study-Final-Report_August_2024.pdf. . The values presented in Table 11 above represent income eligible specific values that stakeholders agreed to as part of the Heat Pump Metering Study process. While these income eligible specific values are not presented in the Heat Pump Metering Study, they are based on the efficiency values listed in Table 2-15 on page 55 of the study.

[38] This is the portion of the average natural gas heated participant's annual usage determined (through the billing analysis' VBDD analysis) to be associated with space heating.

to generate heat. Last, the team calculated savings by taking the difference in the consumption in the existing and installed system scenarios. In addition to calculating the heating related fossil fuel savings, the team also estimated the furnace fan and boiler pump savings resulting from upgraded equipment.

## Results

Table 25 summarizes the team's evaluated fossil fuel ~~and associated electric~~ savings.

For additional context, the team compared the engineering algorithm-based savings with the result of the team's natural gas billing analysis. While the results of the billing analysis were not sufficiently precise (±38%) to report savings for natural gas furnace and boilers, they still offer insight into the general reasonableness of the engineering-based values. With a point estimate of 7.0 MMBtu and ±38% precision, the 90% confidence interval of the billing analysis (4.3 – 11.3 MMBtu/year) includes the furnace savings in (10.8 MMBtu/year). However, the engineering result for natural gas boilers (12.1 MMBtu/year) falls just outside the upper end of the confidence interval.

**Table 25. Heating Systems Savings Summary**

| **Fuel Type** | **Equipment Type** | **MMBtu** (Savings/year) |
|---|---|---|
| Natural Gas | Furnace | 10.6 |
| Heating Oil | Furnace | 4.1 |
| Propane | Furnace | 7.8 |
| Natural Gas | Boiler | 12.1 |
| Heating Oil | Boiler | 8.9 |
| Propane | Boiler | 8.9 |

# Section 5 Refrigerator and Freezer Replacement

Between 2021 and 2023, replacing inefficient refrigerators and freezers with new, high efficiency models made up 10% of total IESF annual savings.

The tracking data provided by RI Energy included unit size but did not include information about the age or configuration of replaced appliances, which are primary factors that drive consumption. However, as part of the participant survey, the team asked respondents who had a refrigerator or freezer replaced to self-report its approximate age and configuration.[39]

As shown in Table 25 , most of the participants self-reported their refrigerator or freezer was less than 13 years old. This means they were manufactured since the last two rounds of federal standards took effect (2011 and 2014).[40,41] This also means that the potential savings associated with replacement is less than with a larger proportion of older units. The recency of their age estimates is supported by their self-reported configuration. Specifically, less than half of participants self-reported an older, more traditional configuration (43%) versus a more modern style such as side-by-side (27%), French door (16%), or bottom freezer/four-door model (13%).

To avoid relying on self-reported data in the future, the team has included a recommendation in the report that IESF collect and provide future evaluators with auditor estimates of appliance age, size, and configuration.

**Table 26. Self-Reported Appliance Ages**

| | Refrigerators | Freezers |
|---|---|---|
| Less than 13 years ago (2011 – present) | 90% | 85% |
| 14 – 23 years ago (2001 – 2010) | 7% | 2% |
| More than 24 years ago (Before 1993) | 3% | 6% |
| Total | 100% | 100% |

## Approach

Similar to the previous IESF impact evaluation, the team used billing analysis to evaluate refrigerator and freezer replacement savings. Specifically, the team ran an "appliance only" model for participants who only installed a replacement refrigerator or freezer (i.e., no other electric IESF measures). This focused

[39] The team did not ask respondents to self-report the replaced appliance's size, which is measured in cubic square feet of capacity. Unlike approximate age and configuration, which was determined by using visual aids, the team was not confident that respondents could provide a reliable estimate of appliance size.
[40] https://appliance-standards.org/blog/how-your-refrigerator-has-kept-its-cool-over-40-years-efficiency-improvements
[41] https://appliance-standards.org/product/refrigerators-and-freezers#:~:text=KEY%20FACTS%3A,almost%2030%25%20more%20storage%20volume.

approach helps the model isolate the savings associated with these appliance upgrades, which increases the possibility of a statistically robust billing analysis-based result by removing variability from the modeling process.

To buttress this approach, the team also estimated savings using engineering algorithms that leveraged data collected through the participant survey. The team did not ultimately use the engineering-based approach to report results—as detailed in the next section—the billing analysis results were sufficiently statistically significant. However, the alternative approach offered additional insight for the team's consideration.

## Results

The team's "appliance only" billing analysis model found that participants who received a refrigerator replacement saved, on average, 285 kWh/year. As shown below, the precision associated with the refrigerator replacement savings was ±16%—well within the evaluation's stated statistical requirements (better than ±25% precision at the 90% confidence level) for prioritizing billing analysis results over another evaluation method.

**Table 27. Refrigerator Replacement Savings**

| Measure | Billing Analysis Sample | Savings (kWh/year) | Precision (at 90% CI) |
|---|---|---|---|
| Refrigerator Replacement | 524 | 285 | ±16% |

It is important to note that billing analysis-based refrigerator savings is lower than both the results of the previous evaluation (467 kWh/year, also billing analysis-based) and the team's engineering algorithm-based approach for the current study based on the participant survey (496 kWh/year).

The similarity of the prior evaluation results and the engineering algorithm results could suggest those savings are more reflective of the actual savings generated by IESF replacing participant's refrigerators. However, the team believes the billing analysis result of 285 kWh/year offers the most accurate savings, especially for prospective application for several reasons:

1. **Sufficiently Precise Results.** As noted earlier in the report, the team prioritized billing analysis results over other methodologies when the model results are sufficiently precise, which is the case for refrigerator replacement.
2. **Lack of Program Verified Appliance Characteristics.** Engineering algorithms are entirely dependent on the quality and reliability of the inputs used to inform those algorithms. The team's participant survey offered self-reported insight into replaced appliances, but it is far less reliable than the actual appliance age, size, and configuration as determined by the auditor at the time of the assessment.[42]
3. **Efficiency Trends.** Older refrigerators manufactured prior to more recent and more stringent federal efficiency standards will, over time, make up a smaller and smaller portion of the appliances replaced by IESF. This natural appliance turnover process is already underway and

[42] Manufacturer date and capacity is typically available on appliance name plates.

likely a contributing factor to the disparity between this and prior impact evaluation.[43] With the program replacing increasingly modern and efficient appliances, it follows that savings from this evaluation would be less than the last evaluation and that the decline may continue as part of future program cycles and evaluations.

Given the lack of IESF-collected appliance characteristic data and the clear downward trend in refrigerator consumption, which affects prospective application, the team does not see a reason to overrule the sufficiently precise billing analysis results in favor of the alternative engineering savings estimate.

Table 28 presents the "appliance only" billing analysis model results for replaced freezers, which are a much smaller part of the IESF program. Specifically, the model included over 500 replaced refrigerators but only 21 replaced freezers. Lesser participation, and therefore a smaller sample of participants in the billing analysis, is the primary driver of the lesser precision (±50%) associated with the model's estimate of 238 kWh/year savings on average for replaced freezers.

**Table 28. Freezer Replacement Savings**

| Measure | Billing Analysis Sample | Savings (kWh/year) | Precision (at 90% CI) |
|---|---|---|---|
| Freezer Replacement | 21 | 238 | ±50% |

Like the refrigerator replacement measure, the team also estimated savings for replaced freezers using a participant survey-based algorithmic approach. The outcome of the exercise was a savings of 333 kWh/year. That value is more than the billing analysis-based estimate, but in much closer alignment than the billing analysis and engineering algorithmic results for refrigerator replacement (285and 496 kWh/year, respectively).

While the precision associated with the freezer replacement billing analysis does not meet our typical statistical requirements (again, better than ±25% precision at the 90% confidence level), the team believes it is the most appropriate value for RI Energy to use prospectively for multiple reasons:

1. **Methodological Alignment.** The team had a preference to use a consistent evaluation approach for refrigerator and freezer replacements because disparate approaches can cause methodologically induced disconnects between similar measures.
2. **Relativity to Refrigerator Savings.** The freezer savings from the previous evaluation, as well as the current engineering analysis, are both less than the comparable refrigerator savings. These findings—freezer consumption/savings being less than refrigerator savings—is consistent with industry findings.[44] Consequently, it would not make sense to pair the statistically significant refrigerator results from the billing analysis (285 kWh) with the engineering estimate for freezers (333 kwh/year). Instead, using the billing analysis for both measures, which includes a statistically valid result for refrigerators, maintains this relationship between relative savings.

[43] The prior evaluation also did not provide appliance characteristics that would enable a comparison, nor did the previous impact evaluation undertake a participant survey to gather such information like this study did.

[44] Chapter 7: Refrigerator Recycling Evaluation Protocol. The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures. Available at https://www.nrel.gov/docs/fy17osti/68563.pdf.

3. **Efficiency Trends.** Much of the logic provided above for refrigerators (i.e., the program replacing an increasing percentage of modern and efficient appliances) is relevant for freezers too. As such, it also follows that savings from this evaluation would be less than the last evaluation and may decline further as part of future program cycles and evaluations.

# Section 6 Impact of Weatherization on Secondary Heating

In this section, our team summarizes the approach and results of our analysis of the impact of IESF weatherization on secondary electric and other fuels (other than electric and natural gas) heating usage. This analysis complements the team's analysis of the impact of weatherization of participant's primary heating fuel (in Section 4) and provides greater perspective on the full range of weatherization benefits.

Our team's evaluation of the RI Energy's EnergyWise Single Family (EWSF) program last year (October 2023) determined that homes weatherized through EWSF changed not only how they use their primary heating system but also—when present in the home—their secondary heating sources. For example, after weatherizing their home, a participant may stop or reduce using an electric plug-in space heater since their weatherized home is less drafty. It is also possible that a weatherized participant could use their secondary heating system more post weatherization because—due to the improved building shell—the space heater can sufficiently heat a portion of their home without turning on the primary heating system.

As part of this IESF-specific impact evaluation, the team revisited the approach originally used for EWSF to understand what impact weatherization had on IESF's secondary heating usage.

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 235 participants that received weatherization measures in 2021–2023 to answer two important questions[45]:

1. **What is the prevalence of secondary heating among participants?** More specifically, what percent of weatherization participants used secondary heaters as a supplemental source of heating before and/or after participating in IESF? The answer to this question is critical for appropriately applying the weatherization savings associated with secondary heating to the full population of IESF participants since many of which do not have secondary heaters.
2. **Which specific weatherized IESF 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. 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.

Of the 235 participants, nearly half (115 or 49%) indicated they used some kind of secondary heating source before and/or after participating in IESF. Most of these participants (86%) self-reported using an **electric secondary heater**—most commonly a portable, plug-in type heater. The team estimated the

[45] The team provided a copy of the participant survey instrument in Appendix C, as well as additional results from the survey in Appendix F

savings associated with electric secondary heaters following IESF weatherization using the secondary electric heating billing analysis described later in this section.

Another 19% indicated they used **wood or propane-**powered secondary heating source, specifically a wood or pellet-fired stove (11%) or a wood or propane fireplace (9%). The team estimated savings for these secondary heating participants using an engineering approach that leveraged the secondary electric heating billing analysis.

Another 3% 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 4. Consequently, no additional analysis is required.

**Table 29. Secondary heating equipment types (All Fuels)**

| Secondary heating equipment types | Equipment used for secondary heat | | |
|---|---|---|---|
| | Count | % among reporting secondary heat use (n=115)* | % all respondents (n=235) |
| **Electric heaters** | **99** | **86%** | **42%** |
| Portable, plug-in heater | 81 | 70% | 34% |
| Ductless mini-split system | 2 | 2% | 1% |
| Ducted heat pump system | 2 | 2% | 1% |
| Electric baseboard | 6 | 5% | 3% |
| Fireplace (electric) | 28 | 24% | 12% |
| Wall mounted heater (electric) | 0 | 0% | 0% |
| **Gas heaters** | **4** | **3%** | **2%** |
| Fireplace (gas) | 4 | 3% | 2% |
| **Other fuels heating** | **22** | **19%** | **9%** |
| Wood or pellet stove | 13 | 11% | 6% |
| Fireplace (propane, wood) | 10 | 9% | 4% |

*The denominator for this percentage is the number of participants that self-reported using some type of secondary heating before and/or after IESF not all weatherized IESF participants. Some respondents identified multiple types of secondary heating equipment type, therefore the count of responses by heating type exceeds 115 and the sum of percents is more than 100%. (Reminder: 51% of weatherized IESF participants reported they did not use any kind of secondary heat before or after IESF.)

# Electric Secondary Heating

As noted above, 99 of the surveyed IESF weatherization participants self-reported using electric secondary heating sources before and/or after participating. This equates to a 42% saturation of secondary electric heating customers amongst weatherized IESF participants.

The impacts of secondary heating can be evaluated only when isolated from the primary heating fuel. The team had access to billing data for electricity and natural gas consumption data, but no data on delivered fuel quantities. Since were not enough participants with electric primary heating and natural gas secondary heating to generate reliable estimates, the team focused billing analysis efforts on weatherized participants with natural gas primary heating that use(d) electricity to power a secondary heating source.

## Approach

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 (Section 4). 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 – each identified through the survey. Like the natural gas weatherization analysis, the team used a PPR regression to estimate secondary heating electricity savings due to weatherization.

Electric pre and post consumption was modeled the same as natural gas but with 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($\tau_H$) during month m, based on daily average temperatures on those dates.
- $C_m$ is the average daily cooling degree days at the base temperature($\tau_C$) during month m.

The team calculated base temperatures $\tau_H$ and $\tau_C$ using a variable degree day analysis. The team fit values $\mu$, $\beta_H$ & $\beta_C$ 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 electric secondary heating analysis, the participant needed to:

- Be part of the natural gas primary heating system billing analysis
- Have enough months of pre- and post-IESF electric billing records
- Successfully mapped a control group participant with a similar post-period consumption profile

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 51 weatherized natural gas-heated participants that completed the survey: 23 that self-reported they used secondary electric heating sources (before and/or after participation) and 27 that reported they did not.

**Table 30. 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** | **115** | **120** |
| Included in the gas analysis study | 54 | 72 |
| Could not be mapped to billing data | 32 | 38 |
| Insufficient pre- and/or post-participation billing data | 23 | 27 |
| Did not match control with data in post period | | |
| **Overall** | **23** | **27** |

For the secondary electric heating model, the team also used a pool of matched "future" participants (i.e., IESF participants that weatherized their home in 2022–2023) 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:

$$ADCct = b_1 Treatment_c + b_2 Wx_c + b_3 App_c + b_4 DHW_c + b_5 LagADC_{ct} + \sum_{month\ i} b_{6i} Month_{it} + e_{ct}$$

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.
- $Wx_c$ = 1 if customer *c* received air sealing or insulation measures, 0 if customer *c* does not use air sealing or insulation measures.
- $App_c$ = 1 if customer *c* received a freezer or refrigerator rebate, 0 if customer *c* did not receive freezer or refrigerator rebate.
- $DHW_c$ = 1 if customer *c* is in received aerators or showerheads during the evaluation period, 0 if customer *c* did not receive aerators or showerheads.
- $LagADC_{ct}$ = 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.
- $e_{ct}$ 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.

## Results

As shown in Table 31, the team's modeling estimated that natural gas heated IESF participants who weatherized their homes and used secondary heating before and/or after IESF saved an additional 213 kWh/year. This represents only 3% of the total annual electric consumption of participants with secondary heating, but nearly half (44%) of the natural gas primary heating 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 natural gas-heated weatherized customers who used secondary electric heating used much less after IESF).[46]

The precision associated with the savings estimate (±46%) is higher than the team's standard reporting threshold, but the point estimate suggests positive savings. As such, it represents the evaluation team's best estimate of savings associated with electric secondary heating usage associated with IESF weatherization. However, as explained earlier in the report, the decision to prospectively claim these secondary electric heating savings—or any other savings values included in this study—ultimately resides with RI Energy.

**Table 31. Electric Secondary Heating Billing Analysis Results**

| Measure | Billing Analysis Sample N | Energy Savings (kWh) | Precision at 90% Confidence (% +/-) | Normalized Annual Consumption (kWh) | % of NAC | Normalized Annual Heating Consumption (kWh) | % of Heating NAC |
|---|---|---|---|---|---|---|---|
| Weatherization | 50 | 213 | ±46% | 6,994 | 3.0% | 481 | 44% |

Table 32 converts the results above to reflect the weatherization savings associated with reduced secondary electric heating usage for the *average* IESF weatherization participant. The average weatherization participant reflects a mix of the 42% of participants that use secondary *electric* heating (213 kWh of additional savings) and the remaining 58% of participants that do not (no additional savings). As shown below, the weighted average of these participant types comes out to 90 kWh/year.

This average secondary electric heating savings is applicable for weatherized participants that use natural gas and delivered fuels for their primary heat. It is not applicable for participants that use electricity as their primary heating fuel as the electric savings reported in Table 32 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). Consequently, applying these savings to a home that primarily heats with electricity would lead to a double-counting of these electric benefits of weatherization.

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

**Table 32. Per-Participant Electric Secondary Heating Savings**

| Participant Type | Percent of Weatherization Participants | Energy Savings (kWh/year) |
|---|---|---|
| With secondary electric heating | 42% | 213 |
| Without secondary electric heating | 58% | 0 |
| **Average Across All Participants** | **100%** | **90** |

The savings presented in Table 32 are based on the weatherization participants who received a mix of air sealing, insulation, or both. To estimate the secondary electric heating savings specific to air sealing and insulation, the evaluation team leveraged difference in savings between participants who received either or both weatherization measures (93 therms/year per the billing analysis) and those who received both (i.e., 111 therms/year per disaggregation of the billing analysis through building simulation). (Both values are presented in Table 3.) The ratio of these two perspectives on weatherization savings (111 therms/93 therms) is 1.19. This ratio, in turn, serves as a multiplier for applying the savings in Table 32 (reflecting a mix of participants who received air sealing and/or insulation) to participants who received both air sealing and insulation.

**Table 33. Calculating Electric Secondary Heating Savings for Weatherization Participants Who Received Both Air Sealing and Insulation**

| Measure | Natural Gas Savings (MMBtu) | Secondary Electric Savings (kWh) |
|---|---|---|
| Air Sealing and/or Insulation | 9.3 | 90 |
| Air Sealing and Insulation | 11.1 | 107 |
| **Ratio** | **1.19** | **1.19** |

Next, the team disaggregated the 107 kWh savings associated with both air sealing and insulation into its constituent parts based on the building simulation analysis.. The results are presented in Table 34.

**Table 34. Average Air Sealing and Insulation Secondary Electric Savings**

| Measure | Natural Gas Savings | Percent of Cumulative Weatherization Savings | Average Secondary Electric Savings |
|---|---|---|---|
| Air Sealing | 5.1 | 46% | 49 |
| Insulation | 6.0 | 54% | 58 |
| Air Sealing and Insulation | 11.1 | 100% | 107 |

## Benchmarking

Our team conducted an industry search for other secondary heating savings associated with weatherization but found very little. For most sources we only found approaches for estimating primary heating savings only. The most recent EWSF evaluation cited above also used a billing analysis to estimate savings attributed to secondary heating sources and yielded similar results for a larger participant population.

**Table 35. Comparison of Electric Secondary Heating Billing Analysis Results**

| Measure | N | Savings (kWh) | Precision (± at 90% CI) | NAC (kWh)[47] | % of NAC | HNAC (kWh) | % of HNAC |
|---|---|---|---|---|---|---|---|
| IESF (2021-2022) | 50 | 213 | 46% | 6,994 | 3.0% | 481 | 44% |
| EWSF (2021) | 132 | 209 | 19% | 9,184 | 2.2% | 456 | 46% |

The current analysis of the IESF customers included fewer homes and has a precision that is higher than ideal when reporting results. However, the results are quite close to the estimate identified in the recent EWSF study which did have a larger sample and greater precision.

# Wood & Propane

Since the team does not have access to actual pre- and post-consumption data for wood or propane fireplaces and stoves, the team started with a simplified assumption: the secondary heating needs of IESF participants using wood/pellet and propane are the same as IESF participants that use electric secondary heating. This simplifying assumption is necessary in the absence of reliable consumption data and helpful because the team determined the savings associated with secondary electric heating billing analysis as part of the billing analysis described above. However, our team's review of the fuel-specific survey results revealed that participants that use wood/propane for secondary heating do so differently than participants that use electricity for secondary heating and that adjustments to determined secondary electric heating savings were necessary.

Specifically, as shown in Table 36, a larger percentage of IESF survey respondents using wood and propane secondary heaters self-reported that they used them less frequently (44%) relative to IESF participants that use electric secondary heaters (24%). This disparity implies that wood and propane secondary heaters play a smaller role in providing IESF participant with heat and would therefore generate less per participant savings than electric secondary heating due to weatherization. To account for this usage difference, the team used the information in Table 36 to determine that participants use their wood and propane heaters, on average, 18 hours/week while participants with secondary electric heat use their

[47] The participants in this table use natural gas as their primary heating fuel. This differs from **Error! Reference source not found.**, 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.

heaters an average of 21 hours/week.[48] A comparison of these values suggests wood and propane heaters are used 85% as much as electric heaters. This difference is approximate, based on the best available survey data, and may not reflect the full range of reasons why people use (or do not use) wood and propane stoves (i.e., for ambiance versus heat).

**Table 36. 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 | 20 | 24% | 41 | 49% | 22 | 27% |
| Wood and Propane heating | 8 | 44% | 5 | 28% | 5 | 28% |

Usage is not the only difference between secondary electric, wood, and propane heating though. To account for efficiency differences between the three different supplemental heating systems, we researched common product efficiencies for each heating fuel. Table 37 summarizes the efficiencies found through the team's literature review for electric heaters, propane heaters, and wood stoves.

Next, the team multiplied the usage ratio by the efficiency difference to calculate a "Total Savings Ratio" to convert the billing analysis-based savings for secondary electric heaters into the relevant savings for weatherized participants that use propane heaters and wood stoves for secondary heating. To make this possible, the team also converted the average secondary electric heating savings for weatherization participant with secondary electric heating (213 kWh) from kWh to MMBtu.

The savings in the tables below offer the team's best estimate of likely wood and propane heating savings from weatherization. However, it is important to note that these best estimates are not infallible. To develop these savings estimates, the team made a series of engineering adjustments—with unquantifiable uncertainty—to the electric secondary heating billing analysis reported above, which inherently had its own uncertainty given the model precision of ±46% at the 90% confidence level.

As noted previously in this report, the ultimate decision of whether to prospectively claim these savings—that reflect the evaluation team's best estimate of secondary heating savings associated with weatherization—resides with RI Energy.

[48] To calculate this number, the team assigned discrete values for the weekly hours of use for each of the three bins in Table 36. This corresponded to 3.5 hours of use for the 'Occasionally' bin, 21 hours of use for the 'Sometimes' bin, and 38.5 hours of use for the 'Often' bin. Following this assignment, the team calculated a weighted average of the hours of use for both electric heaters and wood and propane heaters. This generated an average of 21.4 hours of use for electric heaters, and 18.1 hours of use for wood and propane heaters.

**Table 37. Weatherization Savings for Supplemental Propane Heaters and Wood Stoves**

| Usage Ratio | Usage Ratio | Efficiency | Total Savings Ratio | Secondary Electric Heat Savings (kWh) | Secondary Heat Weatherization Savings (MMBtu) |
|---|---|---|---|---|---|
| Electric heaters | 1.00 | 100%[49] | 1.00 | 213 | 0.73 |
| Fireplace (propane, wood) | 0.85 | 74%[50] | 0.63 | N/A | **0.46** |
| Wood or pellet stove | 0.85 | 70%[51] | 0.60 | N/A | **0.44** |

Like secondary electric heating, not all IESF weatherization participants use propane or wood for secondary heating. Because a relatively small fraction of participants use either non-electric secondary heat, the average savings across all IESF weatherization participants is quite low for both wood/pellet stoves and fireplaces.

**Table 38. Per-Participant Wood/Pellet Stove and Fireplace Secondary Heating Savings**

| Secondary Heating Type | Scenario | Weight | Secondary Heat Weatherization Savings (MMBtu) |
|---|---|---|---|
| **Wood or pellet stove** | With secondary wood heating | 0.11 | 0.44 |
| | Without secondary wood heating | 0.89 | 0.00 |
| | **Average Across All Participants** | **1.00** | **0.05** |
| **Fireplace (propane, wood)** | With secondary propane heating | 0.09 | 0.46 |
| | Without propane wood heating | 0.91 | 0.0 |
| | **Average Across All Participants** | **1.00** | **0.04** |

[49] Electric space heaters are 100% efficient. More information here: https://www.cadet.glendimplexamericas.com/en-us/articles/how-efficient-are-electric-heaters

[50] 74% is the average efficiency of stoves that are currently EPA certified in the EPA-Certified Wood Stove Database. Available at https://cfpub.epa.gov/oarweb/woodstove/index.cfm?fuseaction=app.search.

[51] Advanced combustion stoves typically have efficiencies of 65%–75%, as described here: https://www.energy.gov/energysaver/wood-and-pellet-heating.

# Appendix A Evaluation Scope of Work

RI - IESF Impact
Evaluation SOW_FIN

# Appendix B Additional Impact Methodology & Results

## Additional Billing Analysis Details

This section describes our billing analysis process in greater detail than provided in the main body of the report.

- Applicable Measures
- Treatment Group Selection
- Control Group Selection
- Data Preparation
- Model Specification

### Applicable Measures

As shown in Table 39, our team will use billing analysis to estimate savings for the following electric and gas measures. We anticipate the billing analysis will produce statistically significant results for these measures, which we have defined as results with greater than 25% precision at 90% confidence.

- **Electric**. LEDs (general service, EISA EXEMPT, and reflectors), Refrigerator Replacement, and Freezer Replacement
- **Natural Gas.** Heating Systems and Weatherization

To ensure robust results, our team will use engineering algorithms to assess savings for each of the identified electric measures. We will compare the algorithmically derived results to the billing analysis results to validate their reliability.

Also, it is likely that the billing analysis will not produce statistically significant savings for each of the specific IESF lighting measures listed above (LEDs (general service, EISA EXEMPT, and reflectors). In this event, the team will aggregate these individual lighting measures and model savings for the group. This aggregation approach works well since billing analyses occurs at the household level anyway—making it difficult to differentiate savings between very similar measures.

### Treatment Group Selection

For our electric and natural gas billing analyses, we define treatment groups as those customers who satisfy the measure installation criteria shown in Table 39.

**Table 39. Billing Analysis Treatment Group Details**

| Savings Fuel | Measures | Installation Period |
|---|---|---|
| Electric | LEDs (All Types)<br>Refrigerator Replacement<br>Freezer Replacement | January 1, 2021 through October 31, 2022* |
| Natural Gas | Weatherization<br>Heating System Replacement | January 1, 2022 through October 31, 2022 |

*We restrict the treatment groups to those IESF customers who had measures installed by October 31, 2016 to ensure that each matched control customer has 12 months of data after the treatment customer's installation date.

Discussions at the kick-off meeting confirmed that no significant changes in IESF delivery occurred between 2021 and 2022 that would render aggregating participants across years for evaluation purposes inappropriate. For the remainder of this analysis plan, we refer to the aggregated group of 2021 and 2022 IESF participants as the treatment group.

### Control Group Selection

In addition to the treatment group customers described above, we also use a set of control group customers to account for the impact of macroeconomic factors and other influences on pre- and post-program energy consumption that are unrelated to the installation of program measures. These factors include, but are not limited to, macroeconomic trends, the movement of people in and out of homes, and fluctuations in per-unit energy costs. For this analysis, we define our control group as the IESF participants from 2022 and 2023 that participate after the evaluation period for those in the treatment group. It's important to note that, though these participants later received measures through IESF, we will only make use of their energy consumption data prior to participation.

**Table 40. Billing Analysis Control Group Details**

| Savings Fuel | Measures | Installation Period |
|---|---|---|
| Electric | Any IESF Measure | January 1, 2022 through December 31, 2023 |
| Natural Gas | Any IESF Measure | January 1, 2022 through December 31, 2023 |

### Creation of Pre- and Post-Periods

As mentioned above, the treatment group are customers who have installed at least one IESF measure between 2021 and 2022. However, since treatment participation period is two years long and customers IESF measures at various times, we will determine customer-specific pre and post periods. For each customer, the day before the earliest IESF installation date (usually the date of the audit when measures such as lighting and aerators are installed) is the latest day of pre-period. Conversely, the day after each customer's last installation date marks the first day of post period. We will not include customers' energy consumption between pre and post period in billing analysis. To further ensure a clear demarcation between the pre and post periods, we will use one month before pre-period, as well as one month after post-period as a holdout month. Since billing cycles do not perfectly align with monthly cycles, using a holdout month will ensure we have clearly defined pre and post periods. Table 41 provides an example of pre- and post- periods for a specific customer.

**Table 41. Example of Pre-Post Period Determination**

| First Installation | 12-month Pre-Period | Latest Installation | 12-month Post-Period |
|---|---|---|---|
| February 18, 2021 | February 2020 – January 2021 | May 3, 2021 | June 2021 – June 2022 |

### Data Preparation

Before specifying the billing analysis models, we will conduct two data preparation steps:

- Weather Normalization
- Billing Data Screening
- Matched Control Group Selection

#### *Weather Normalization*

To control for the effect of weather during the billing analysis period and to normalize the results to reflect a typical meteorological year, the evaluation team acquired actual and typical meteorological year weather data (TMYx) from the National Oceanic and Atmospheric Administration for all Massachusetts weather stations. The team mapped each customer to the closest weather station based on the customer's ZIP code. For each station, the team used a variable base degree day (VBDD) analysis to identify the optimal base temperatures for each participant by calculating heating degree days (HDDs) and cooling degree days (CDDs). The participant-specific base for calculating HDD was selected from a range of 55° F to 75° F while CDD selected a base from the range 65° F to 80° F using 5° increments for both ranges. We modeled each time span (pre and post participation) independently and so they can have different bases. The team used actual weather in the billing analysis regression model to quantify weatherization savings and then used normal weather data (TMYx 2007-2021) to adjust the savings estimates to reflect a typical meteorological year.

#### Billing Data Screening

After identifying the treatment and control group customers, we will apply a set of billing data screening criteria to ensure that our billing analysis model uses clean and accurate consumption data for each time interval. We will exclude customers who meet one or more of the following criteria from our analysis:

- Unable to link billing data to program participation data
- Insufficient pre- or post-billing data (i.e., less than nine months of pre or post months)
- Billed consumption does not meet reasonable monthly values (outlier removal, i.e., remove 1$^{st}$ and 99$^{th}$ percentile)
- Large changes in pre- to post- installation period energy consumption (i.e., +/- 80%)

#### *Matched Control Group Selection*

After conducting the data screening process described above, we match each treatment group customer to a "future" (2022 and 2023) IESF participants to develop a control group similar, in terms of both the customer profiles and energy usage, to the treatment group.

The control group customers also participated in IESF; therefore, we assume that they are generally similar (in terms of housing stock, income eligibility, and consumption habits) and offer a reasonable counterfactual for participants in 2021 and 2022. It is also unlikely that many of these "future" IESF participants made many of the energy efficiency improvements offered through the program prior to participating, which means the billing analysis results will be closer to gross than net savings (although the exact location on the gross-to-net savings continuum varies by measure, as described earlier in the plan).

Our team will use the quasi-experimental matched control group (MCG) method to identify a specific "best match." The team's MCG approach will use a nearest-neighbor algorithm to match each treatment customer to a specific control group customer. In other words, the MCG approach results in a one-to-one match between a specific treatment and a specific control group customer based on both customers' energy consumption pattern over the 12 months prior to the treatment customer's participation in IESF.

Our MCG approach does allow for one-to-many mapping, that is, a customer in the control group can potentially be the "best match" for more than one customer in the treatment group. As discussed during the kick-off meeting, our team will explore matching treatment group participants to more than one control customer and conduct a scenario analysis to determine whether model fit and/or estimated savings differ between the two matching scenarios.

### Model Specification

Our team will use a monthly Post Program Regression (PPR) model to estimate average measure-specific savings . The general form of our PPR model follows[52]:

$$ADC_{ct} = b_1 Treatment_c + b_2 LagADC_{ct} + \sum_{month\ i} b_{3i} Month_{it} + \sum_{month\ i} b_{4i} Month_{it} * LagADC_{ci}$$

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.
- $LagADC_{ct}$ = 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.
- $e_{ct}$ is the error term from the regression model.

In the model above, we derive annual, measure level savings from the coefficient $b_1$, which represents the average daily savings (kWh for electric, therms for natural gas) attributed due to the program. We may augment the general model shown above with terms that characterize the dwelling (i.e., attached/detached, size) and characterize other IEFS measures that impact same-fuel consumption to augment the general model described above if those terms sufficiently improve how the model fits.

To normalize energy savings that are weather sensitive, we will use customers' zip codes to capture customer specific TMYx (2007-2021) weather data. We will get an annual average HDD by using customers in the analysis and use that to extrapolate average daily savings to an annual level.

[52] If we need to estimate savings for more than one weather-sensitive or base load measure, we will add the appropriate terms for each measure.

# Additional Engineering Algorithm Details

The Impact Evaluation Supporting Documentation workbook contains a full set of impact evaluation results as well as the body of information required to arrive at the results.

The workbook contains four sections:

1. The **Savings Results** section summarizes the per-unit energy savings for electric, natural gas, propane, and heating oil measures, which are linked to the Measure-Specific tabs where the detailed calculations occur.

2. The **Measure-Specific Calculations** section, which comprises the bulk of the workbook, documents the ex ante and ex post savings for each measure, as well as the detailed calculations behind the savings estimates. The study team used the same methodology as the previous evaluation unless a more recent or relevant approach was identified. Each measure is documented on its own tab and accessible via the Table of Contents shown below.

| Measure-specific Detailed Calculations | |
|---|---|
| **Measure Type** | **Measure Name** |
| Weatherization & Heating Systems | Boilers |
| | Furnaces |
| | WiFi-Thermostat |
| | Air Sealing |
| | Insulation |
| | Mini-Split Heat Pump (Electric Resistance Baseline Only) |
| Appliances | Smart Strips |
| | Refrigerator Rebate |
| | Room Air Conditioner Replacement |
| | Dehumidifier |
| | Clothes Washer and Dryer |
| | Freezer |
| Domestic Hot Water | Showerheads |
| | Faucet Aerators |
| Education Materials | Education Materials |

Below is an example of a measure-specific calculation tab, in this case Boilers. Each measure-specific calculation tab is structured the same: the text box at the top summarizes the measure followed by a summary of the per unit savings results compared to the savings listed in the 2024 TRM (which is most cases is consistent with the previous evaluation's results). Below that summary, the team included a synopsis of the savings approach and the algorithm used.

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## Boilers

**Summary:**
The team calculated evaluated savings using existing HVAC equipment saturation in the provided audit data, and leveraged billing analysis heating consumption data from this evaluation where relevant. The previous evaluation was able to use billing analysis to evaluate this measure, so the previous efficiency assumptions are unknown. The savings per unit are lower for oil units compared to natural gas/propane units because the existing oil unit efficiency (77%) is higher compared to the existing natural gas or propane unit (75%).

Because existing and replacement HVAC efficiency data was not available, the team used the same HVAC efficiency requirements identified in the recent Massachusetts Heat Pump Metering Study, which provided baseline and replacement equipment efficiencies for HVAC equipment including boilers and furnaces based on analysis of the Massachusetts Residential Baseline Study.

| Measure Name | 2024 TRM Page Number | 2024 TRM Savings Value | Evaluated Savings Per unit | Units | Notes |
|---|---|---|---|---|---|
| 2024 Electric Income Eligible Single Family Heating System Retrofit - Boiler, Oil | M-389 | 10 | 6 | kWh | |
| | | 7.8 | **8.8** | MMBtu | |
| 2024 Electric Income Eligible Single Family Heating System Retrofit - Boiler, Other | M-389 | 16 | 6 | kWh | |
| | | 7.9 | **11.8** | MMBtu | |
| 2024 Gas Income Eligible Single Family Boiler | M-499 | 16 | 6 | kWh | |
| | | 16 | **11.8** | MMBtu | |

| | |
|---|---|
| **Savings Analysis:** | The savings calculation is based on the following algorithm. This is consistent with the method used to estimate savings. The evaluation verifies the savings estimate by verifying the average AFUE of the baseline and efficient case equipment and the average annual heat load. |
| **Algorithm:** | $\Delta MMBtu = MMBtu_{base} - MMBtu_{EE}$<br>$MMBtu_{base}$ = heating load MMBTUs x $(1/AFUE_{base})$<br>$MMBtu_{EE}$ = heating load MMBTUs x $(1/AFUE_{EE})$<br><br>Where:<br>$MMBtu_{base}$ = Actual MMBTu consumption of existing boiler<br>$MMBtu_{EE}$ = Annual MMBTu consumption of high efficiency boiler |

Each table also includes a detailed savings calculations section, which is shown below, again, for boilers. Data inputs are linked to the relevant tab within the Supporting Material section, and color coded for ease of reference.

| KEY |
|---|
| Filled from audit data |
| Assumption |
| Calculation |

| | Evaluated Savings Estimate | | | |
|---|---|---|---|---|
| **Savings Inputs** | **Gas** | **Oil** | **Propane** | **Source** |
| Existing Efficiency (AFUE) | 0.75 | 0.77 | 0.75 | Derated AFUEs for median IE-specific unit efficiencies sourced from MA Residential Building Use and |
| Program Efficiency (AFUE) | 0.89 | 0.87 | 0.89 | MA 2024 TRM (Retail measure requirements, actual AFUE and not rated). Oil boiler requirement equa |
| Average Annual Heat Load, MMBtu | 55.0 | 59.3 | 55.0 | Heating load calculated based on heating consumption and average efficiency for gas, and relative h |
| Consumption with Existing Unit, MMBtu | 73.4 | 77.0 | 73.4 | Calculated |
| Consumption with High Efficiency Unit, MMBtu | 61.6 | 68.1 | 61.6 | Calculated |
| MMBtu Savings/yr | 11.8 | 8.8 | 11.8 | Calculated |
| Therms Savings/yr | 118.2 | 88.5 | 118.2 | Calculated |

| Circulator Pump Savings | Gas | Oil | Propane | Notes | Source |
|---|---|---|---|---|---|
| Furnace fan run hours | 1,014 | 1,014 | 1,014 | Average heating hours from site da | ERS Study Results. Assumption used in 2018 HES Evaluation. |
| Fan motor HP | 0.5 | 0.5 | 0.5 | | ERS Study Results. Assumption used in 2018 HES Evaluation. |
| Fan motor efficiency | 0.65 | 0.65 | 0.65 | Motor efficiency accounts for the i | 2021 Building simulation default assumption |
| Base fan load, kWh | 582 | 582 | 582 | | Calculated |
| Fan Savings percentage | 16% | 15% | 16% | | |
| Fan Savings, kWh | 94 | 87 | 94 | fan savings comes from reduced ru | Calculated |
| Run hour savings | 163 | 151 | 163 | | Calculated |
| Pump HP | 0.04 | 0.04 | 0.04 | | |
| Pump efficiency | 0.8 | 0.8 | 0.8 | | |
| Pump Savings, kWh | 6 | 6 | 6 | | |

Each table also includes a notes section, which adds clarity and transparency to the calculation process.

**Notes**

Detailed HVAC data was not available in program data, so the evaluation team leveraged audit data for weatherization participants, which did included detailed HVAC information. However, a closer review of the existing efficiency data revealed that the program was defaulting to a predetermined value in most instances. This told our team that the values in the program data were not field-tested values and, therefore, should not be considered an empirical data source for the analysis. We also found, particularly for existing heating oil ratings, that the frequently referenced default value (63% AFUE) was appreciably lower than the average existing efficiency rating used in nearby states, which was resulting in much higher than anticipated savings estimates. For these reasons, the team opted to rely on the efficiency assumptions used in the most recent Massachusetts Income Eligible Single Family Impact Evaluation.

Pump savings assumes the run hours are reduced by the same amount as the furnace fan run hours (under the furnace measure).

3. The **Supporting Material** section contains all relevant program data and input assumptions that the study used and are linked within the individual measure tabs for consistent calculations and ease of reference.

| Supporting Material | |
|---|---|
| **Tab Name** | **Description** |
| Input Assumptions | Contains Sources and descriptions of algorithm inputs |
| Program Data | Contains descriptions and values for program data inputs |

4. The **Supplementary Information** section includes results from the other analyses (billing analysis and building simulation) that the evaluation team leveraged when necessary to estimate savings, as well as constants used throughout the workbook.

| Supplementary Information | |
|---|---|
| **Tab Name** | **Description** |
| Billing Analysis Results | Contains a summary of relevant billing analysis and bill disaggregation results |
| Building Simulation Results | Contains a summary of relevant building simulation results |
| Constants | Descriptions and values for engineering constants used in calculations within this workbook |

# Additional Building Simulation Details

The team used calibrated building energy simulation to do the following:

- Determine the relative contribution of air sealing, duct sealing, and different types of insulation (e.g., wall, attic, and basement/floor) toward observed weatherization savings.
- Estimate the impact of weatherization on cooling and fan usage.
  Calculate the savings associated with switching from an electric resistance heating system to a heat pump.

## Segmentation

To calculate savings for these measures, the evaluation team ran building simulations in the REEDR (Residential Energy Efficiency and Demand Response) energy modeling software by creating baseline models calibrated against natural gas and electric billing data, and then inputting post-measure values to calculate savings. In total, the team created four calibrated models, representing gas and electrical homes with and without cooling.

The team considered other segmentation variables, such as building age, but determined that a building's HVAC system had the strongest correlation to consumption in the billing data. The team did not, however, create calibrated models for every HVAC type found in the audit data. Instead, the team applied input-based and output-based adjustments to HVAC types that lacked sufficient data to calibrate. The input-based and output-based adjustments are defined as follows:

- **Input-based Adjustments:** These adjustments involve using calibrated building characteristics from a similar segment to run measure models. This would include using the calibrated models for electrically heated homes with cooling to calculate savings for homes heated by heat pumps.[53] In this example, a heat pump with characteristics that align with residential baseline study data would be input into the calibrated model for electric heat with cooling.
- **Output-based Adjustments:** This process describes when the team modified the outputs from calibrated models to account for differences in HVAC equipment. An example includes calculating a ratio for the difference in cooling consumption for a home cooled by CAC or Room AC, and then applying this ratio to other homes.

The full list of HVAC types found in the audit data and their calculation approach is shown in Table 42 and Table 43 for gas and electrically heated systems, respectively.

[53] For this adjustment, the team started with the calibrated model for an electric radiant HVAC system with cooling and then replaced this HVAC system with a heat pump. In the heat pump model, all the building characteristics are therefore the same as those for the model with the electric radiant HVAC system. The team made this adjustment rather than calibrating the heat pump model separately due to the lack of data provided for homes with heat pumps.

**Table 42. Different HVAC Systems for Natural Gas Heated Homes in Audit Data**

| Heating Type | Cooling Scenario | Calculation Approach |
|---|---|---|
| Natural Gas Furnace | CAC | Create calibrated model. |
| | Room AC | Apply output-based adjustment to the cooling consumption of the gas furnace with CAC model.[54] |
| | None | Create calibrated model. |

**Table 43. Different HVAC Systems for Electrically Heated Homes in Audit Data**

| Heating Type | Cooling | Calculation Approach |
|---|---|---|
| Electric Resistance | CAC | Apply output-based adjustment to the cooling consumption of the electric resistance with Room AC model. |
| | Room AC | Create calibrated model. |
| | None | Create calibrated model. |
| Electric Furnace | CAC | Apply input-based adjustment to the electric resistance with Room AC model. |
| | None | Apply input-based adjustment to the electric resistance with no cooling model. |
| Ductless Heat Pump | Room AC | Apply input-based adjustment to the electric resistance with Room AC model. |

To translate the savings calculated from each segment into final statewide numbers for gas and electric savings, it was necessary to develop a weighting system between each of the different segments created from the audit data. These weights are shown in Table 44, and represent the number of participants in an individual segment relative to the total number of participants that had either gas or electrically heated homes.

[54] Separate models with Room AC and CAC systems were run on the homes contained in this analysis to determine a ratio between the energy consumption between Room AC and CAC systems. This calculation showed that Room AC systems have an annual energy consumption that is 1.53 times that of CAC systems. The team made this adjustment due to the lack of differentiation between Room AC and CAC systems in the billing data, so the team could not create separate calibrated models for both AC types.

**Table 44. Weighting of Different HVAC Systems to Generate Statewide Savings Values**

| Heating Fuel | HVAC System | Weight |
|---|---|---|
| Natural Gas | Gas furnace with CAC | 0.11 |
| | Gas furnace with Room AC | 0.28 |
| | Gas furnace with no AC | 0.61 |
| Electric | Electric Resistance with CAC | 0.03 |
| | Electric Resistance with Room AC | 0.14 |
| | Electric Resistance with no AC | 0.80 |
| | Electric Furnace with no AC | 0.03 |

## Determining Pre- and Post-Program Building Envelopes

To accurately model savings for the weatherization measures specific to IESF participants, the simulation team looked to the audit data to characterize participants' pre- and post-program building envelopes. Specifically, the team first looked to the audit data for pre- and post- measure R values for the insulation surfaces (wall, attic, and basement/floor), as well as the pre- and post- measure ACH50 values.

The audit data, however, only contained brief descriptions of the applied measures ('R-13 Cellulose DP Wall', 'R-30 Fiberglass Batt Faced Unfaced – ATTIC', etc.), rather than explicitly stating the pre- and post-measure R values for the insulation surfaces. Furthermore, the audit data contained no information on the pre- and post-measure ACH50 values. Because of these data limitations, the team performed the following steps to determine the pre- and post-measure values for the weatherization measures necessary to enable simulation modeling:

- **ASHRAE 90.1**. From looking at the measure names in the audit data for walls, floors, and attic knee walls, the team deduced that these surfaces were uninsulated prior to the start of the program. This decision is based off the frequency with which participants were installing densely packed insulation, which is most effective in filling voids that lack insulation to begin with. The team ultimately used the R-values for uninsulated walls, floors, and attic knee walls listed in ASHRAE 90.1 as the pre-measure R-values for these surfaces.
- **Prior RI IESF Impact Evaluation.** While the team deduced that walls, floors, and attic knee walls were uninsulated prior to the start of the program, this was not the case for attic floors. Due to the lack of information for these surfaces provided in the audit data, the team turned to the assumed pre-measure R-value used in the prior analysis of 16.9. To be clear, the value from the previous study was also not directly informed by audit data. However, in lieu of primary data, using the same assumption across evaluations lends consistency to the studies.
- **Recent MA SF IE Impact Evaluation**. As there were no ACH50 values provided in the audit data for either this analysis or the previous IESF analysis, the team turned to the recent MA IE SF

Impact Evaluation for this information.[55] As part of that evaluation, completed earlier this year, the team received a dataset of pre- and post-blower door tests results. Because of lack of other sources for this information, the team defaulted to the pre- and post-measure ACH50 collected as part of the MA SF IE Impact Evaluation.

- **Audit Data**. The team used the measure descriptions in the audit data to determine the post-measure R-values for all three insulation surfaces. After translating the R-values listed in the measure descriptions to effective R-values, the team added these R values to the pre-measure R-values to calculate post-measure R-values.
- Table 45 provides this information for gas-heated homes[56] as well as the methodology used in finding each value.

**Table 45. Pre- and Post-Program Weatherization Characteristics for Gas-Heated Homes**

| Measure | Pre-Program | Post-Program |
|---|---|---|
| Wall Insulation (R) | 3.5 (ASHRAE 90.1) | 11.3 (Audit Data) |
| Attic Insulation (R)[57] | 7.2 (Previous IESF Evaluation) | 28.4 (Audit Data) |
| Floor Insulation (R) | 3.5 (ASHRAE 90.1) | 14.8 (Audit Data) |
| Air Infiltration (ACH50) | 17 (MA IE SF) | 17 (MA IE SF) |

[55] Guidehouse 2024. Income Eligible Single Family Impact Evaluation (MA23R56-B-IESF). Available at: https://ma-eeac.org/wp-content/uploads/MA23R56-B-IESF-Income-Eligible-Single-Family-Impact-Report_FINAL_15AUG2024.pdf

[56] These values are similar for electrically heated homes.

[57] Attic insulation installations in the audit data were divided into insulation installed in attic knee walls and on attic floors. To find the pre- and post-measure R-values for attics, the team used the square footage of installed insulation in both locations as well as each individual R-value to calculate weighted averages representing aggregate attic insulation values.

# Appendix C Insulating Delivered Fuel Homes Planning to Electrify

After this evaluation's planning process was complete, RI Energy asked Cadeo to leverage the ongoing IESF impact activities to develop additional energy impact values for a specific scenario: customers that receive weatherization through IESF in advance of electrifying their primary heating system (i.e., moving from a delivered fuel furnace to a heat pump).

This appendix describes the methodology the evaluation team used to determine end-use-specific impacts and savings for three different scenarios:

1) Upgrading the weatherization of a home heated by delivered fuels
2) Replacing a delivered fuel furnace with a heat pump
3) Upgrading the weatherization on a home heated by delivered fuels and replacing the delivered fuel furnace with a heat pump

## Methodology

In the body of this report, we included weatherization savings by end use for homes heated with heating oil and propane (Scenario #1). **Error! Reference source not found.** and Table 47 summarize those weatherization savings by heating oil and propane, respectively, as well as the pre- and post-weatherization NACs we used to calculate them.

**Table 46. Weatherization Savings for Heating Oil Homes by End Use**

| End Use | Delivered Fuel Pre-NAC | Delivered Fuel Post-NAC | Wx Savings |
|---|---|---|---|
| Heating Oil Heating (MMBtu) | 78.2 | 69.7 | 8.5 |
| Electric Heating (kWh) | 0 | 0 | 0 |
| Cooling (kWh) | 1,148 | 1,095 | 53 |
| Fans (kWh) | 343 | 314 | 29 |

**Table 47. Weatherization Savings for Propane Homes by End Use**

| End Use | Delivered Fuel Pre-NAC | Delivered Fuel Post-NAC | Wx Savings |
|---|---|---|---|
| Propane Heating (MMBtu) | 54.6 | 48.8 | 5.8 |
| Electric Heating (kWh) | 0 | 0 | 0 |
| Cooling (kWh) | 787 | 734 | 53 |
| Fans (kWh) | 235 | 206 | 29 |

The remainder of this appendix outlines the steps the team took to calculate the savings for the other two scenarios: replacing the delivered fuel furnace with a heat pump (#2) and receiving insulation and heat pump replacement (#3).

To calculate these savings, the team took three steps:

**#1. Re-Run IESF Natural Gas Building Simulation Model with a Heat Pump.** To calculate the energy impact of replacing a delivered fuel furnace with a heat pump, the team first swapped the natural gas furnace in our calibrated building simulation model for a heat pump.

**#2. Modify Heat Pump NACs to Account for Differences in Home Size.** Because the modified model (previously a natural gas furnace, now a heat pump) was calibrated for natural gas heated participants, the team needed to adjust the outputs to reflect a delivered fuel participant. To do so, the team leveraged the IESF analysis (as part of the weatherization measure), adjusting natural gas consumption to reflect likely delivered fuel consumption (see TABLE 14 in Section 4). As discussed in the body of the report, this adjustment accounted for differences in home size between natural gas and delivered fuels participants. For heating oil and propane, respectively, **Error! Reference source not found.** and Table 49 show the NACs of the heat pump home derived from the gas furnace home, the adjustment factors related to home size, and the NACs of the heat pump home after accounting for differences in home sizes between homes heated with gas furnaces and with delivered fuels.

**Table 48. NACs of Home After Replacing Heating Oil Furnace with Heat Pump**

| End Use | Heat Pump NAC (Calibrated to Gas Furnace) | Home Size Adjustment | Heat Pump NAC (Calibrated to Delivered Fuel Furnace) |
|---|---|---|---|
| Delivered Fuel Heating (MMBtu) | 0 | 1.08 | 0 |
| Electric Heating (kWh) | 3,163 | 1.08 | 3,416 |
| Cooling (kWh) | 965 | 1.08 | 1,045 |
| Fans (kWh) | 46 | 1.08 | 50 |

**Table 49. NACs of Home After Replacing Propane Furnace with Heat Pump**

| End Use | Heat Pump NAC (Calibrated to Gas Furnace) | Home Size Adjustment | Heat Pump NAC (Calibrated to Delivered Fuel Furnace) |
|---|---|---|---|
| Delivered Fuel Heating (MMBtu) | 0 | 0.74 | 0 |
| Electric Heating (kWh) | 3,163 | 0.74 | 2,341 |
| Cooling (kWh) | 965 | 0.74 | 714 |
| Fans (kWh) | 46 | 0.74 | 34 |

**#3. Apply Percent Heating Savings.** While the cooling and fan savings generated by weatherization and heating system retrofits are additive[58], it is necessary to take an extra step to calculate the total electric heating impact for the combined measures. To do so, the team applied the weatherization upgrades to the heat pump model mentioned in Step 1. Running the model showed that the heating consumption for the heat pump dropped 10% following the weatherization upgrades. Taken altogether, for heating oil and propane homes, **Error! Reference source not found.** and Table 51 respectively show the energy impacts—by end use—for delivered fuel homes under three scenarios: being weatherized, replacing their delivered fuel furnace with a heat pump, and being both weatherized and installing a heat pump.

[58] The cooling savings from the HVAC replacement are primarily coming from the increased cooling efficiency of heat pumps relative to air conditioners. These savings are independent of the weatherization savings from cooling. For fans, meanwhile, the HVAC replacement removes the furnace fan, which also is independent of weatherization upgrades. Therefore, for both of these end uses, the team assumes that the savings between the HVAC replacement and weatherization are additive.

**Table 50. Energy Impacts for Heating Oil Homes by End Use for Weatherization Upgrades and HVAC Replacement**

| End Use | Weatherization Only | Heat Pump Only | Weatherization and Heat Pump |
|---|---|---|---|
| Heating Oil Heating (MMBtu) | 8.5 | 78.2 | 78.2 |
| Electric Heating (kWh) | 0 | -3,416 | -3,074 |
| Cooling (kWh) | 53 | 183 | 236 |
| Fans (kWh) | 29 | 293 | 322 |

**Table 51. Energy Impacts for Propane Homes by End Use for Weatherization Upgrades and HVAC Replacement**

| End Use | Weatherization Only | Heat Pump Only | Weatherization and Heat Pump |
|---|---|---|---|
| Propane Heating (MMBtu) | 5.8 | 54.6 | 54.6 |
| Electric Heating (kWh) | 0 | -2,341 | -2,107 |
| Cooling (kWh) | 53 | 73 | 126 |
| Fans (kWh) | 29 | 201 | 230 |

## Results

**Error! Reference source not found.** and Table 53 respectively convert all the end-use specific impact values in **Error! Reference source not found.** and Table 51 to MMBtus, which allow for a direct comparison in net energy consumption across the three scenarios. This table highlights that replacing a delivered fuel furnace with a heat pump saves substantially more energy than weatherization upgrades, as the gas heating energy of the delivered fuel furnace that is being replaced is much larger than that of electric heating of the added heat pump. While the weatherization upgrades for heating oil homes save 8.8 MMBtu annually, replacing the heating oil furnace with a heat pump saves 67.9 MMBtu. When both measures are applied, the home saves slightly more energy than the HVAC replacement taken in isolation, with 69.6 MMBtu.

**Table 52. Energy Impacts for Heating Oil Homes by End Use Normalized by MMBtu**

| End Use | Weatherization Only (MMBtu) | Heat Pump Only (MMBtu) | Weatherization and Heat Pump (MMBtu) |
|---|---|---|---|
| Heating Oil Heating | 8.5 | 78.2 | 78.2 |
| Electric Heating | 0 | -11.7 | -10.5 |
| Cooling | 0.2 | 0.6 | 0.8 |
| Fans | 0.1 | 1.0 | 1.1 |
| **Total** | **8.8** | **67.9** | **69.6** |

**Table 53. Energy Impacts for Propane Homes by End Use Normalized by MMBtu**

| End Use | Weatherization Only (MMBtu) | Heat Pump Only (MMBtu) | Weatherization and Heat Pump (MMBtu) |
|---|---|---|---|
| Propane Heating | 5.8 | 54.6 | 54.6 |
| Electric Heating | 0 | -8.0 | -7.2 |
| Cooling | 0.2 | 0.2 | 0.4 |
| Fans | 0.1 | 0.7 | 0.8 |
| **Total** | **6.1** | **47.5** | **48.6** |

# Appendix D Lighting Results

Since IESF no longer installs LEDs during assessments, RI Energy does not have a prospective use for lighting-specific evaluation results. However, because lighting made up a meaningful portion of total electric savings in 2021 and 2022 and because the team was completing an electric billing analysis anyway (for electric weatherization and secondary heating), the team also assessed the savings associated with this historically important measure.

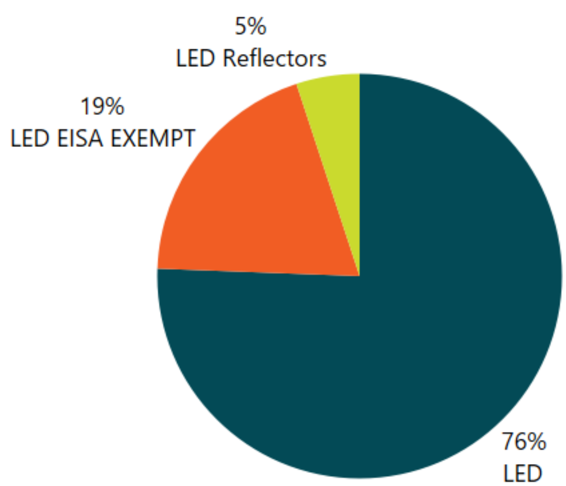
We have limited our reporting of lighting savings to this appendix given its value is exclusively retrospective.

## Installed Lighting

RI Energy installed three different types of lighting measures in 2021 and 2022 during IESF assessments: general service LED lamps, specialty/EISA exempt LED lamps, and LED reflector lamps. On average, participants who received lighting measures during their assessment received an average of 13 total bulbs.

As shown in Figure 8, most of the bulbs installed (76%) in the average IESF participant's home were general service LEDs. Specialty/EISA exempt bulbs made up most of the rest (19%) with balance (5%) being reflectors.

**Figure 8. Lighting Installed in Average IESF Participating Home (2021 and 2022)**




## Approach

Like the previous IESF evaluation, the team used a billing analysis to evaluate lighting measures. Also like the previous study, this evaluation also found it was not possible to attribute statistically significant savings to each type of LED though billing analysis. However, because the program installed more than a dozen LEDs in the average participants' home, the collective savings of these LEDs was large enough for our team to detect via billing analysis and accurately estimate savings at the household level.

Like the process described earlier in this report for the natural gas weatherization billing analysis, our team screened out participants with insufficient electric billing records and/or whose bills exhibited extreme energy consumption. In addition, to isolate lighting savings, we also excluded the small percentage of households that heated their homes with electricity (7%). Excluding these customers from this lighting-focused billing analysis sample minimized variance and allowed our team to better isolate lighting-related savings.

In total, our team included 3,175 2021 and 2022 IESF participants in our lighting billing analysis sample.

**Table 54. Electric Billing Analysis Sample Attrition**

| Reason for Exclusion | Removed | % | Remaining |
|---|---|---|---|
| **All Homes** | | | **7,118** |
| Remove participants with electric heating* | 493 | 7% | 6,625 |
| Insufficient (less than 12 months) Pre- and/or Post-Participation Billing Data | 2,710 | 38% | 3,915 |
| Energy Consumption Outliers (<1st and >99th Percentile) | 77 | 1% | 3,838 |
| Extreme consumption behavior ( < 100 avg monthly kWh or > 10,000 monthly kWh) | 31 | 0% | 3,807 |
| Extreme Changes in Consumption (±>50% Change between Pre and Post) | 70 | 1% | 3,737 |
| Unable to match pre consumption to control | 253 | 4% | 3,554 |
| **Overall** | **3,564** | **50%** | **3,554** |

*To allow the team to detect lighting savings, the team excluded the small number of electrically heated households. Excluding these customers from the billing analysis sample minimized variance and allowed the team to isolate lighting-related savings.

Below is the model specification that our team used to assess household lighting savings:[59]

$$ADC_{ct} = b_1 Treatment_c + b_2 Light_c + b_3 Fridge_c + 4Freeze_c + b_5 LagADC_{ct} + \sum_{month\ i} b_{6i} Month_{it} + e_{ct}$$

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.
$Light_c$ = 1 if customer *c* is in received other lighting measures during the evaluation period, 0 if customer *c* did not receive other light measures.
$Fridge_c$ = 1 if customer *c* is in received a refrigerator rebate during the evaluation period, 0 if customer *c* did not receive a refrigerator rebate.
$Freeze_c$ = 1 if customer *c* is in received a freezer rebate during the evaluation period, 0 if customer *c* did not receive a freezer rebate.

[59] Before arriving at this specification, our team specified several models to try and estimate lighting measure type-specific (e.g., GSL LED versus LED reflector) savings. Consistent with past efforts, our team was unable to develop models that produced sufficiently precise results at this finer level of measure granularity.

*$DHW_c$* = 1 if customer *c* is in received aerators or showerheads during the evaluation period, 0 if customer *c* did not receive aerators or showerheads.
*$LagADC_{ct}$* = 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.
*$e_{ct}$* 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.

## Results

As shown in Table 55, the team estimated that participants who received lighting measures through IESF saved, 145 kWh on average. Since the billing analysis result reflects participant's total household lighting-related savings, the team divided this value by the average number of bulbs installed (13) to arrive at per-bulb savings (11 kWh/year).

**ARE THESE BILLING ANALYSIS RESULTS GROSS OR NET?**
As noted earlier, billing analysis produces a result that lies on a spectrum between net and gross savings. In this instance—because LEDs are widely available, easy-to-install, and relatively affordable—the lighting results should be interpreted as **net** savings. It is also important to note that this billing analysis-based result would also account for removed or failed LEDs (i.e., in-service rate), as well as any cooling- or heating-related impacts (due to post-participation reduction in waste heat) associated with installed IESF lighting.

**Table 55. Lighting Billing Analysis Results**

| Measure | Billing Analysis Sample N | Total Lighting Savings (kWh) | Precision (% +/-) | Average Lighting Measure/Participant | Per-Unit Lighting Savings (kWh) |
|---|---|---|---|---|---|
| Lighting | 3,175 | 145 | 16% | 13.0 | 11 |

## Savings by Installed Quantity

The previous IESF impact evaluation found an inverse relationship between per-bulb lighting savings and the number of lighting measures installed. In other words, once programs install efficient lighting in the subset of most used sockets, there are diminishing savings associated with subsequent installations which leads to a lower average per-bulb savings.

Our team observed a slightly different trend as part of this study. First off, as shown in Table 56, there was a relatively small difference in average per-bulb savings regardless of the number of bulbs installed. Second, we found that homes that received 11-15 bulbs saw the greatest per bulb savings with an average of 13 kWh per bulb.

**Table 56. Per-Bulb Savings by Quantity of Bulbs Received**

| Number of Bulbs | Relevant Participants in Billing Analysis Sample N | Per Bulb Energy Savings (kWh) | Precision (% +/-) |
|---|---|---|---|
| 1–5 | 191 | 8 | 28% |
| 6–10 | 282 | 10 | 12% |
| 11–15 | 213 | 13 | 15% |
| 16–20 | 103 | 12 | 14% |
| 21 or More | 166 | 11 | 22% |
| **Overall** | **956** | **11** | **7%** |

# Appendix E Participant Survey Instrument

IESF Impact
Evaluation Participa

# Appendix F Participant Survey Results

RI - IESF Participant Survey Results.pdf